Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt
2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt
3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

* **Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

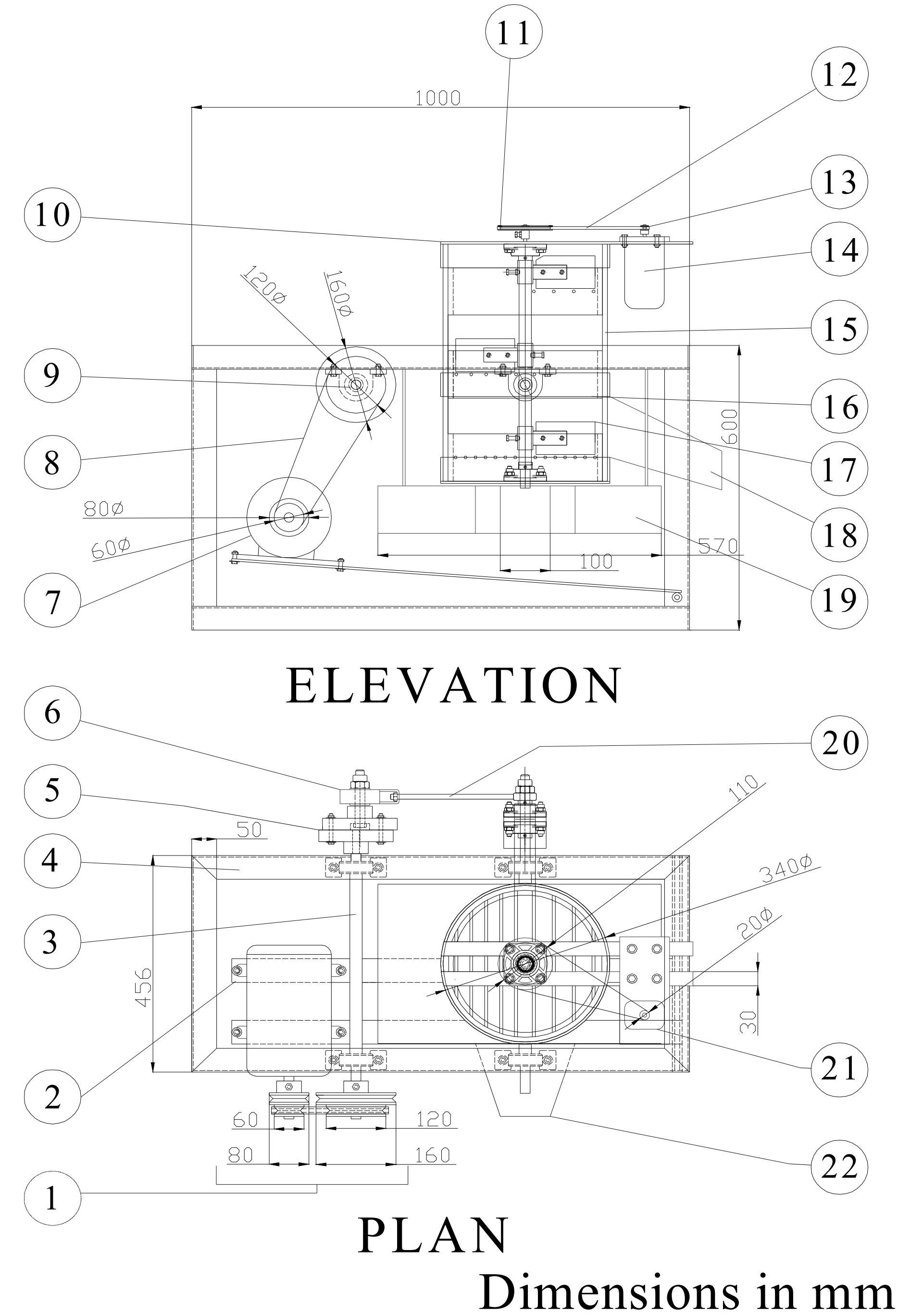
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

cos θ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

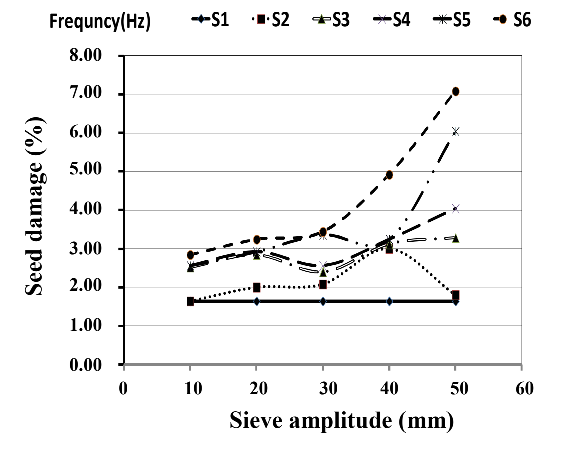
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

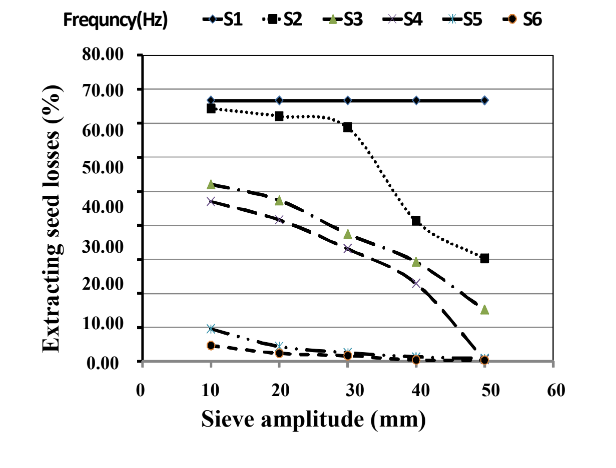
The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage



B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

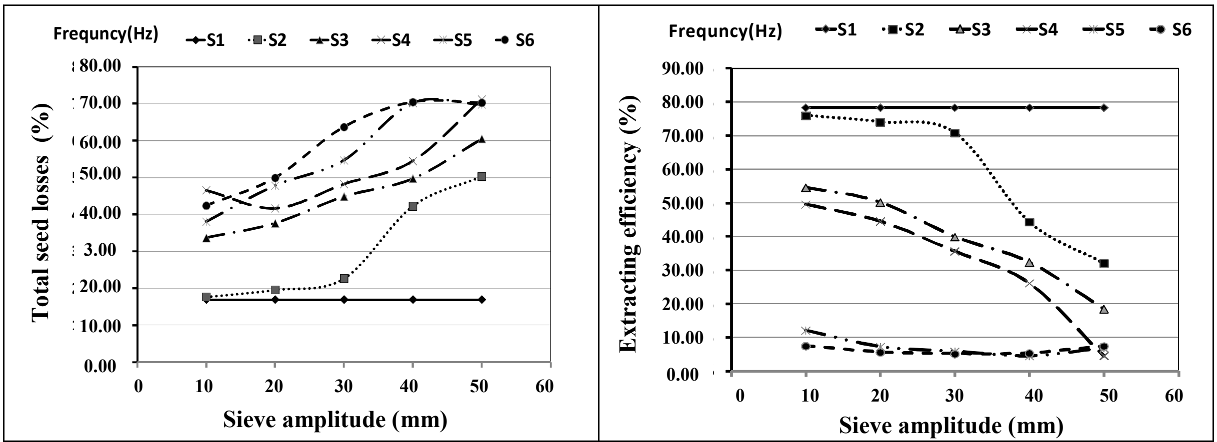
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses

B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

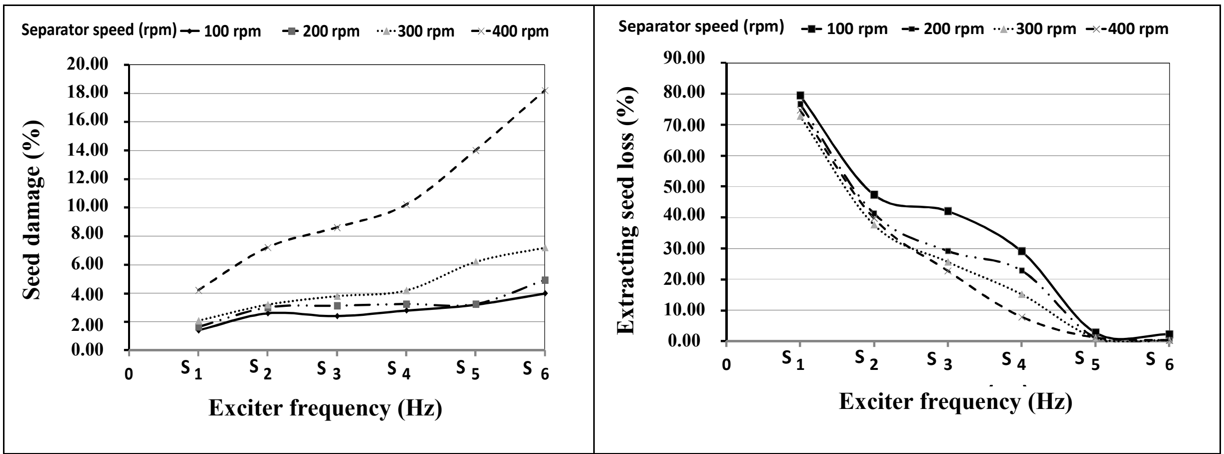
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage	B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

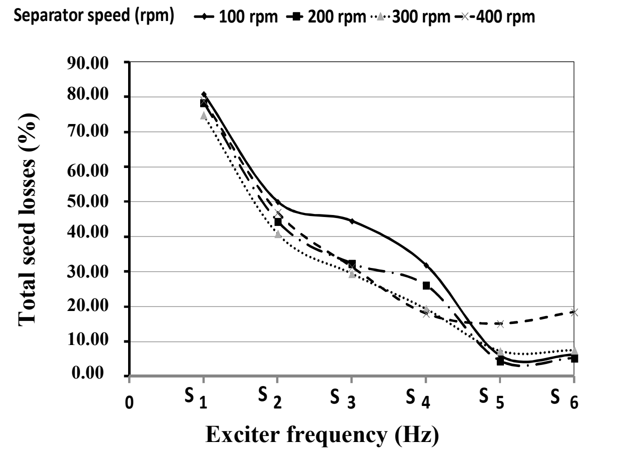
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

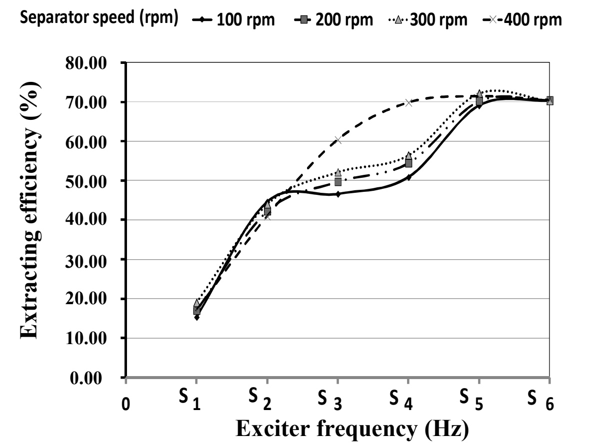
Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses



B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

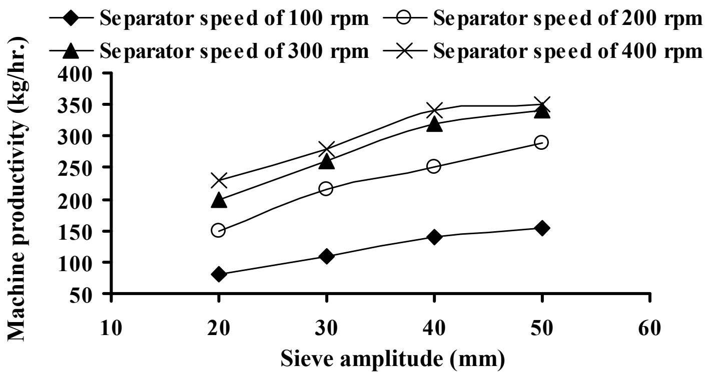


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

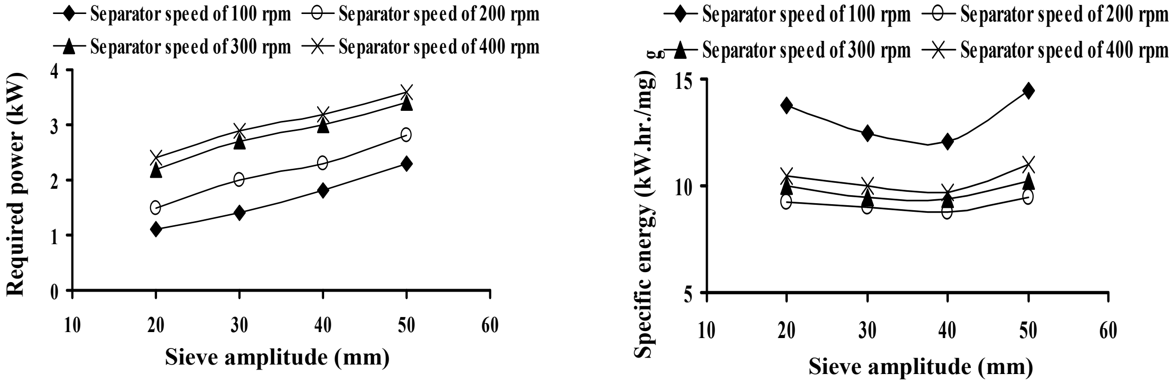


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

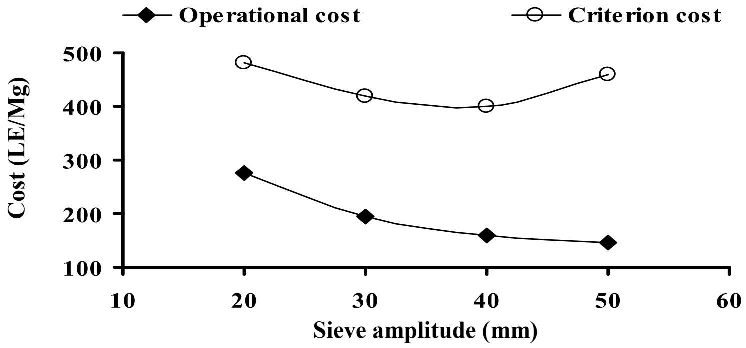


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــــع وتقييـــــــم أداء آلـــــــــة محليــــــــة الصنـــــع لتفـــريـط بـــذور الـرمـــــان

نجلاء صلاح أنور[1] - محمد محمد مراد حسن[1] - محب محمد أنيس الشرباصي[2]- طارق حسين على[3]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علـــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt
2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt
3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

*** Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

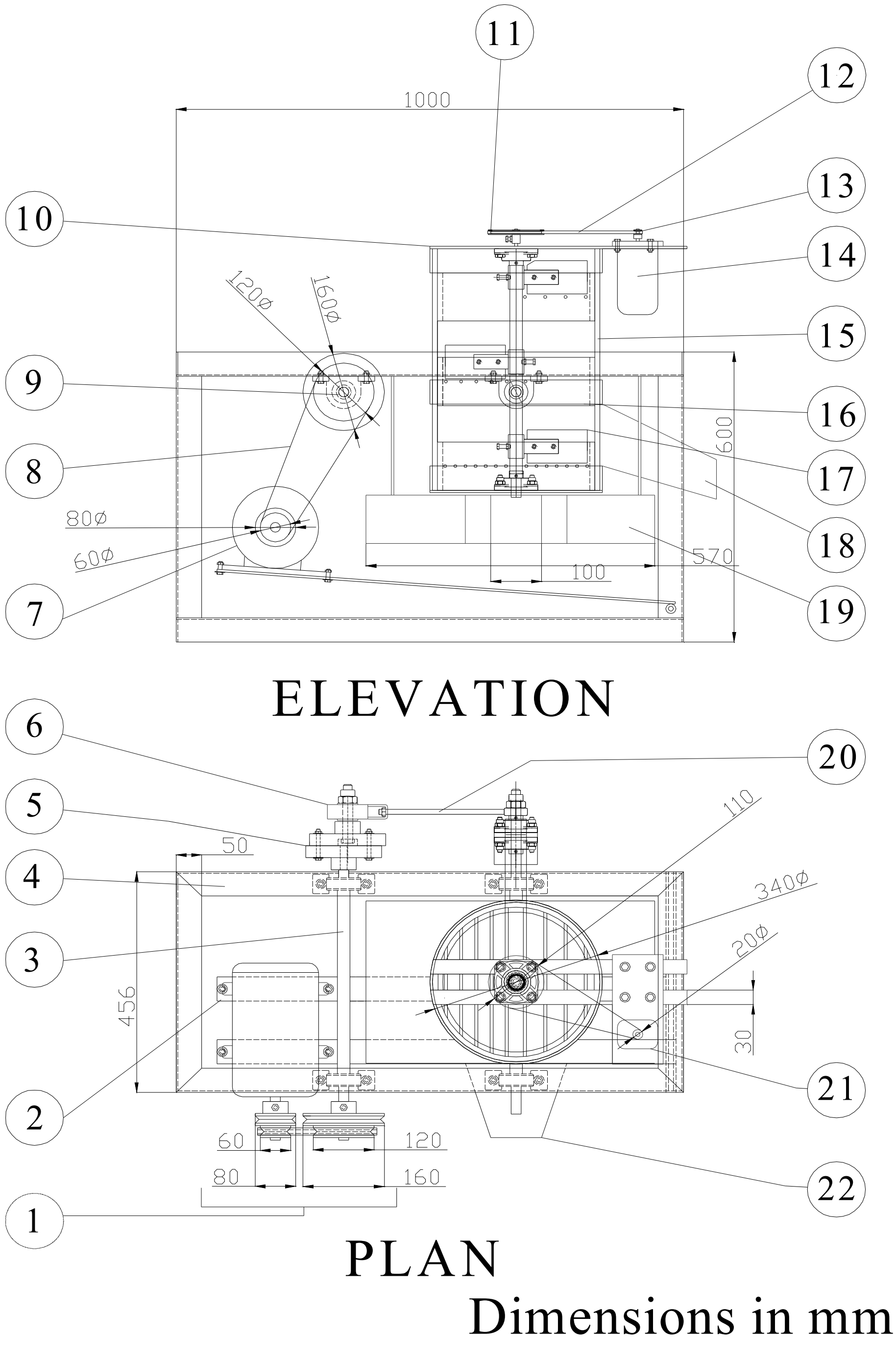
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

cos θ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

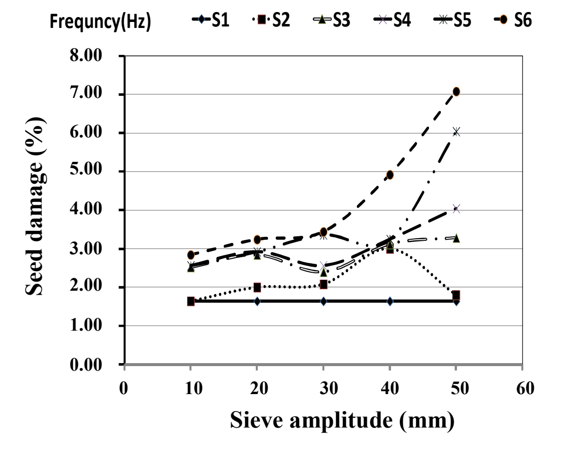
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

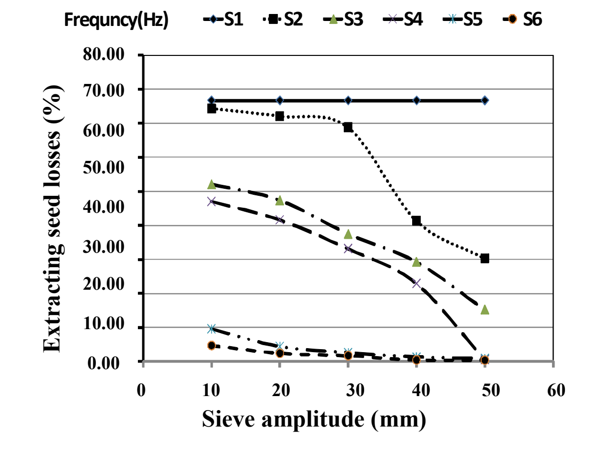
The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage



B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

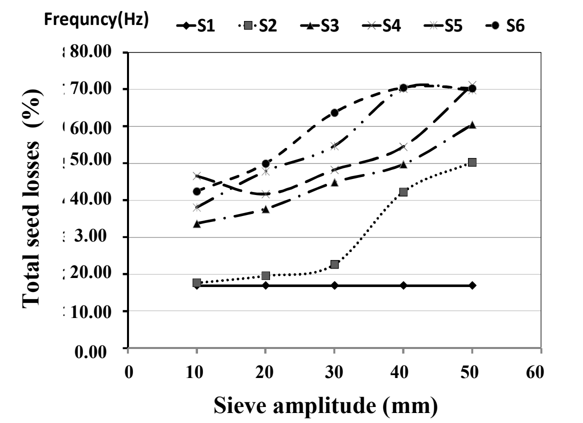
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

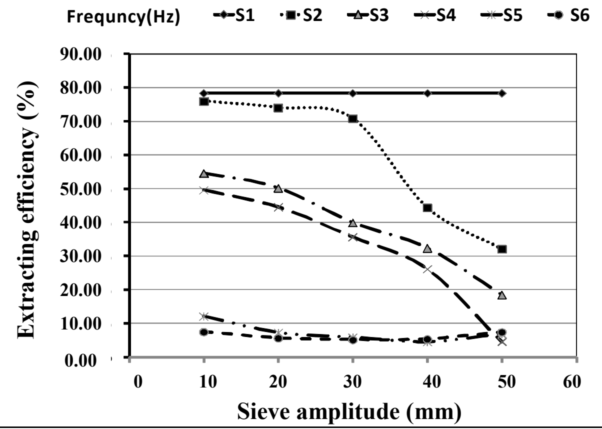
It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses



B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

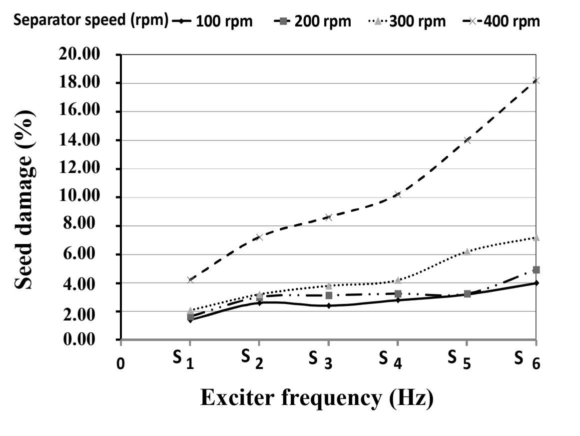
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

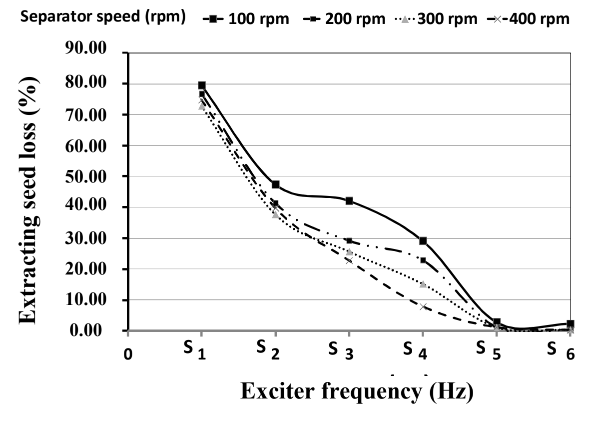
The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.





A. Effect of separator speed and exciter frequency on seed damage	B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

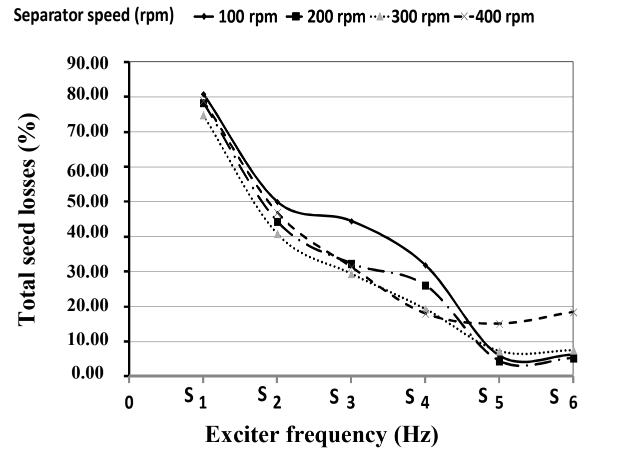
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

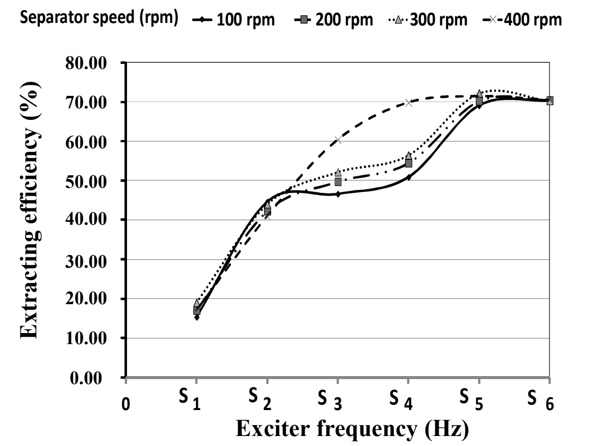
Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses



B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

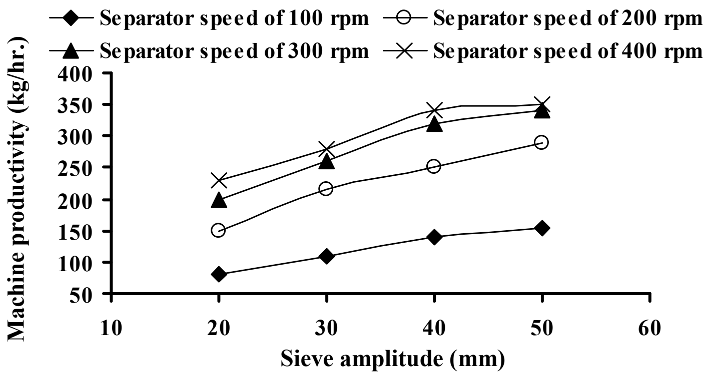


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

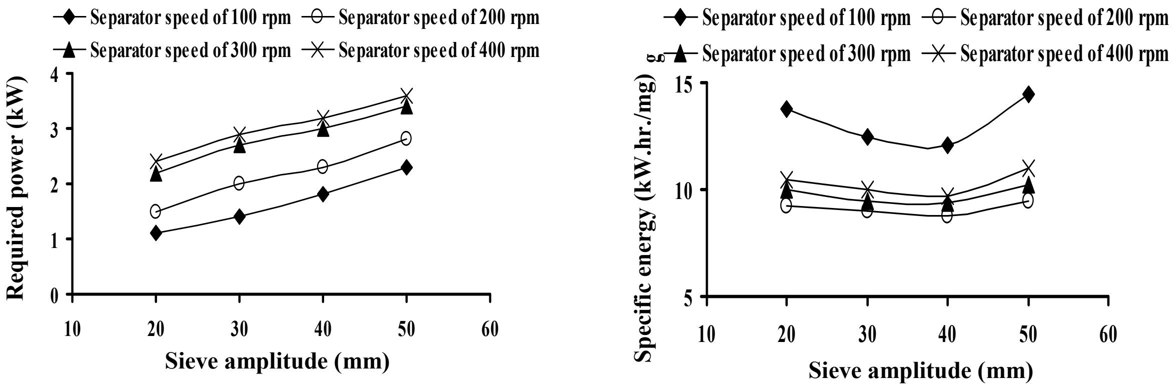


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

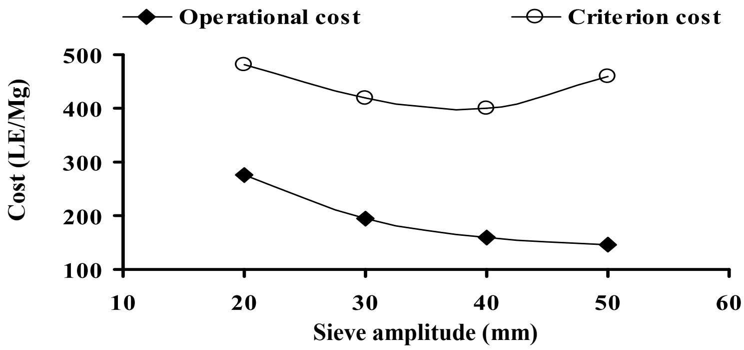


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــــع وتقييـــــــم أداء آلـــــــــــة محليـــــــــة الصنــــــع لتفـــريـط بـــذور الـرمــــان

نجلاء صلاح أنور[1] - محمد محمد مراد حسن[1] - محب محمد أنيس الشرباصي[2]- طارق حسين على[3]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علـــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt

3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

* **Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

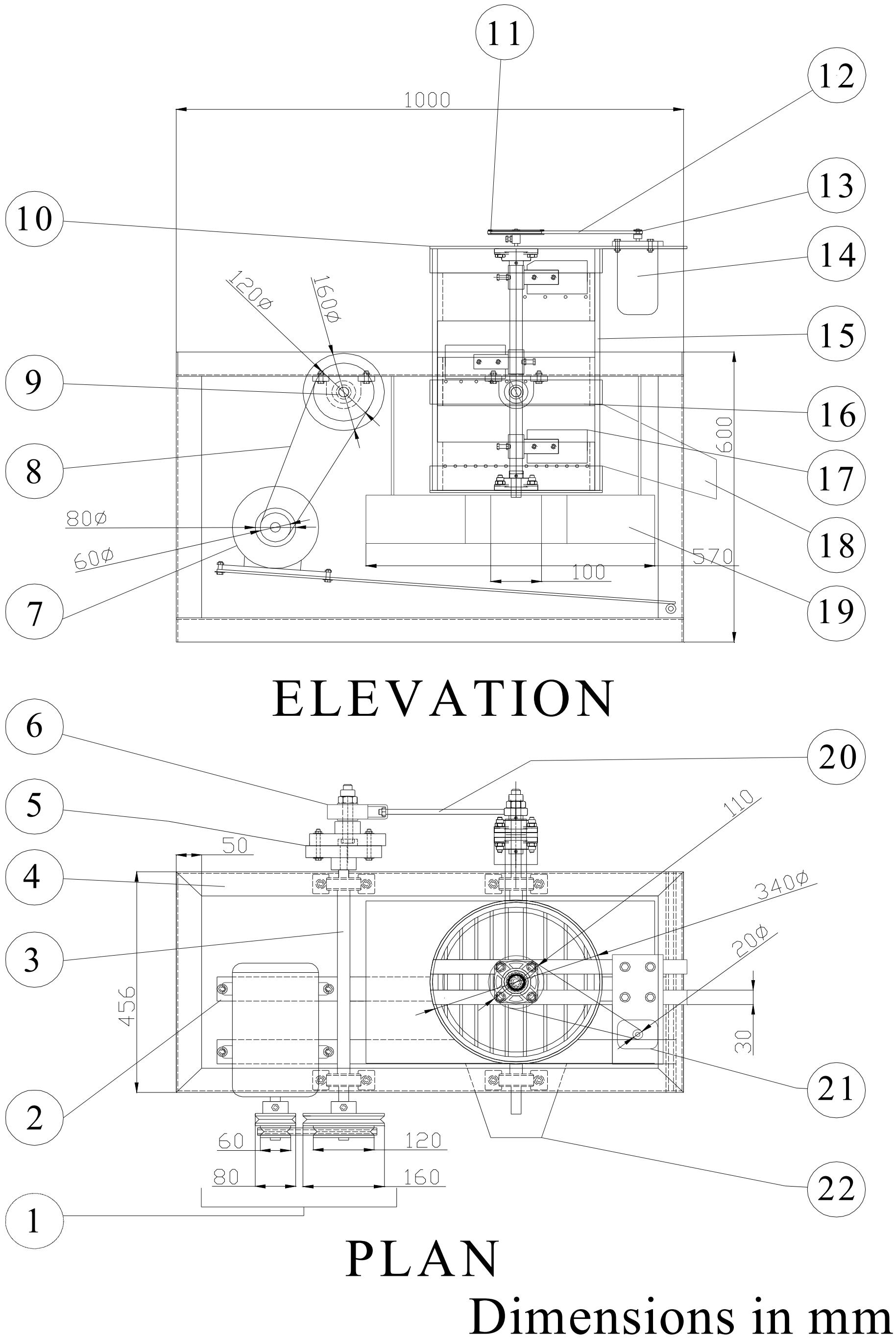
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%)=\frac{M_u}{M_u + M_c}\times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

$\cos\theta$ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

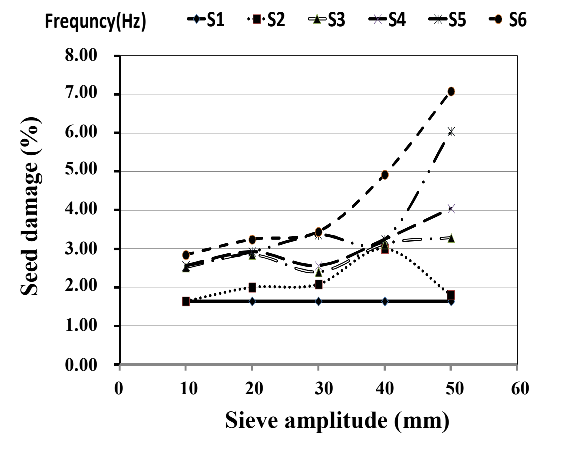
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

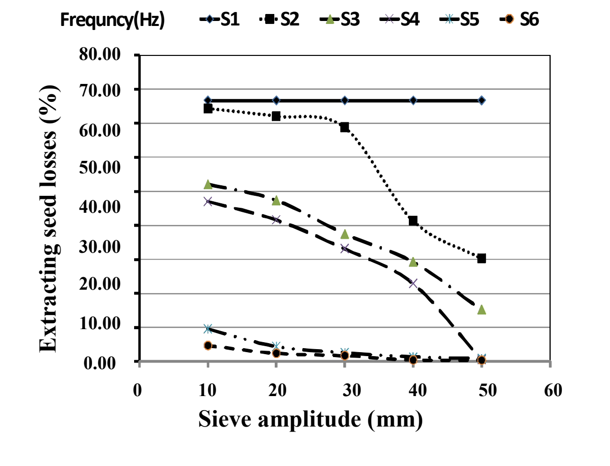
The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage



B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

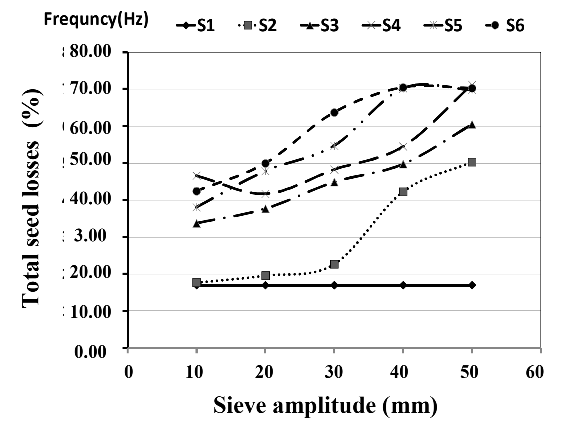
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

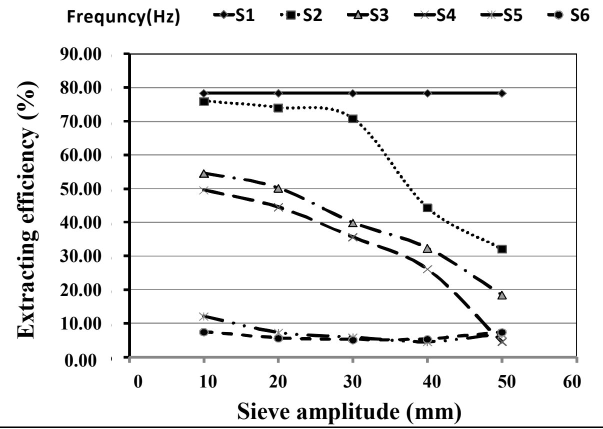
It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses



B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

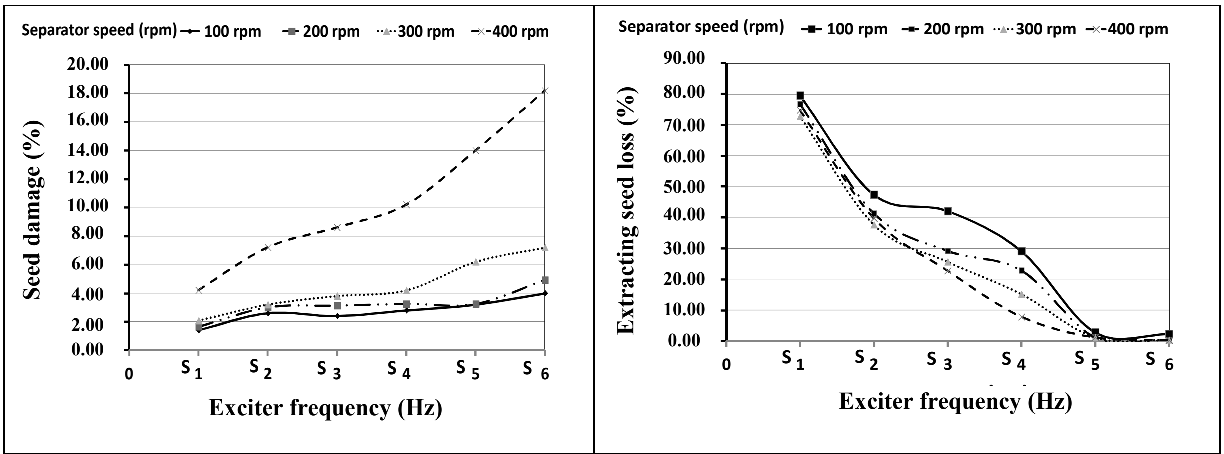
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage	B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

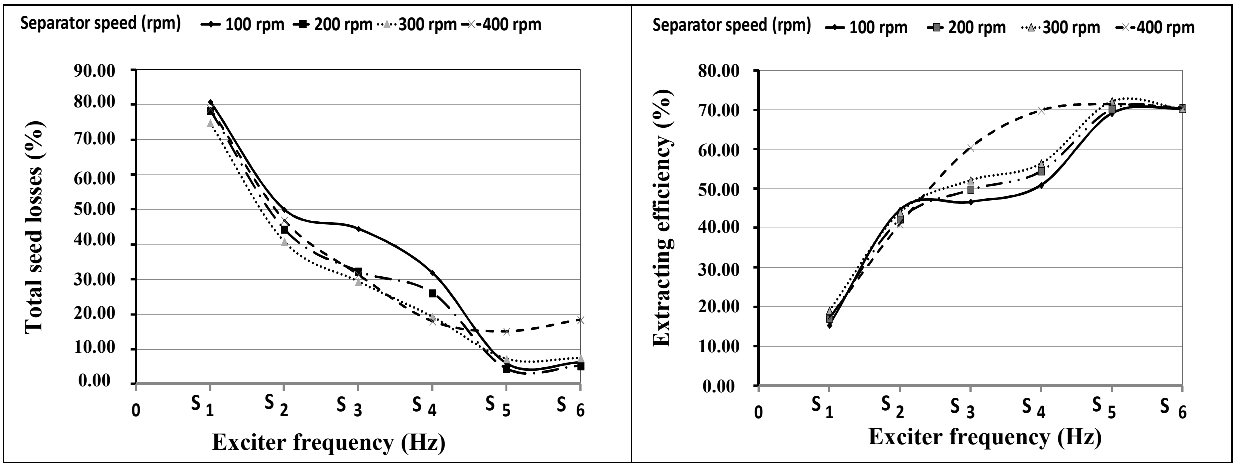
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses

B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

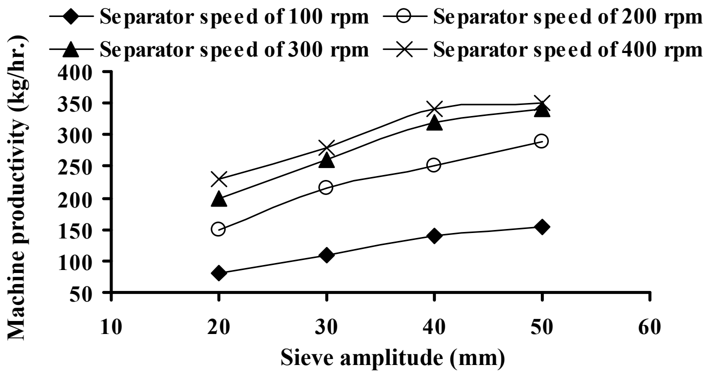


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

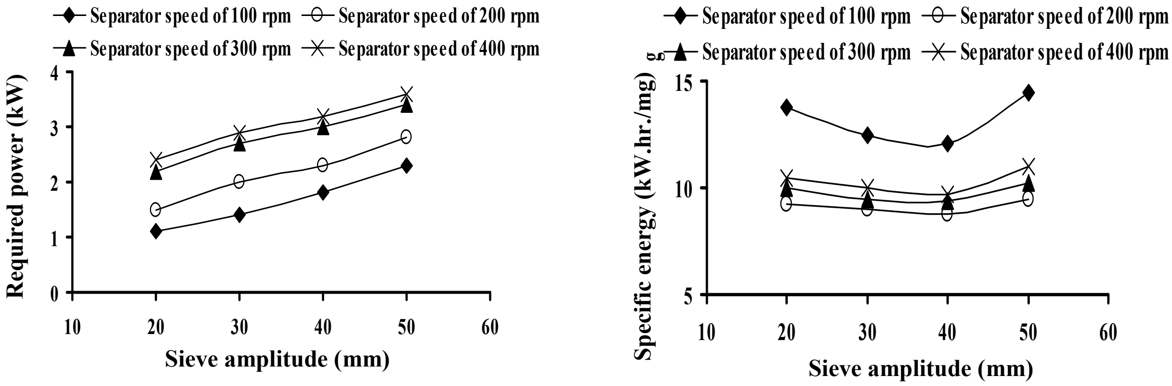


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

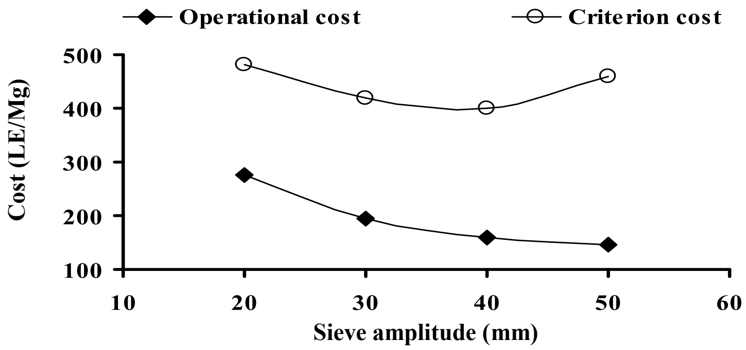


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــع وتقييـــــم أداء آلـــــــة محليـــــة الصنـــع لتفـــريـط بـــذور الـرمـــان

نجلاء صلاح أنور[1] - محمد محمد مراد حسن[1] - محب محمد أنيس الشرباصي[2]- طارق حسين على[3]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علـــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt

3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

* **Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

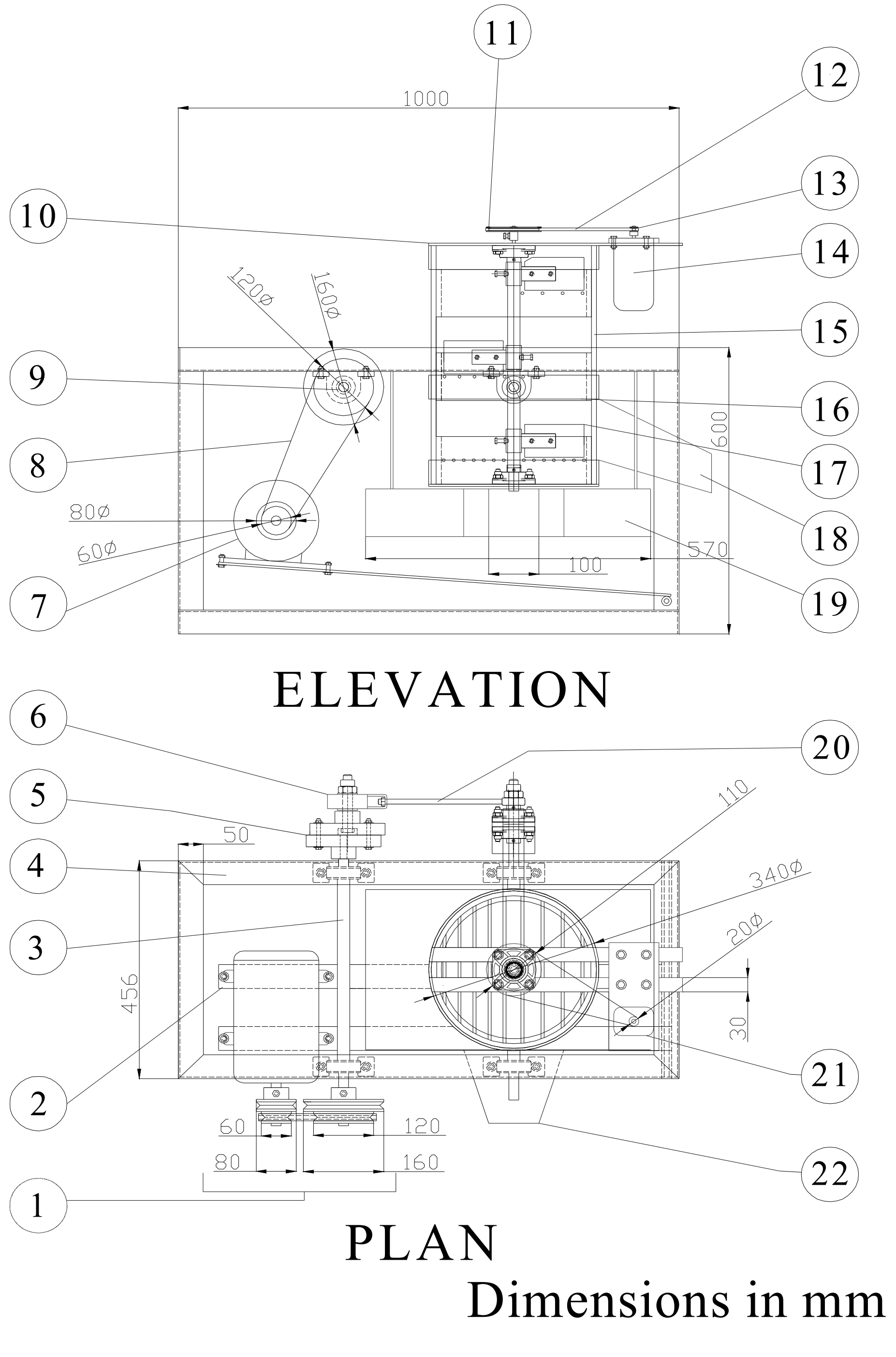
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

$\cos\theta$ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

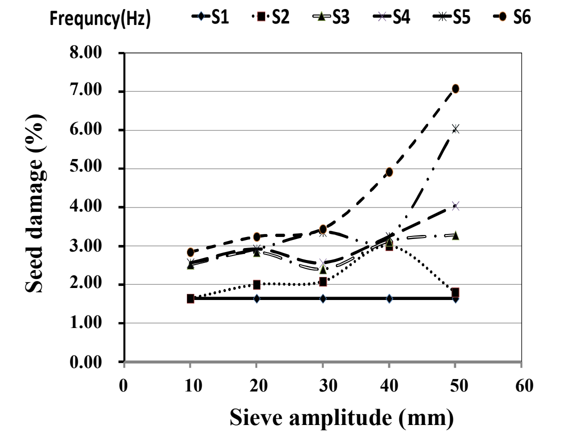
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

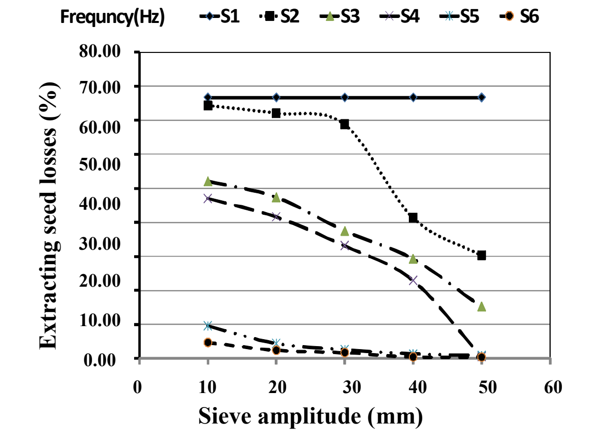
The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage



B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

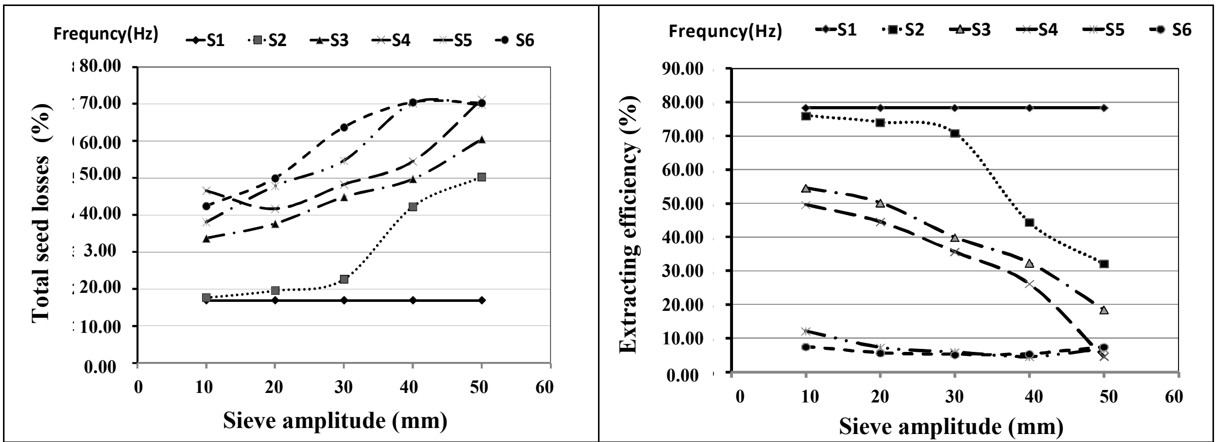
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses

B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

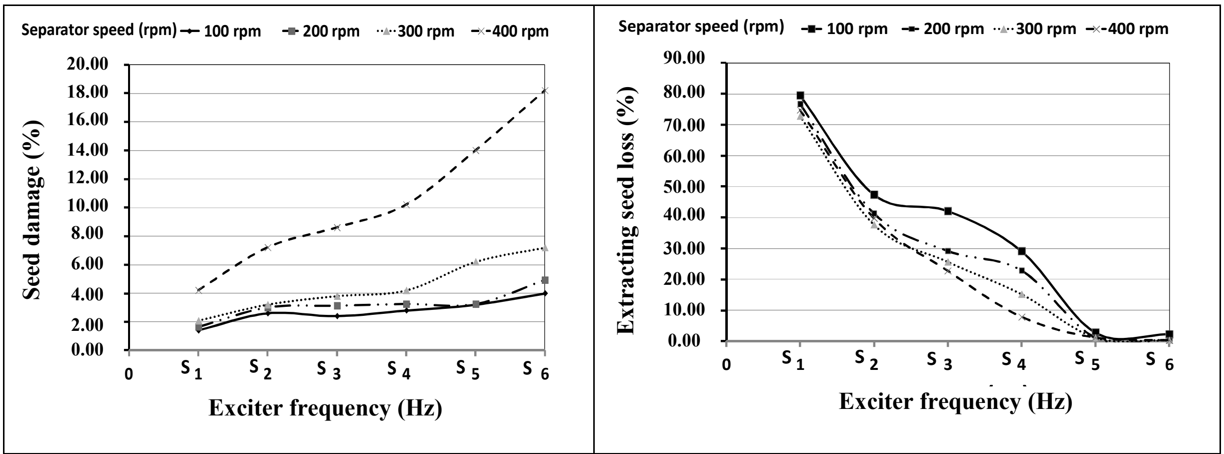
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage	B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

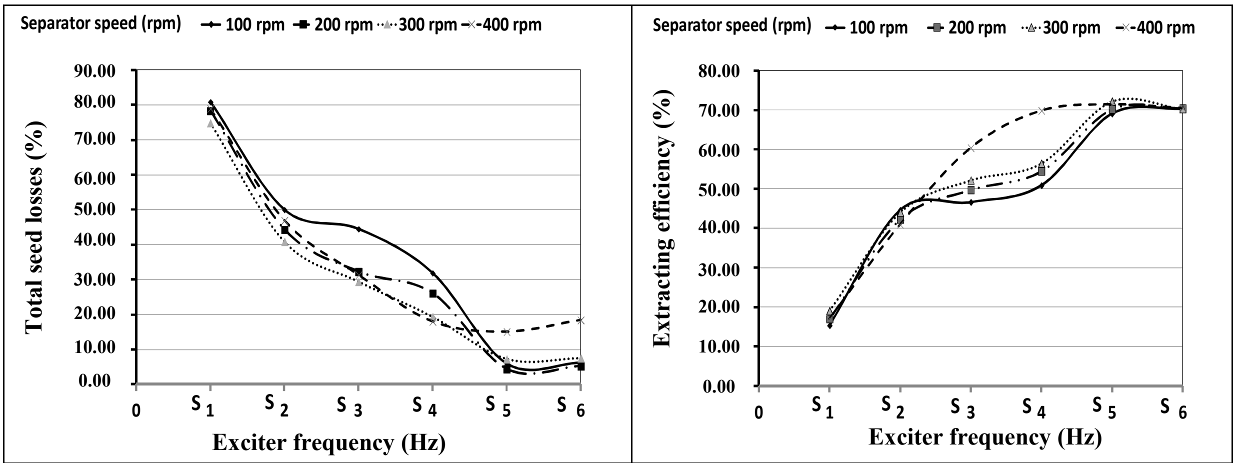
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses

B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

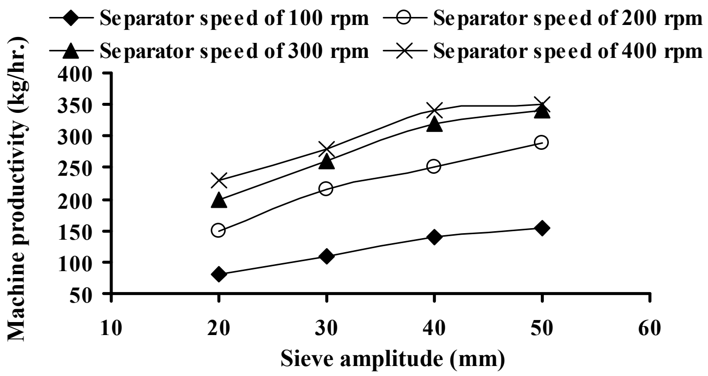


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

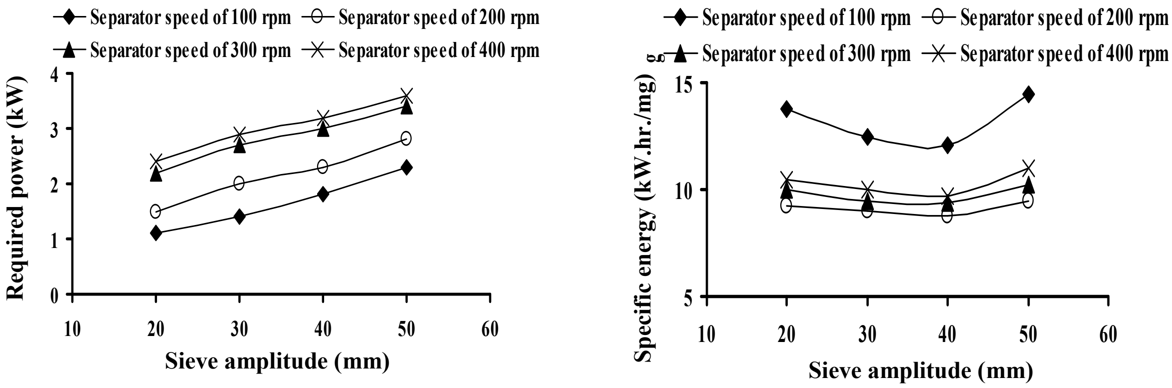


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

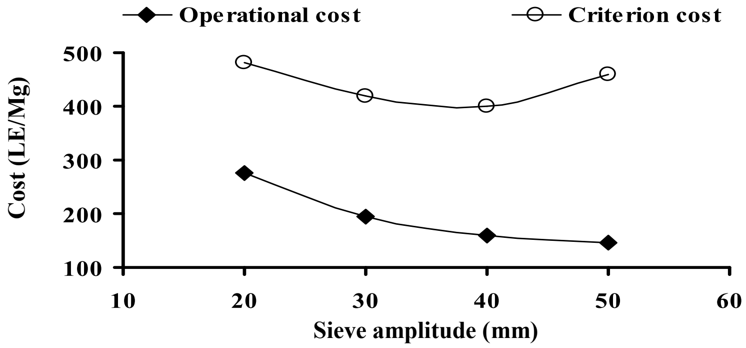


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيــــع وتقييـــــــم أداء آلــــــــــة محليـــــــــة الصنــــع لتفـــريـط بـــذور الـرمـــــان

نجلاء صلاح أنور[1] - محمد محمد مراد حسن[1] - محب محمد أنيس الشرباصي[2]- طارق حسين على[3]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علـــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt

3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

*** Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

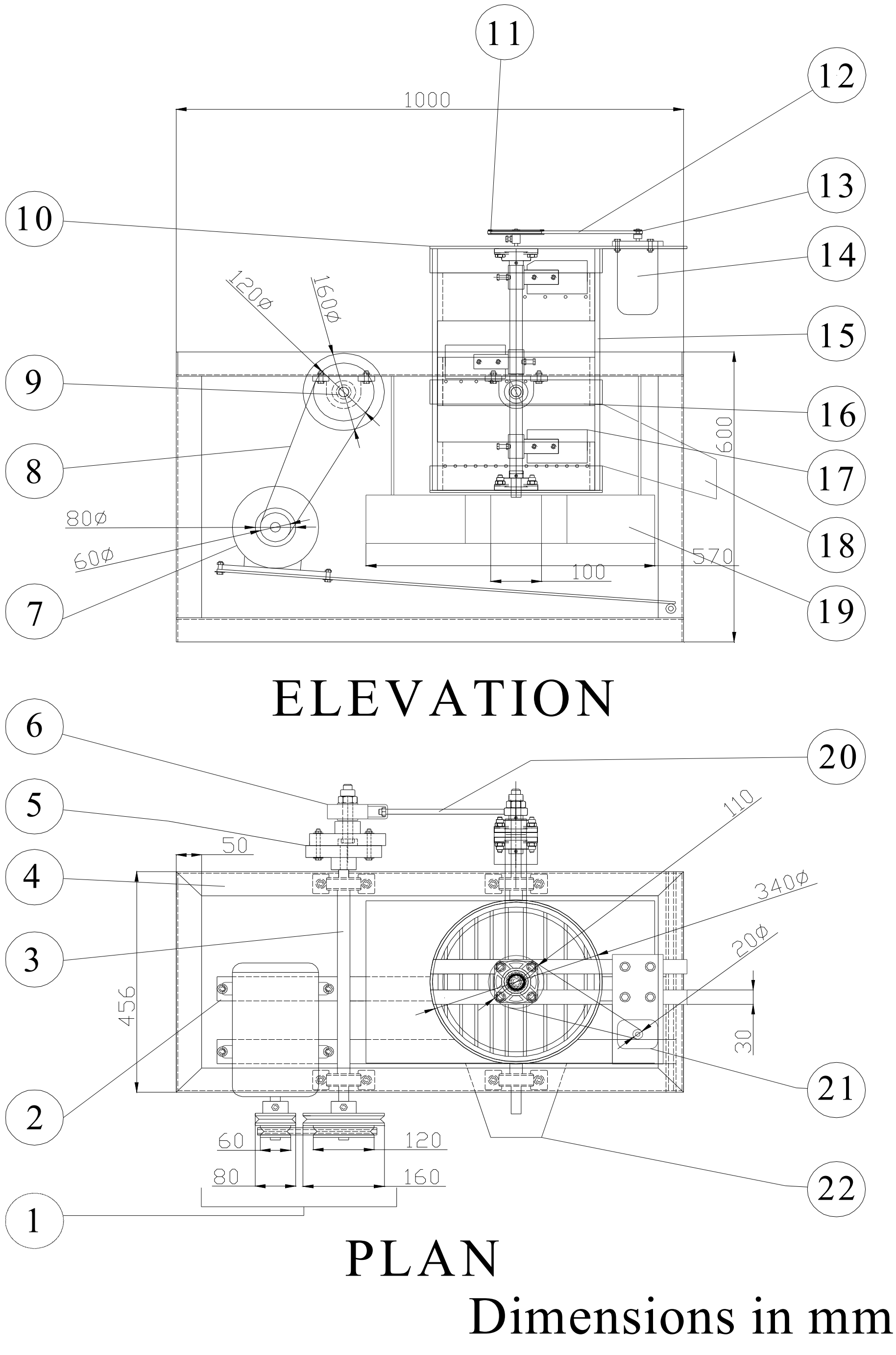
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

$\cos\theta$ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

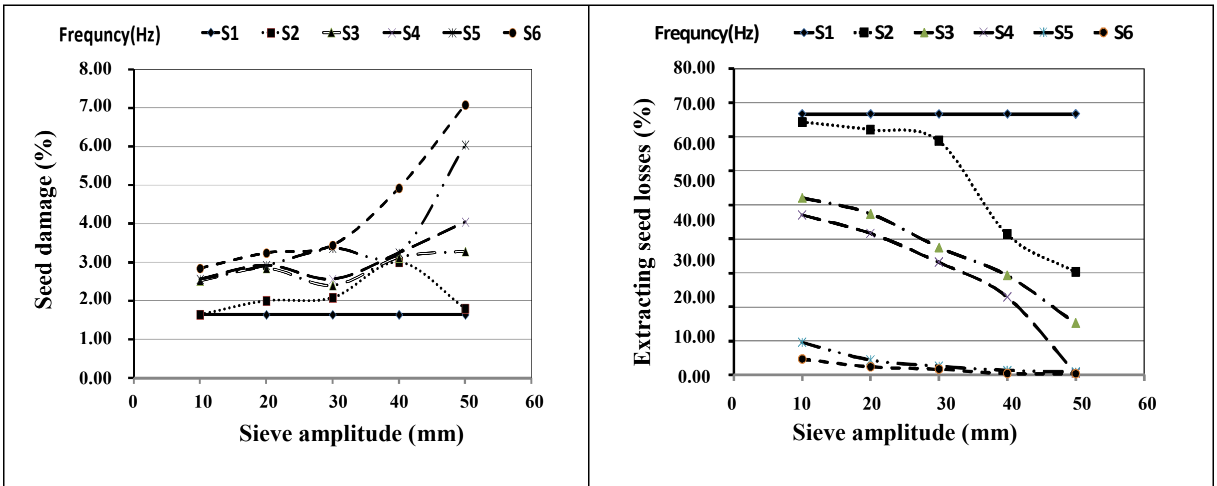
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage	**B. Effect of sieve amplitude and exciter frequency on extracting losses**

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

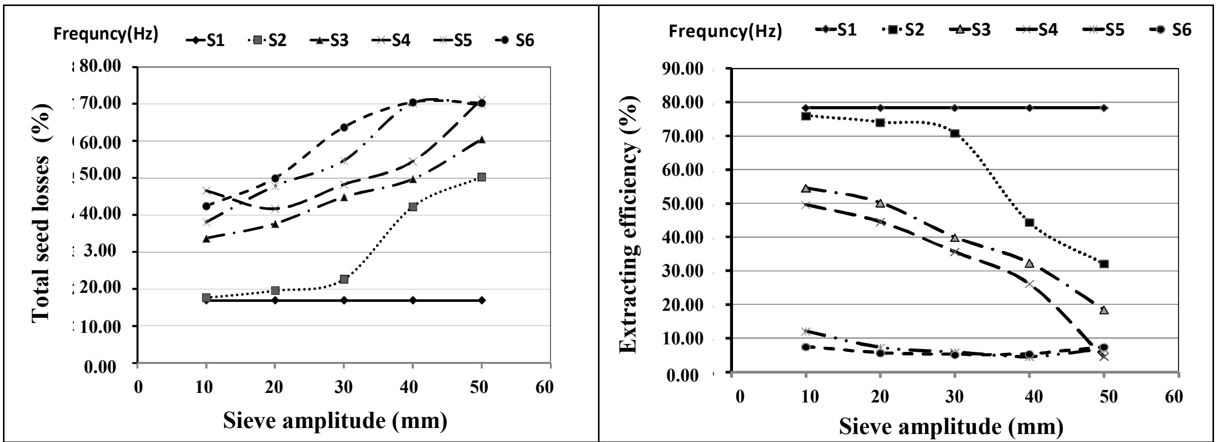
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses	B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

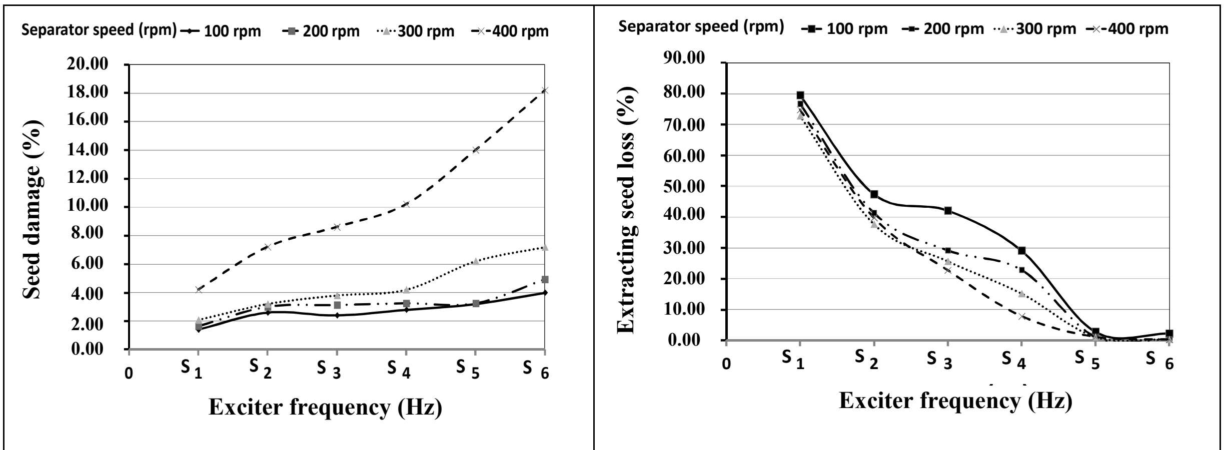
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage	B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

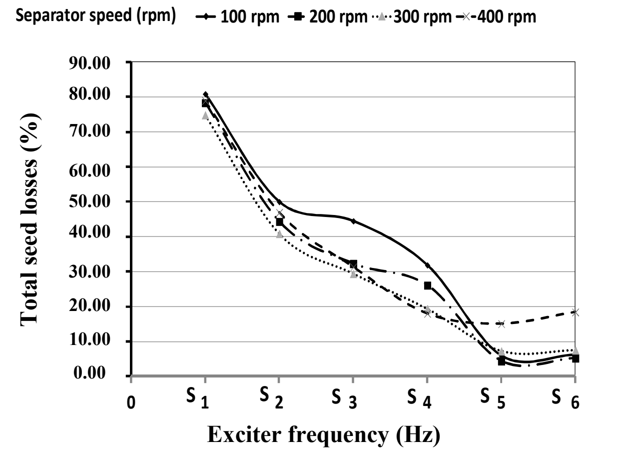
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

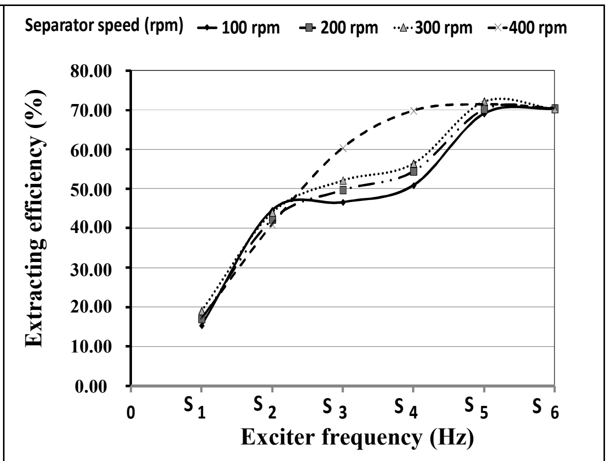
Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses



B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

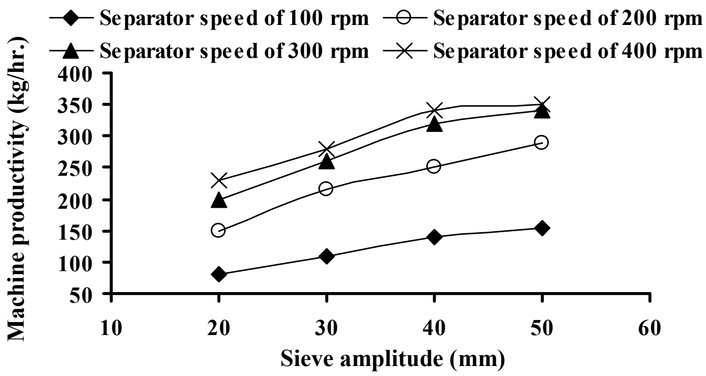


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

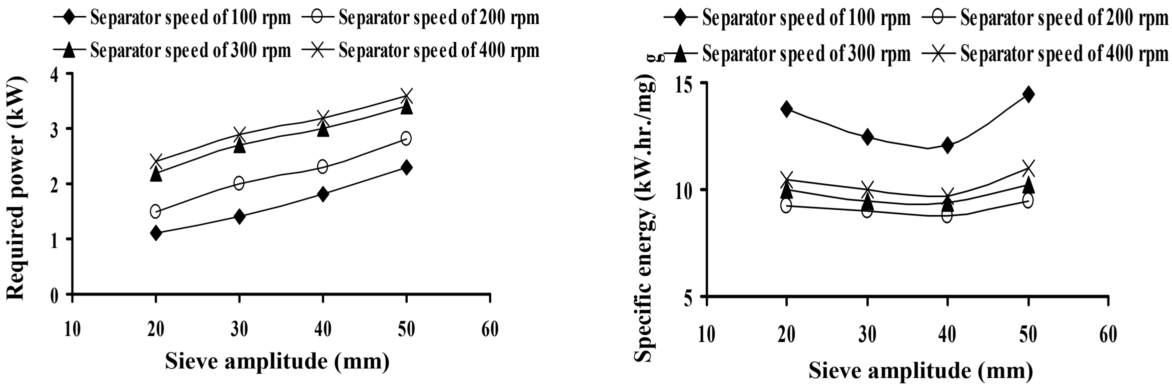


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

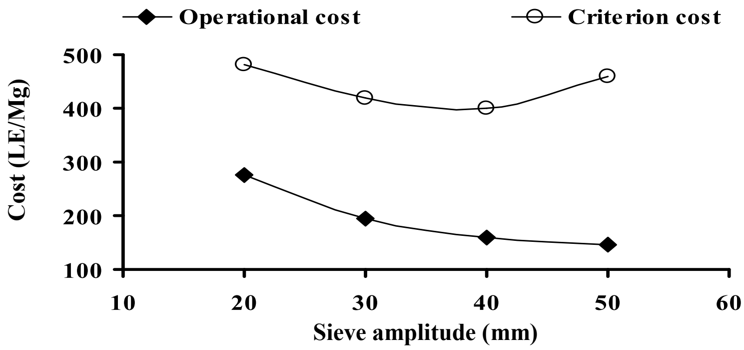


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــــع وتقييـــــــم أداء آلــــــــــة محليـــــــــة الصنــــع لتفـــريـط بـــذور الـرمـــــان

نجلاء صلاح أنور[١] - محمد محمد مراد حسن[١] - محب محمد أنيس الشرباصي[٢]- طارق حسين على[٣]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علـــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt

3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

*** Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

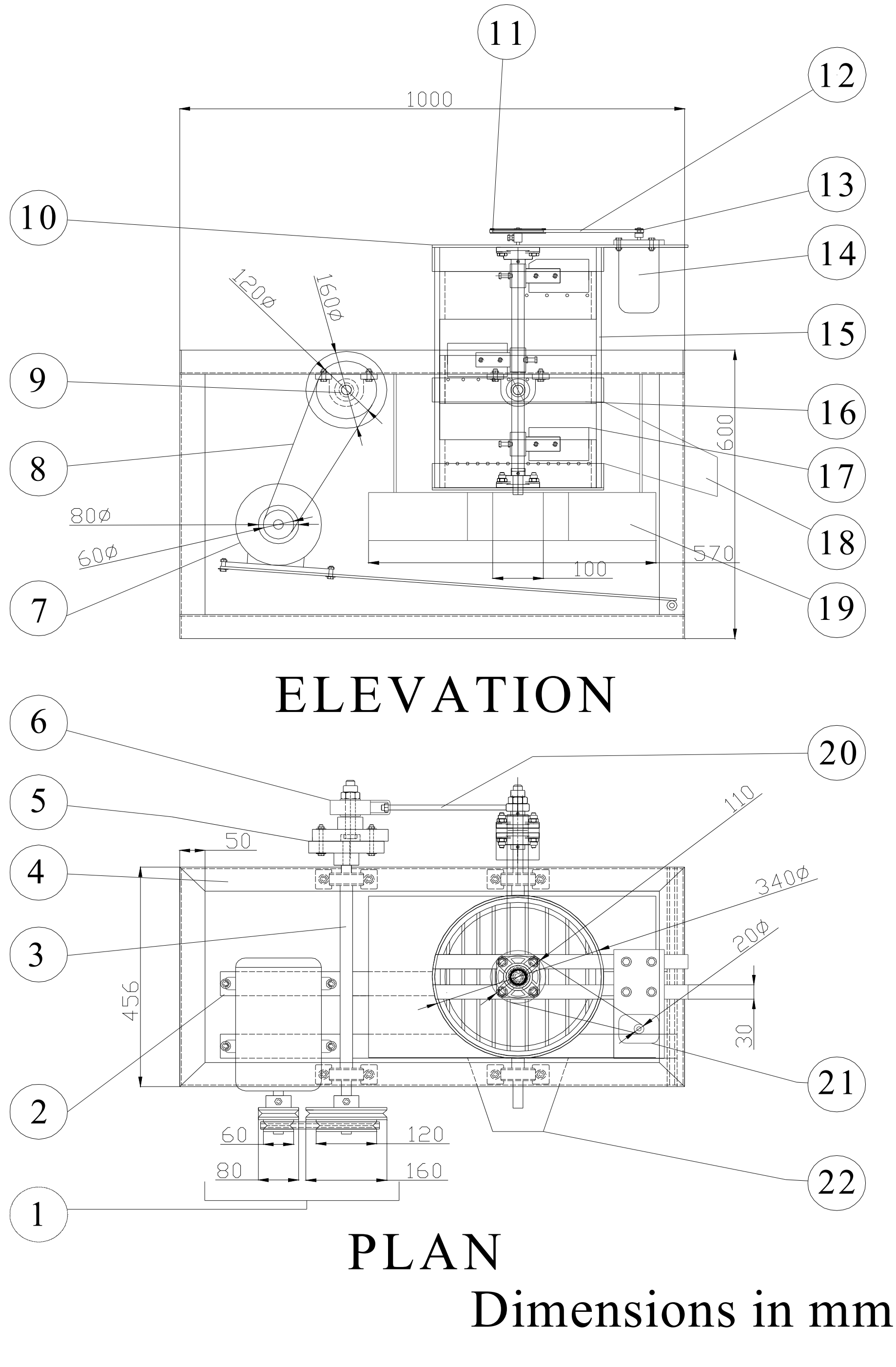
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

$\cos\theta$ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

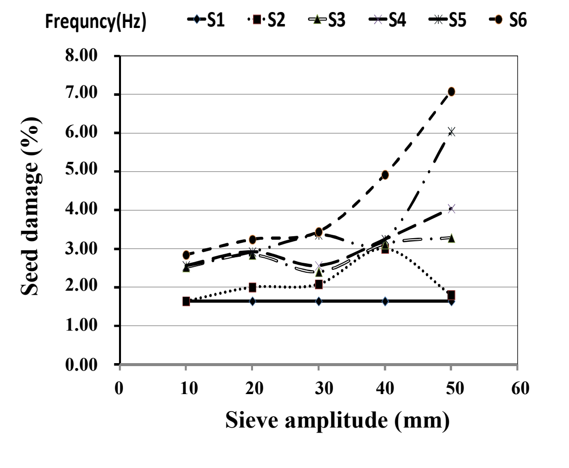
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

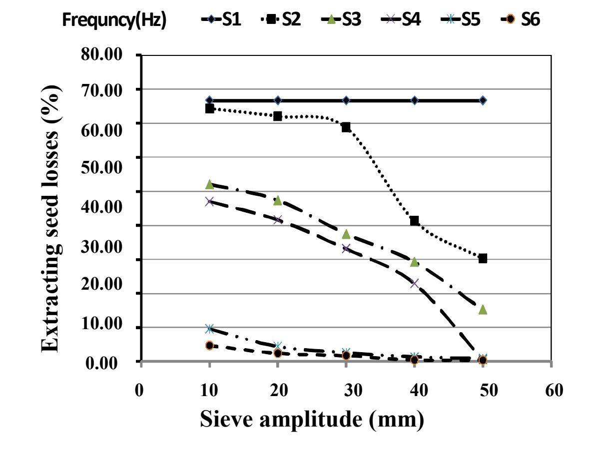
The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage



B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

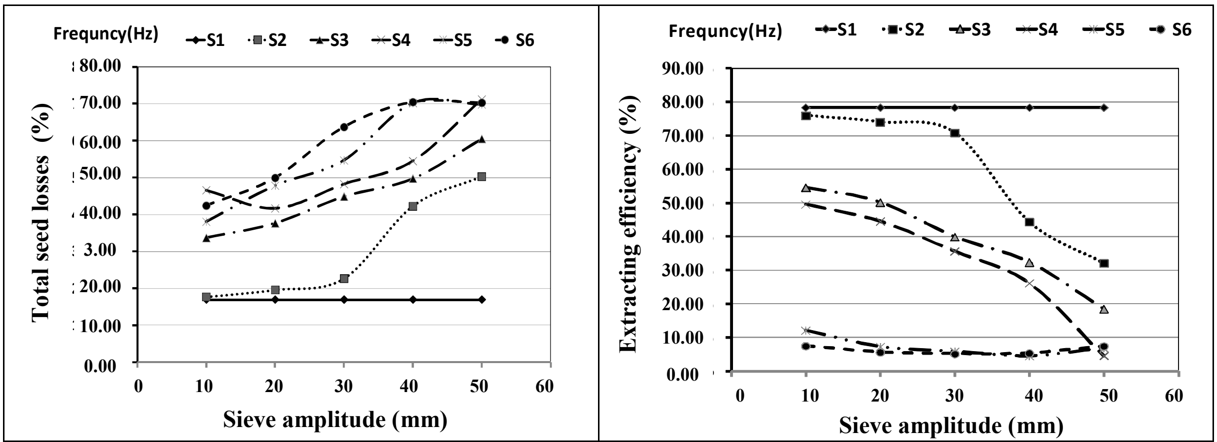
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses

B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

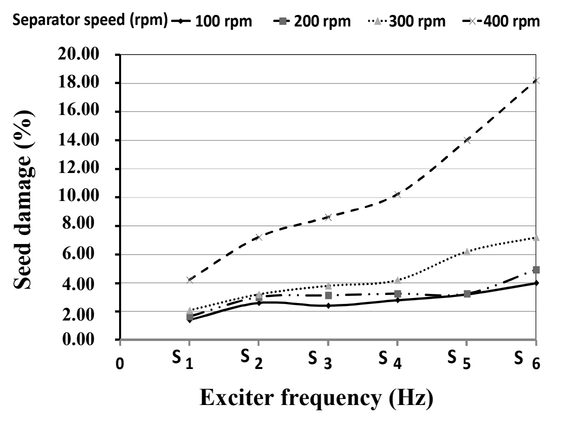
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

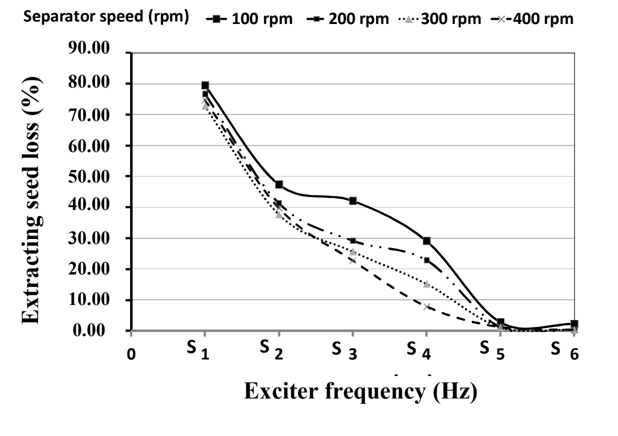
At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage



B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

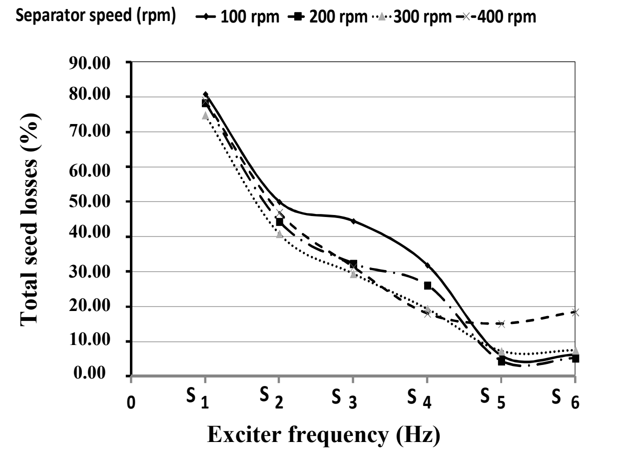
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

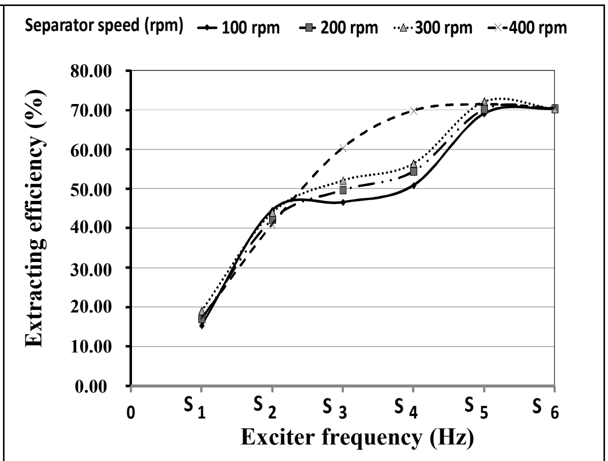
Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses



B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

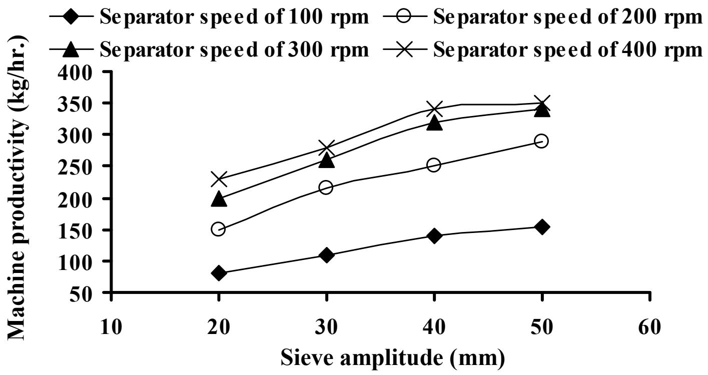


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

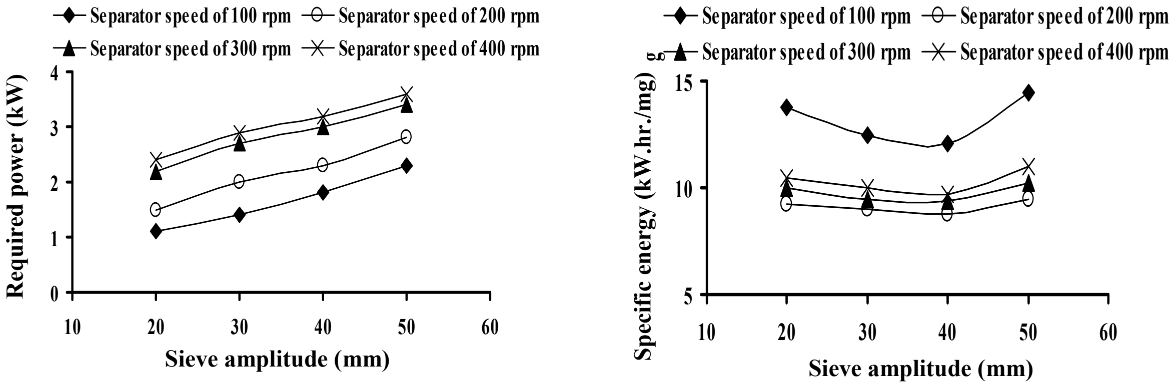


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

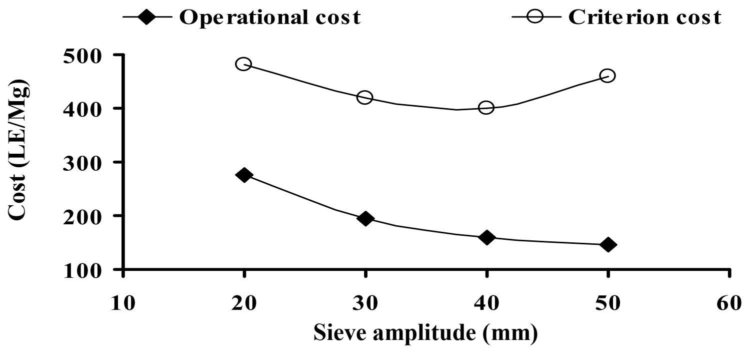


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــع وتقييـــــم أداء آلــــــــة محليــــــــة الصنــــع لتفـــريـط بـــذور الـرمــــان

نجلاء صلاح أنور[1] - محمد محمد مراد حسن[1] - محب محمد أنيس الشرباصي[2]- طارق حسين على[3]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt

3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

*** Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

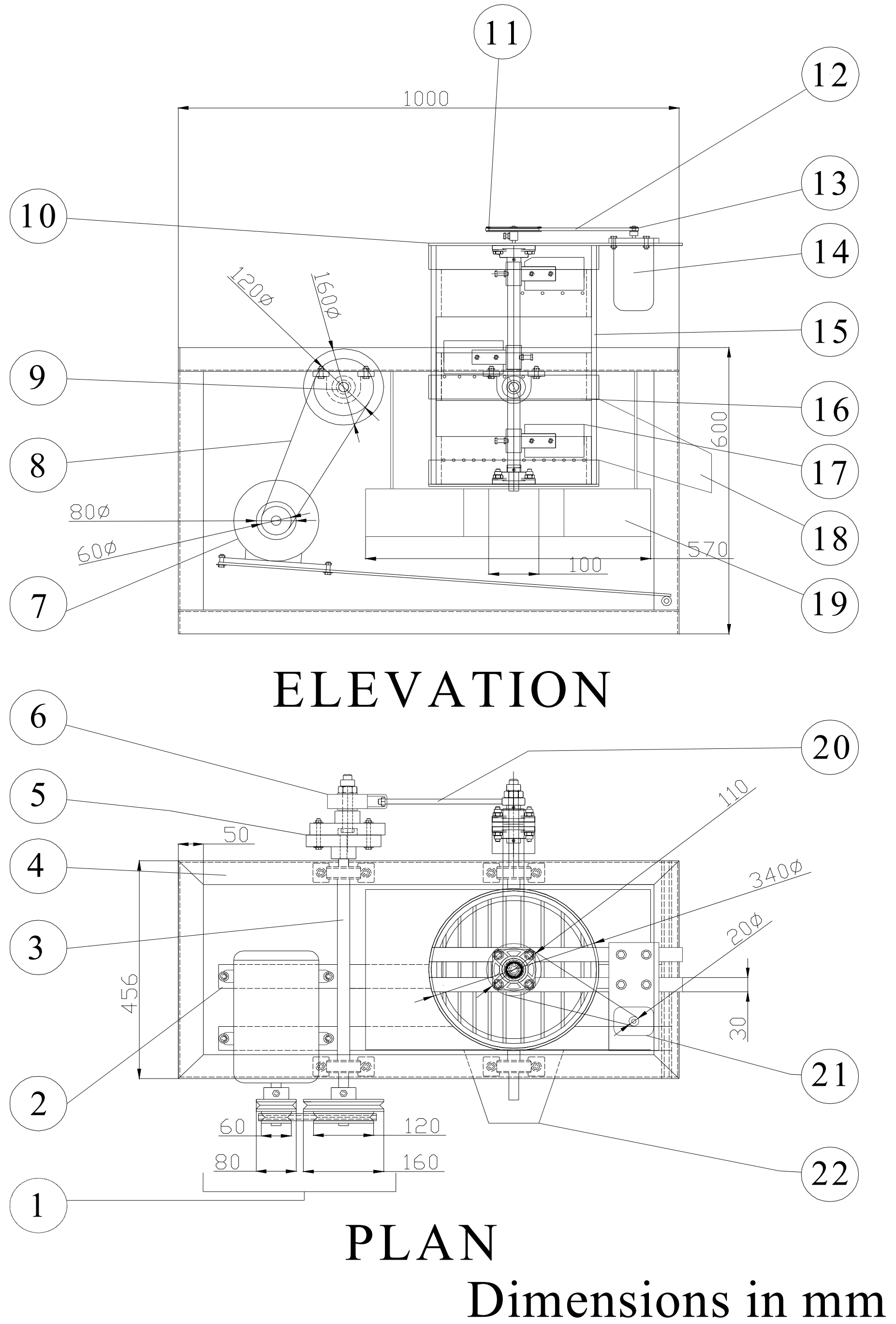
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%)=\frac{M_u}{M_u + M_c}\times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

$\cos\theta$ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

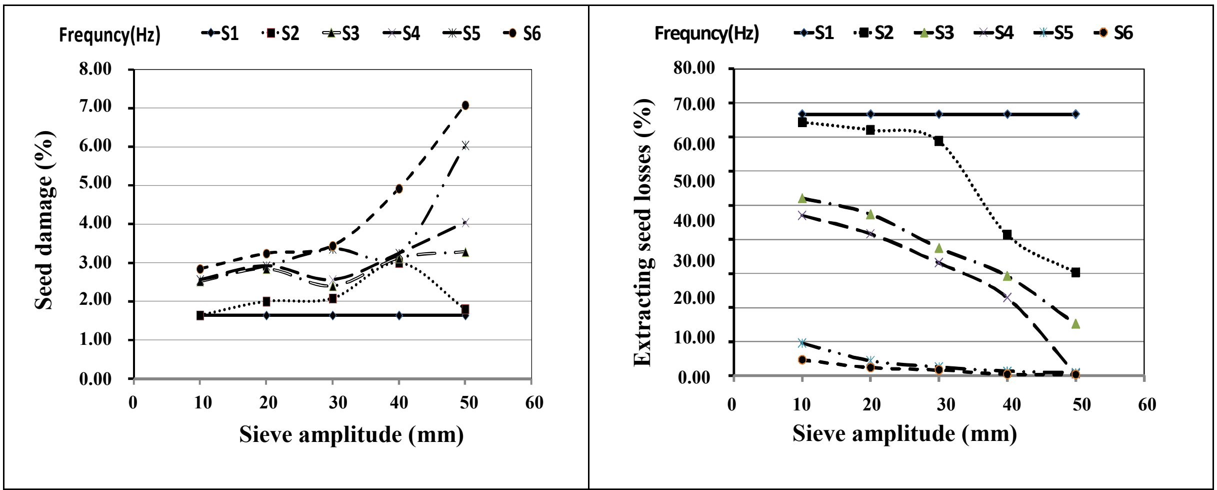
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage	B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

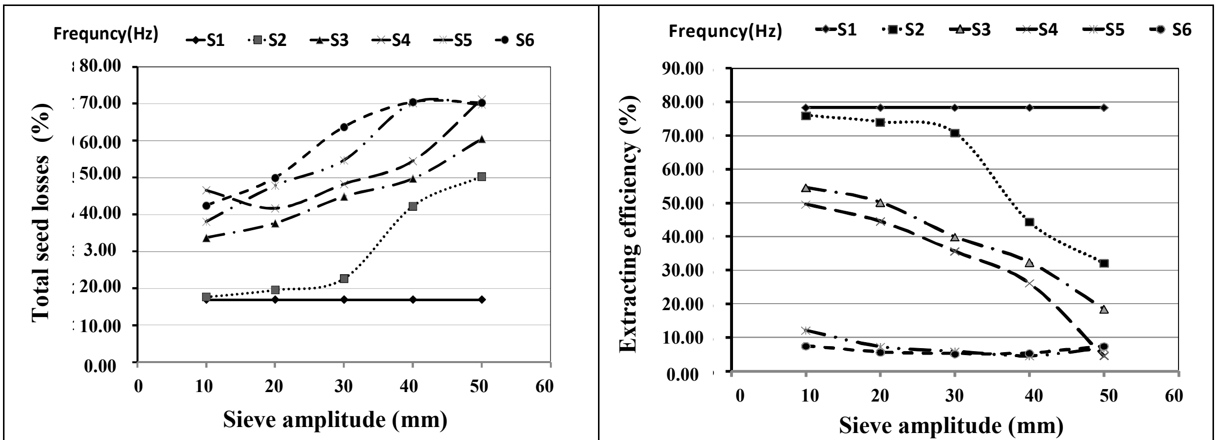
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses

B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

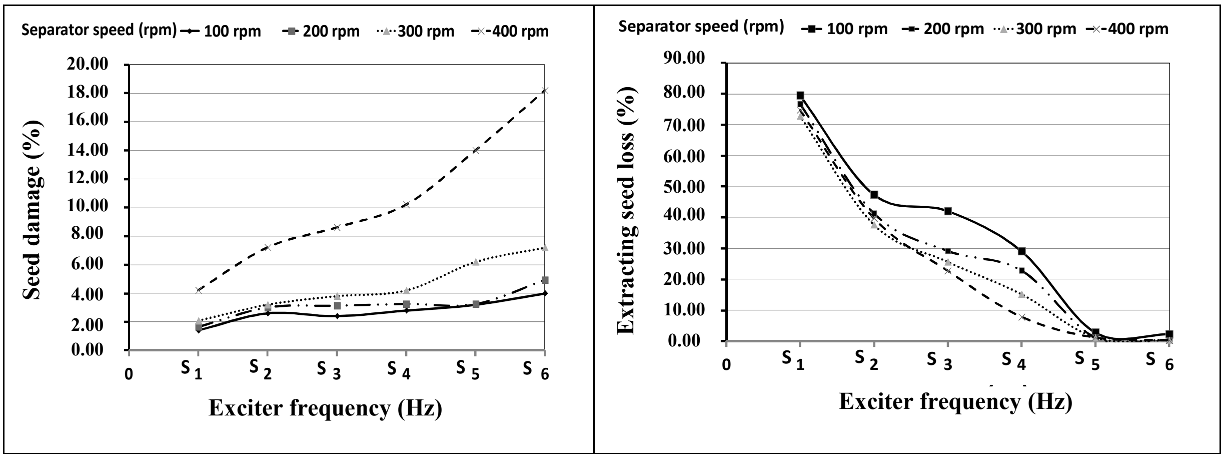
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage	B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

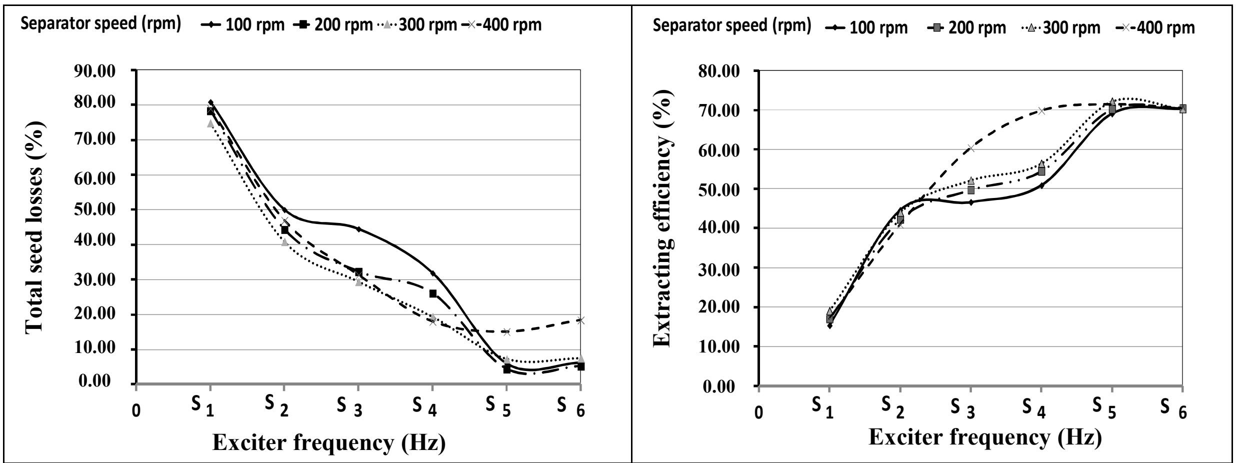
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses

B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

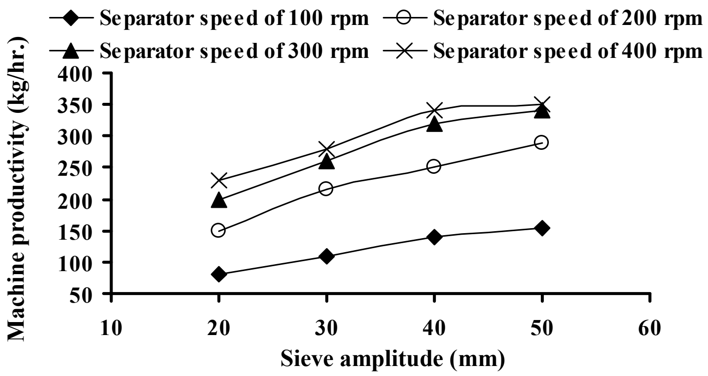


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

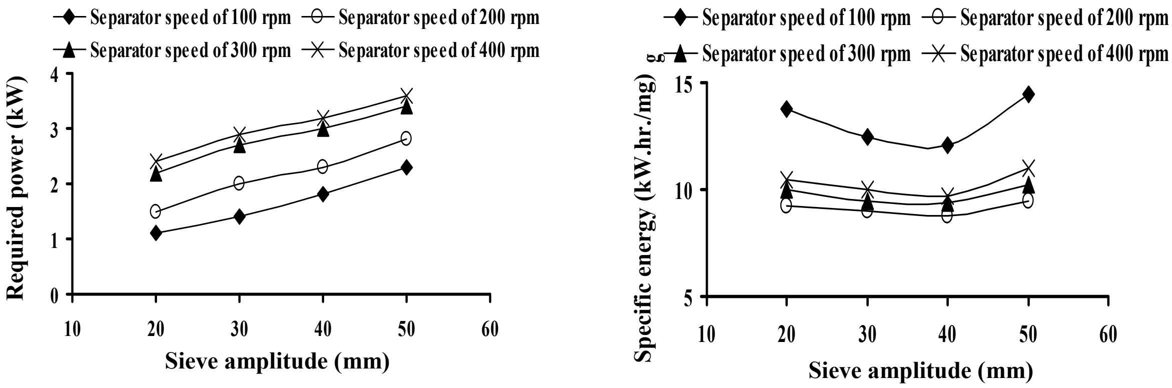


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

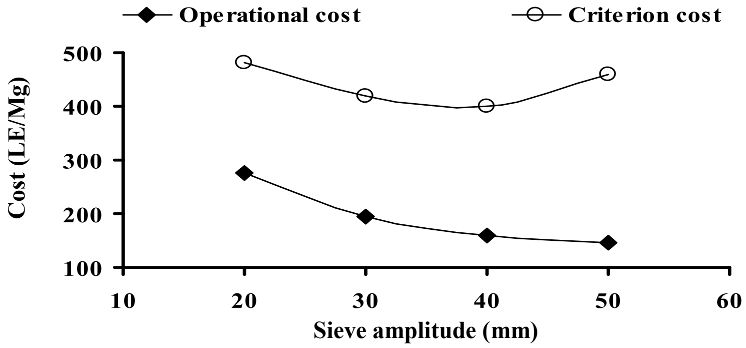


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــــع وتقييـــــــم أداء آلـــــــــــة محليـــــــــة الصنـــــع لتفــــريـط بـــذور الـرمــــــان

نجلاء صلاح أنور[1] - محمد محمد مراد حسن[1] - محب محمد أنيس الشرباصي[2]- طارق حسين على[3]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt
2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt
3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

* **Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

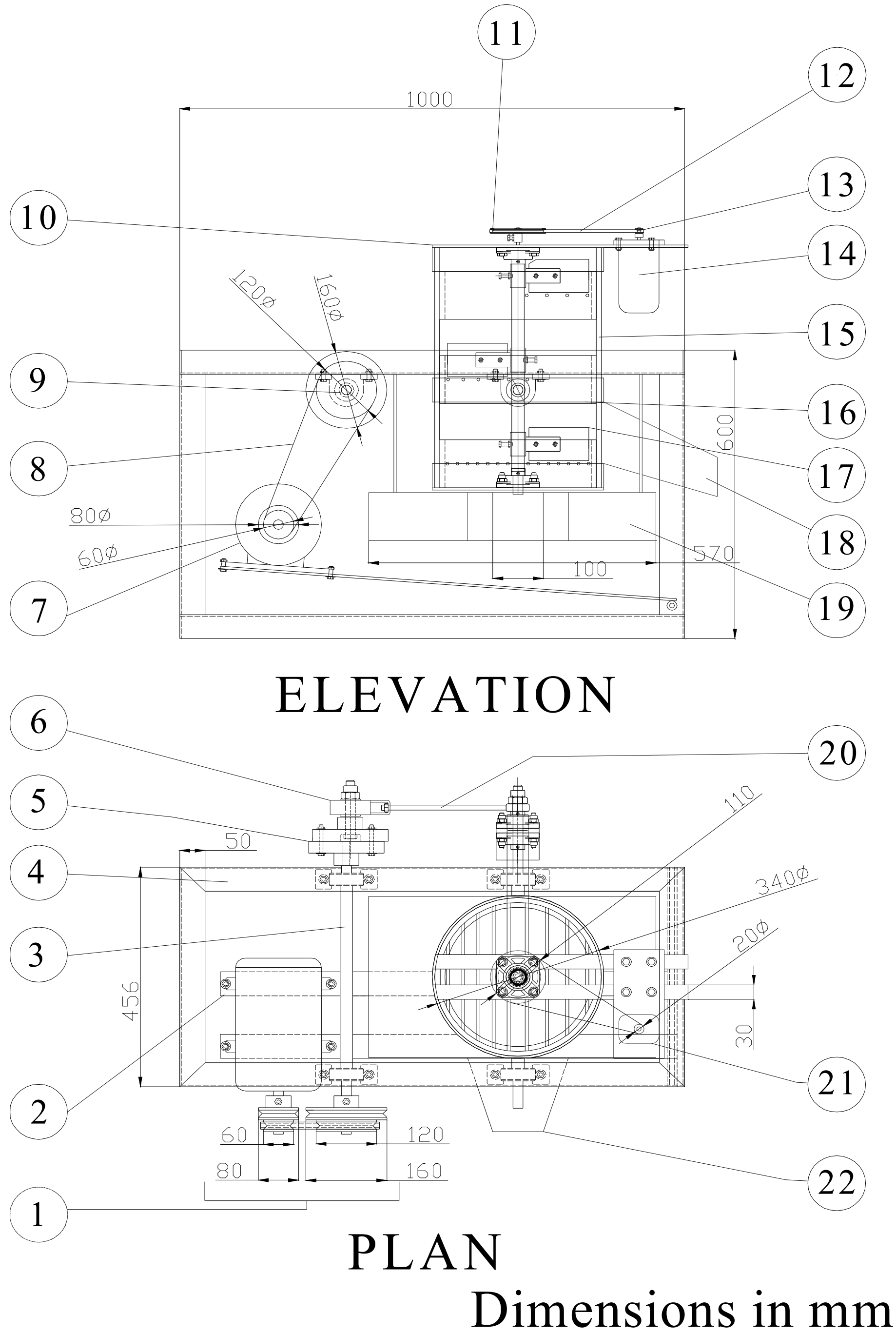
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

$\cos\theta$ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

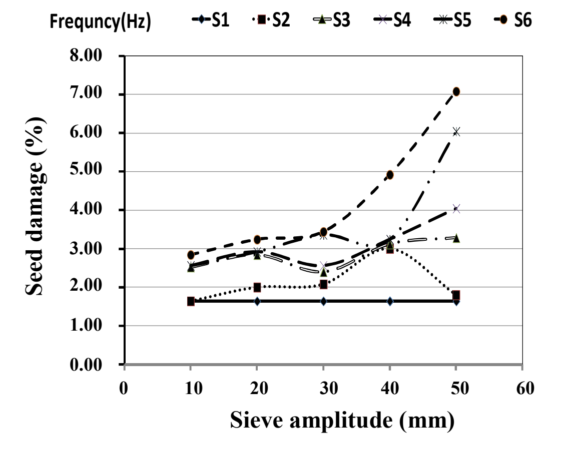
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

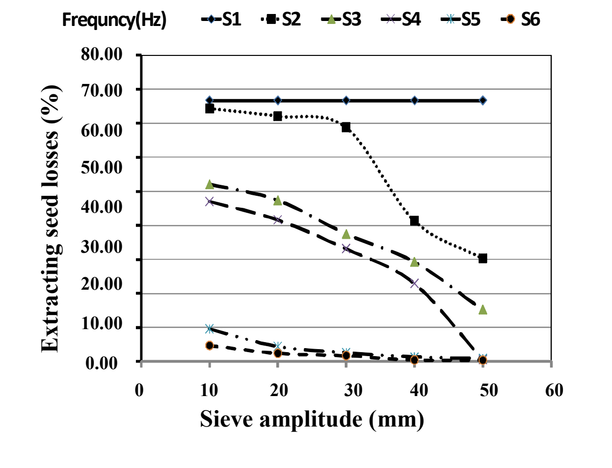
The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage



B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

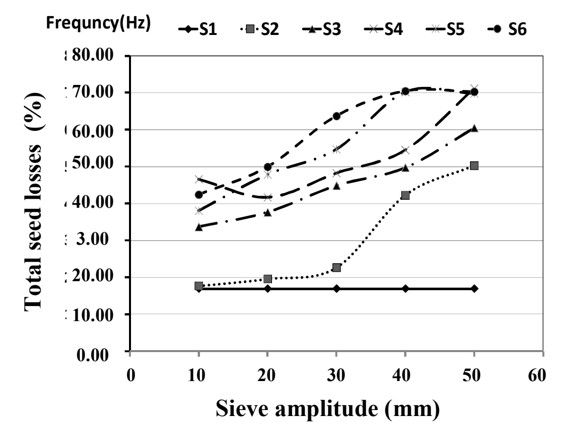
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

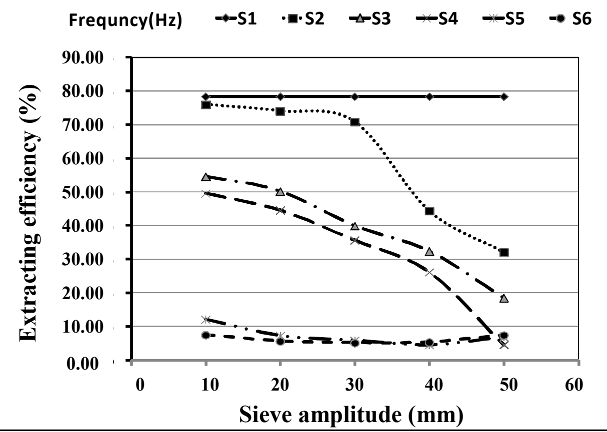
It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses



B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

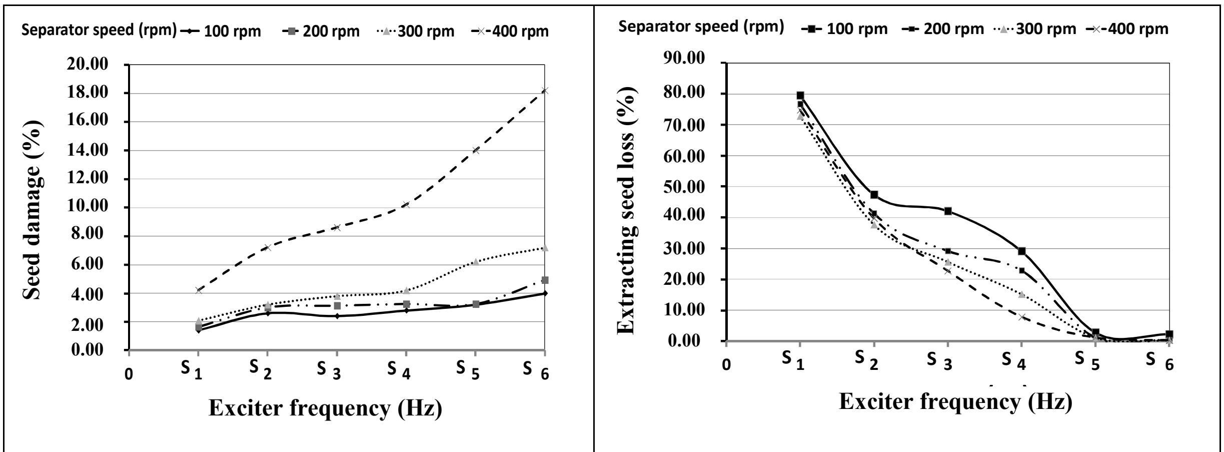
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage	B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

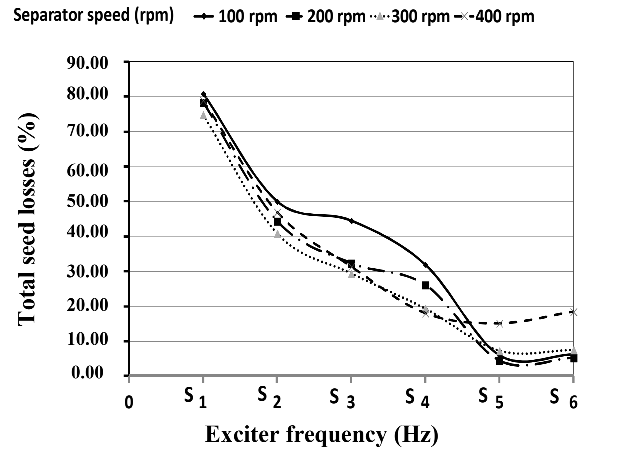
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

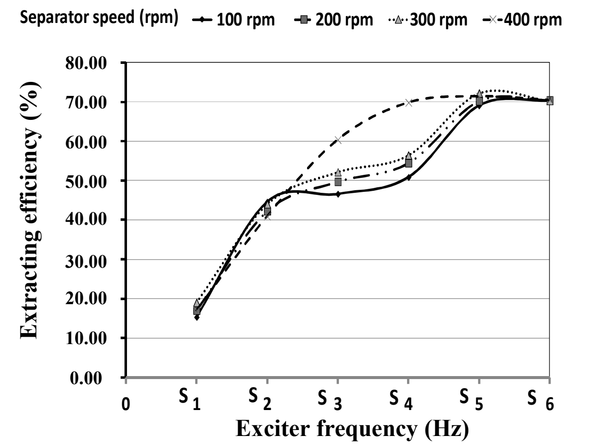
Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses



B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

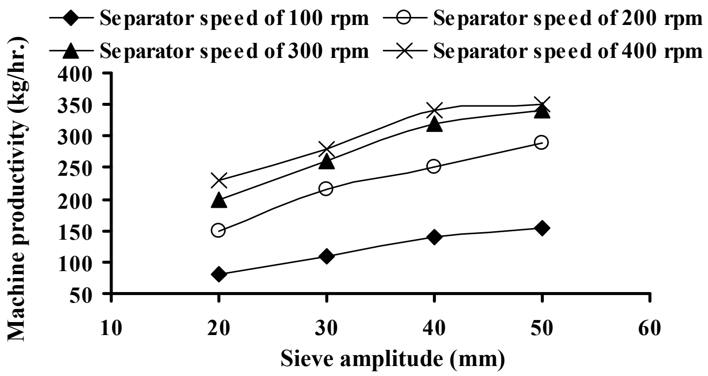


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

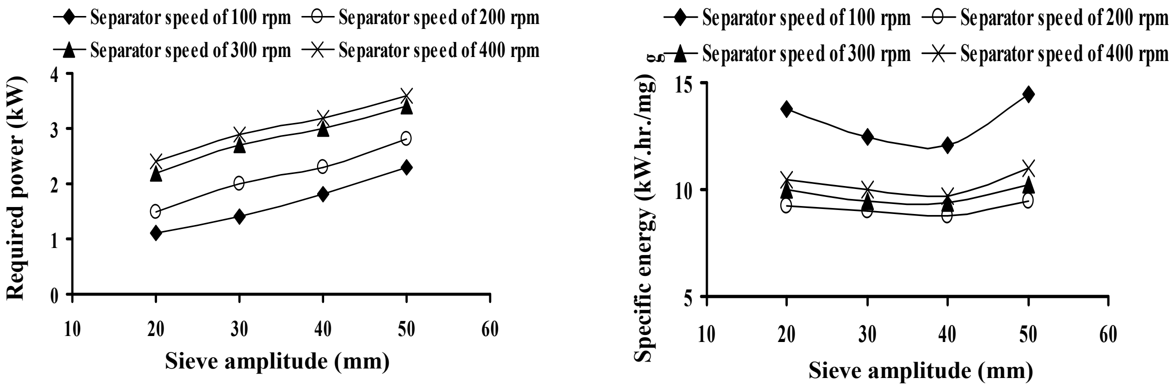


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

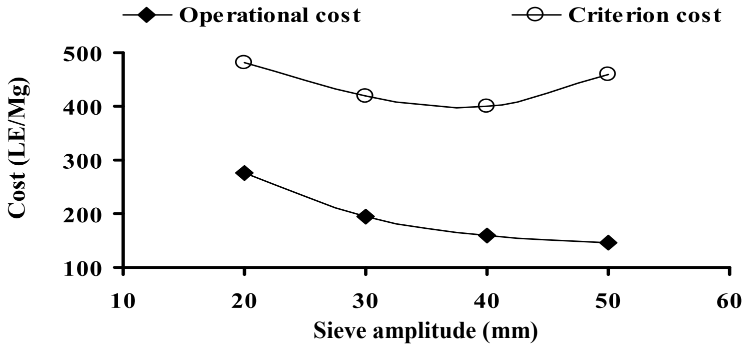


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــــع وتقييـــــــم أداء آلـــــــــــة محليـــــــــة الصنـــــع لتفـــريـط بـــذور الـرمـــــان

نجلاء صلاح أنور[1] ـ محمد محمد مراد حسن[1] ـ محب محمد أنيس الشرباصي[2] ـ طارق حسين على[3]

١ـ قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢ـ قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣ـ قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية ـ مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١ـ أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢ـ أ.د. محمود مصطفى علـــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt

3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

*** Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

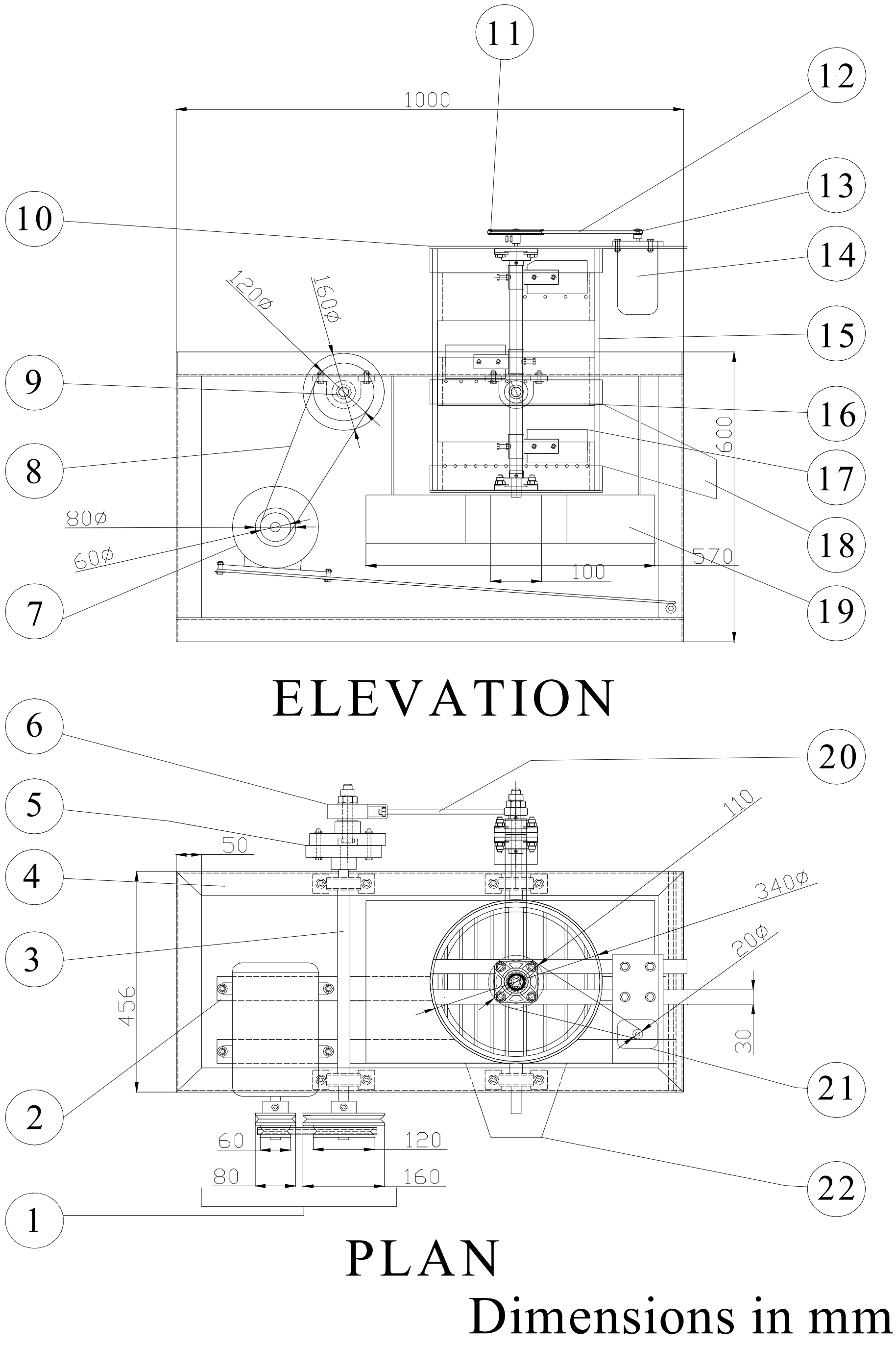
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%)=\frac{M_u}{M_u + M_c}\times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

cos θ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

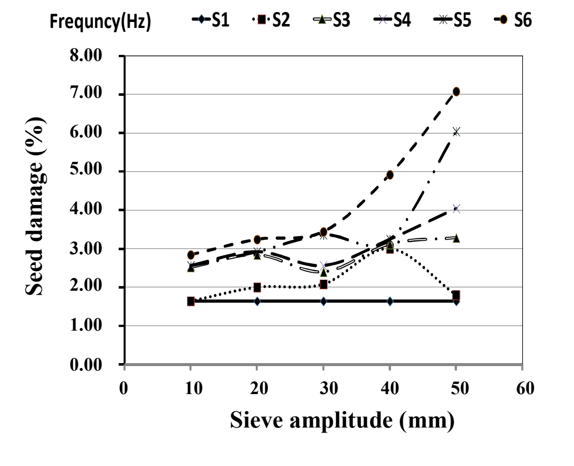
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

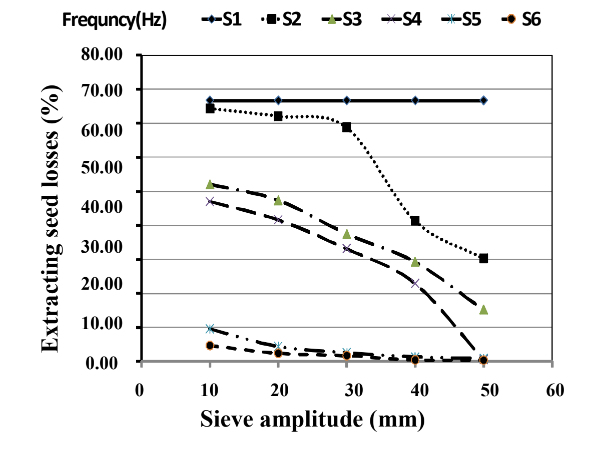
The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage



B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

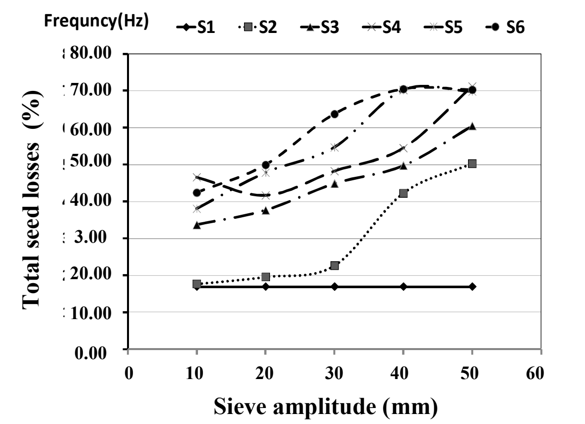
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

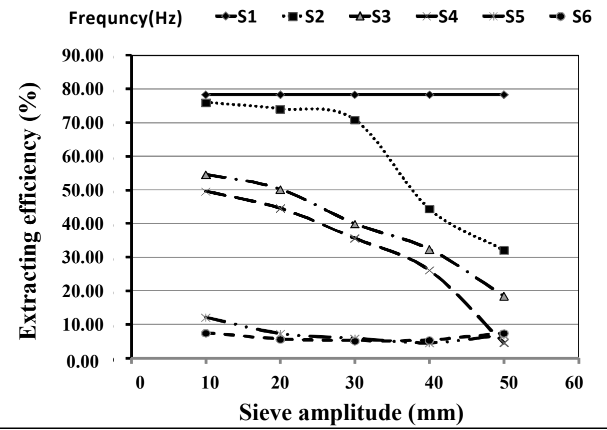
It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses



B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

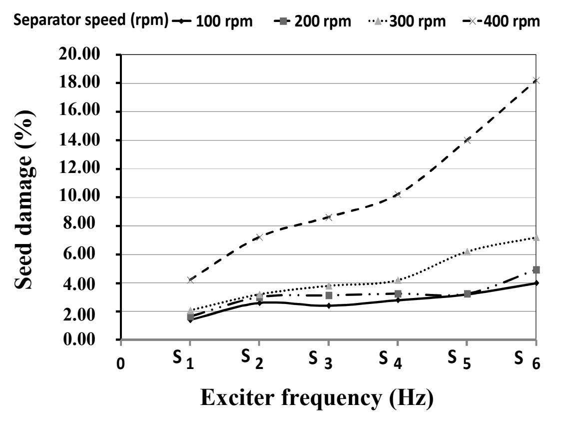
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

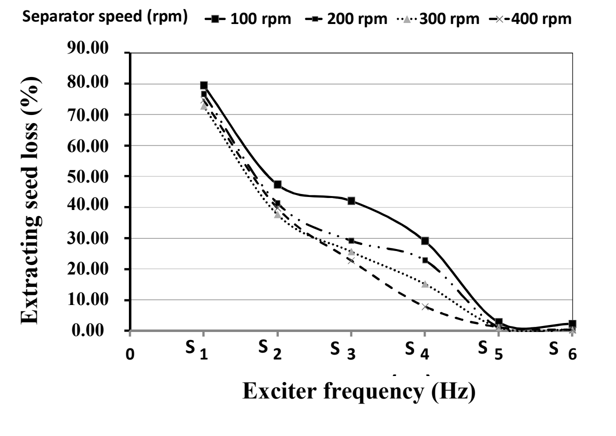
The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.





A. Effect of separator speed and exciter frequency on seed damage	B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

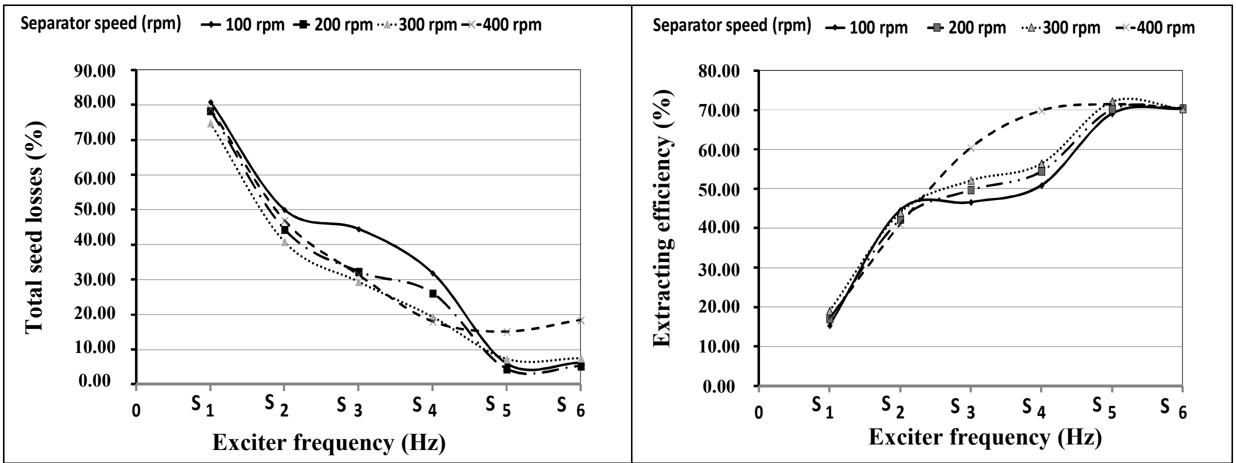
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses

B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

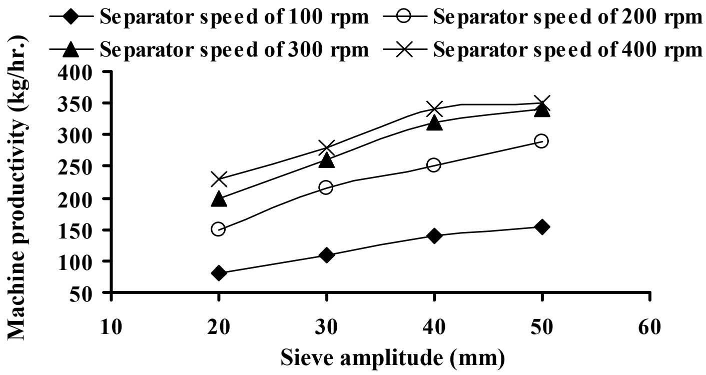


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

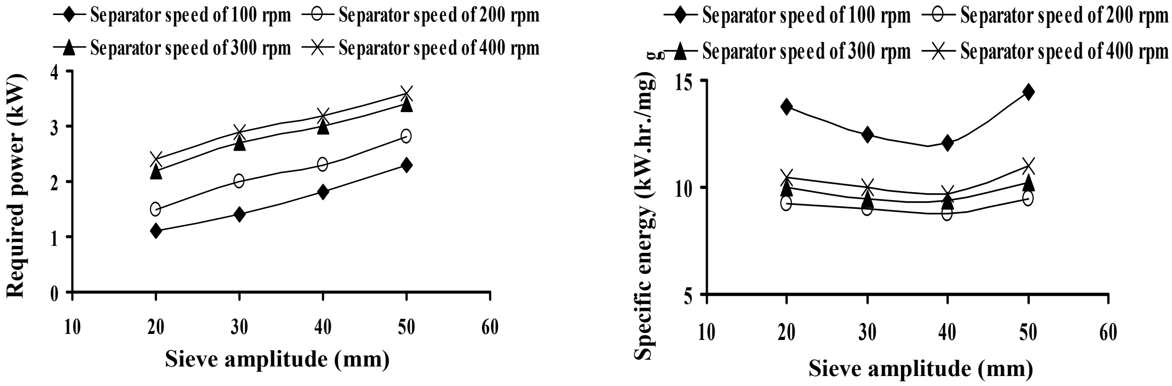


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

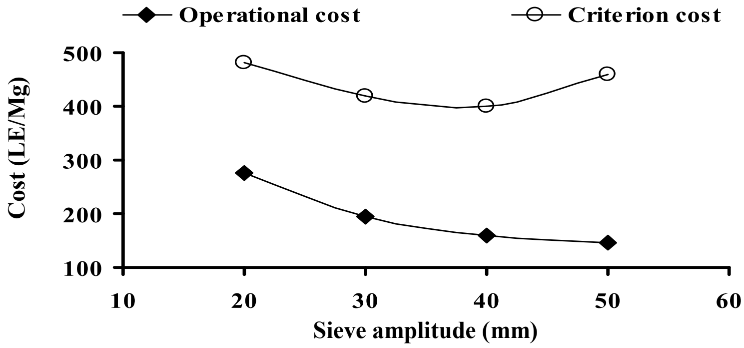


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــــع وتقييـــــــم أداء آلـــــــــــــة محليـــــــــــة الصنـــــع لتفـــــريـط بــــذور الـرمــــــان

نجلاء صلاح أنور[1] - محمد محمد مراد حسن[1] - محب محمد أنيس الشرباصي[2]- طارق حسين على[3]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt

3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

* **Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

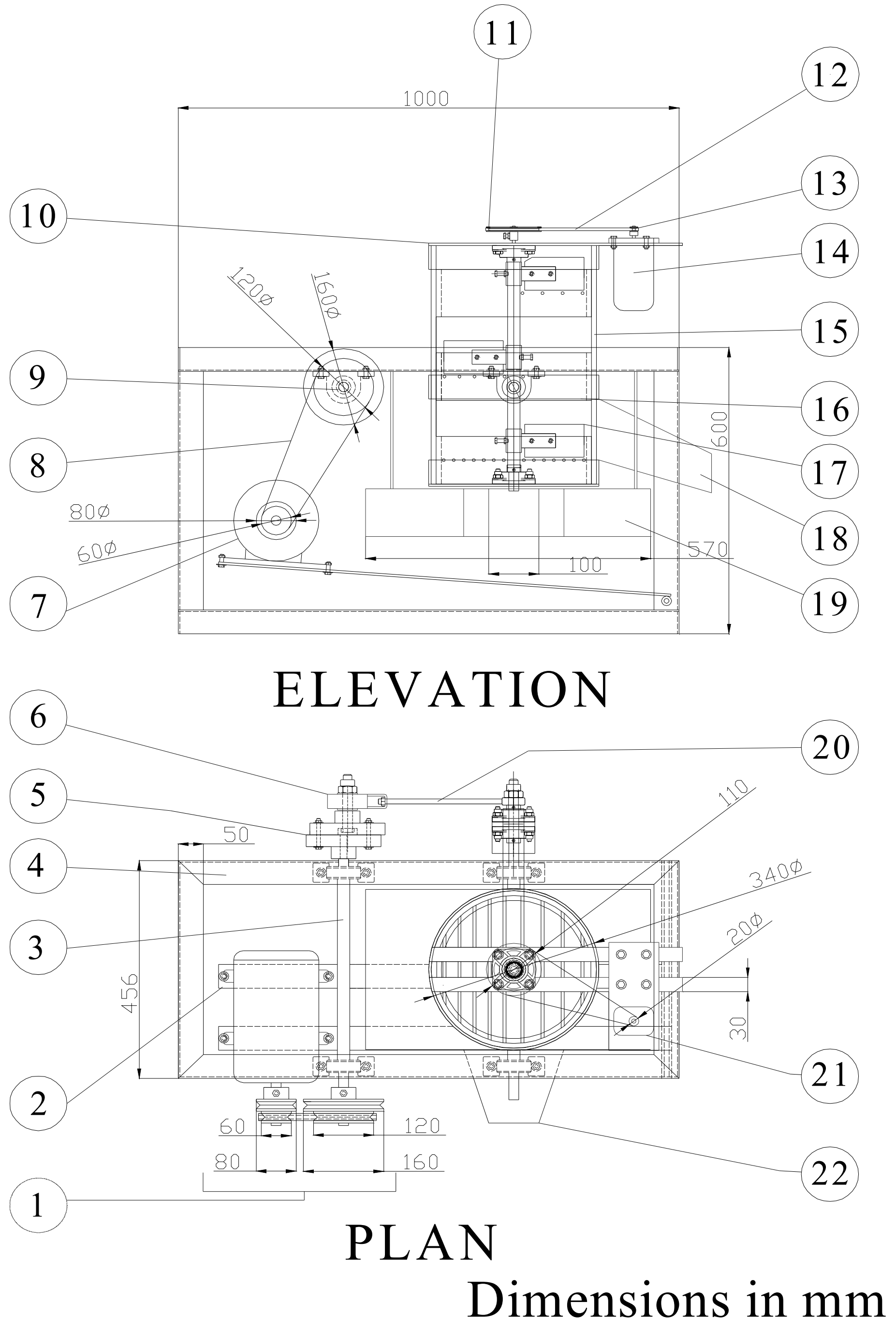
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

$\cos\theta$ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

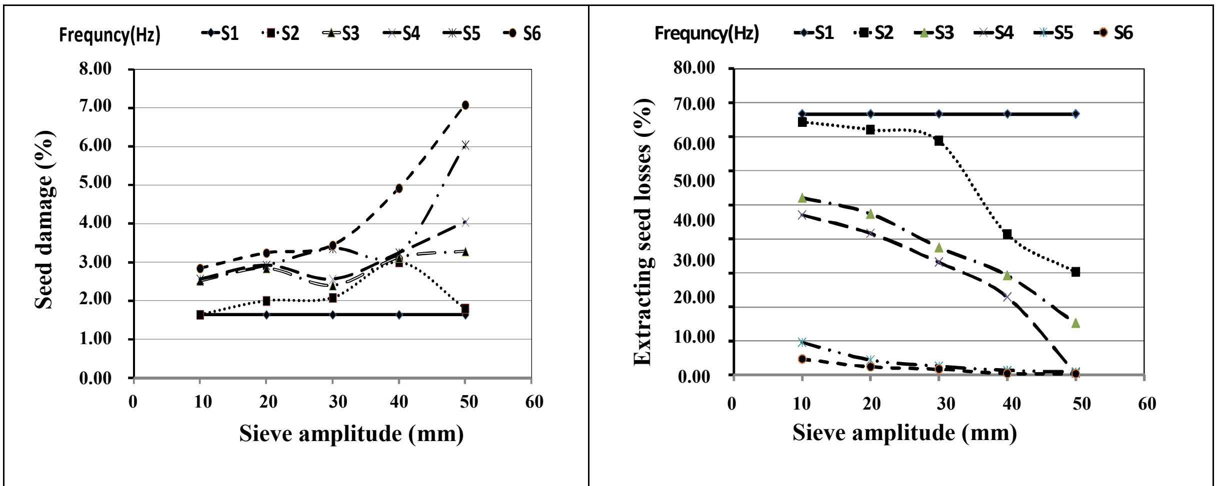
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage

B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.

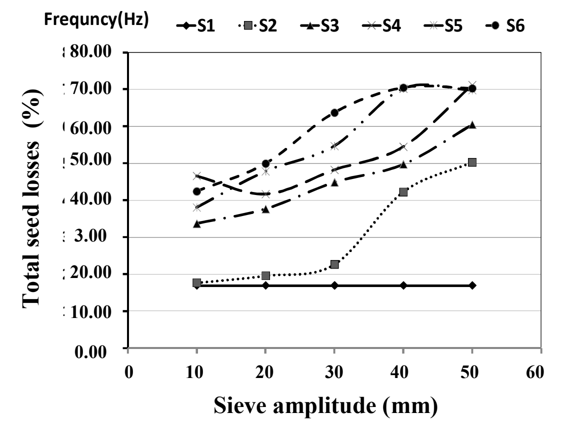
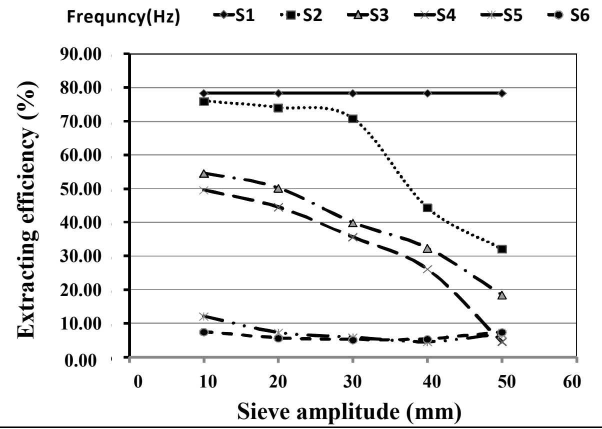
A	B
	
A. Effect of sieve amplitude and exciter frequency on total seed losses	**B. Effect of sieve amplitude and exciter frequency on extracting efficiency**

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

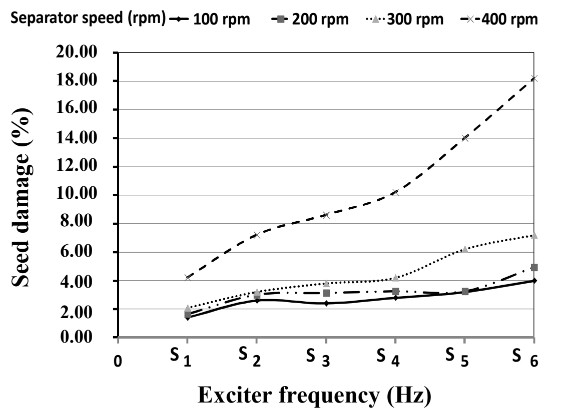
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

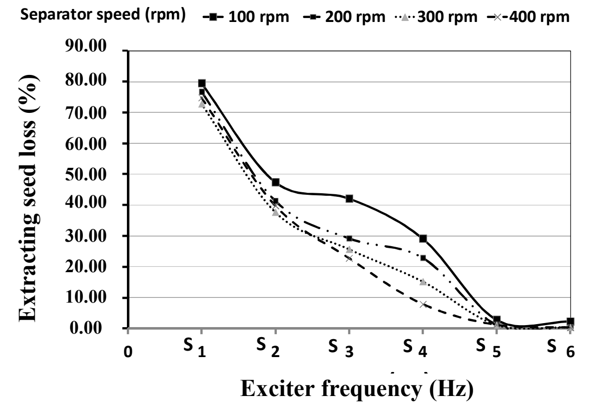
At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage



B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

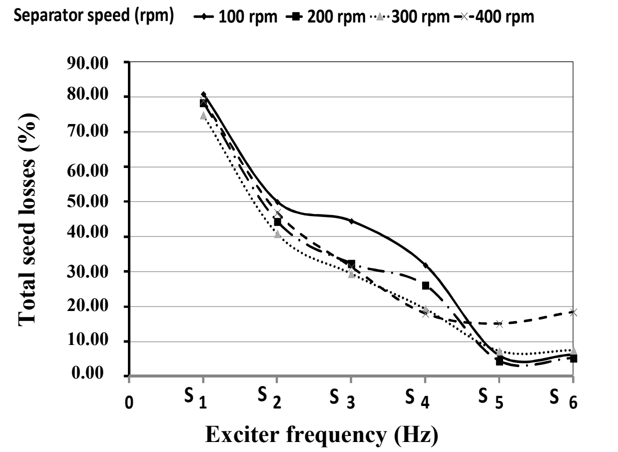
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

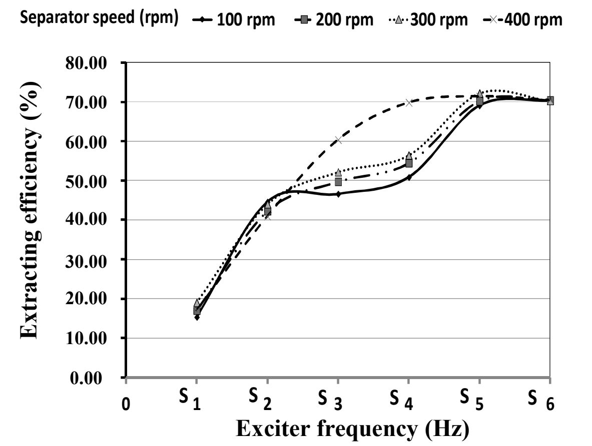
Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses



B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

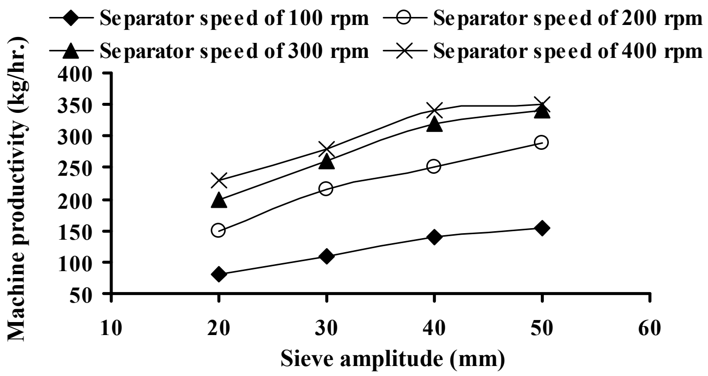


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

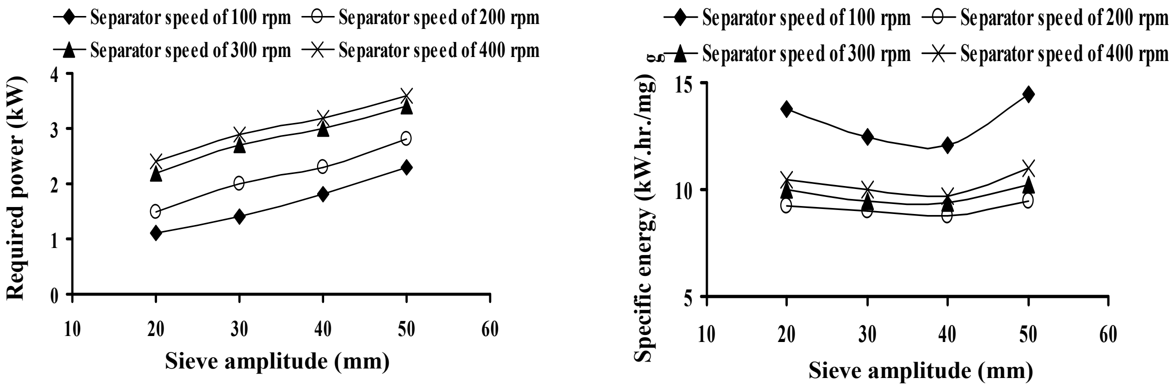


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

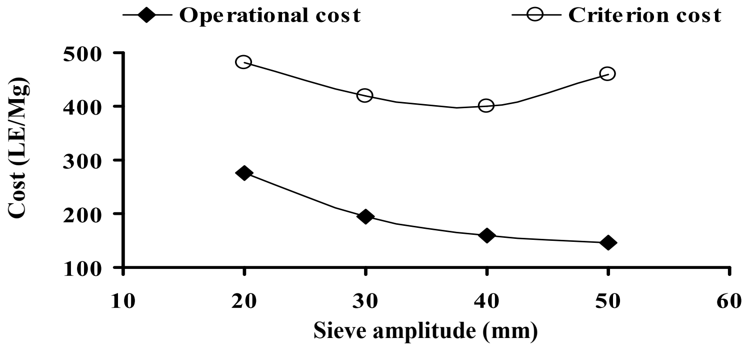


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــــع وتقييـــــــم أداء آلــــــــــة محليـــــــــة الصنـــــع لتفـــريـط بـــذور الـرمــــــان

نجلاء صلاح أنور[1] - محمد محمد مراد حسن[1] - محب محمد أنيس الشرباصي[2]- طارق حسين على[3]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علـــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt

3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

*** Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

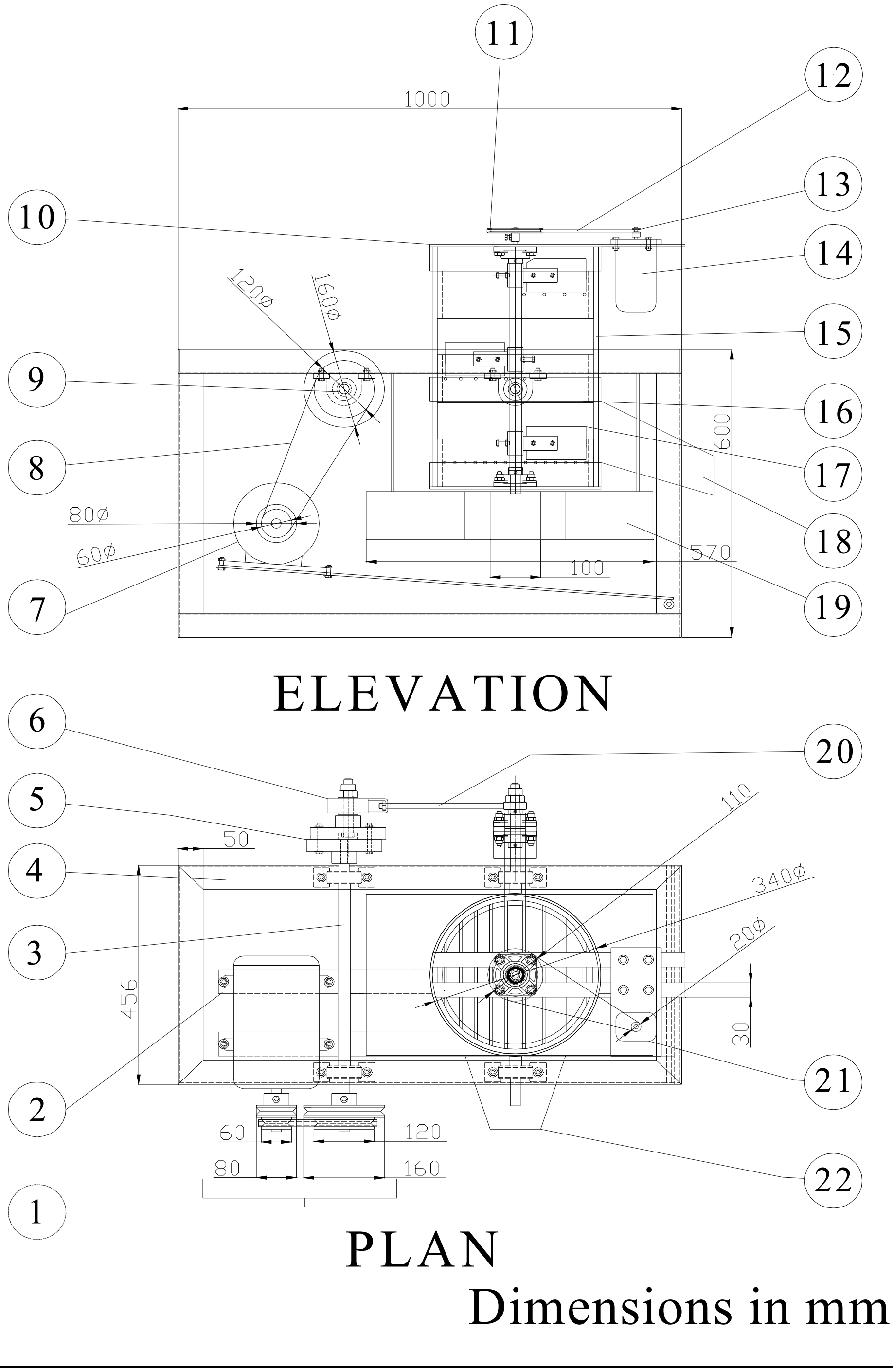
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

$\cos\theta$ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

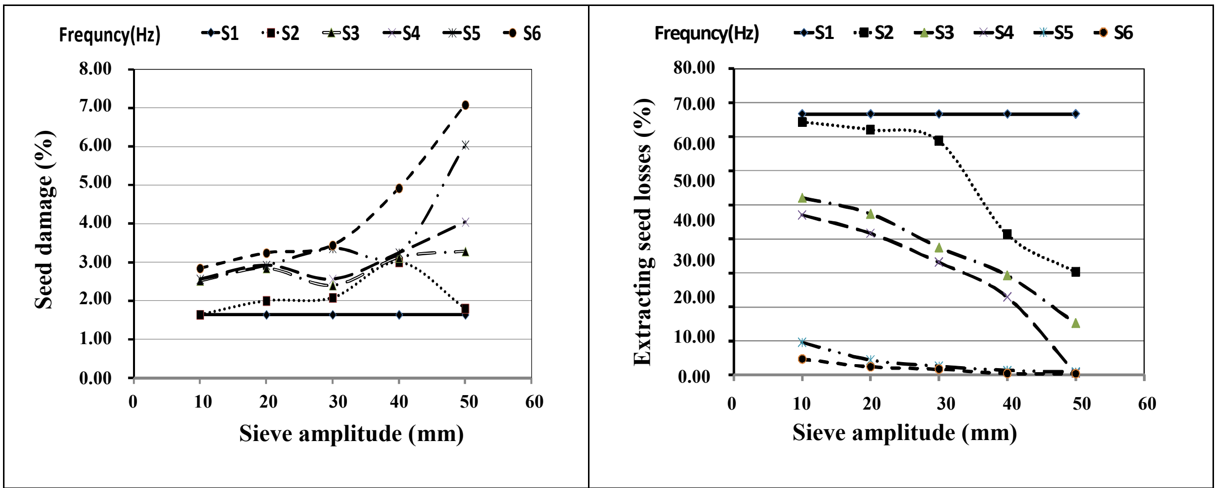
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage

B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

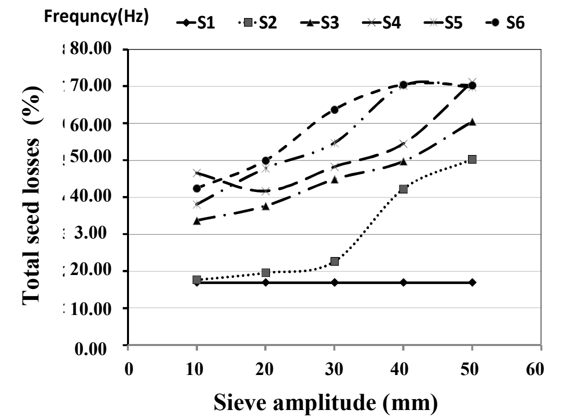
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

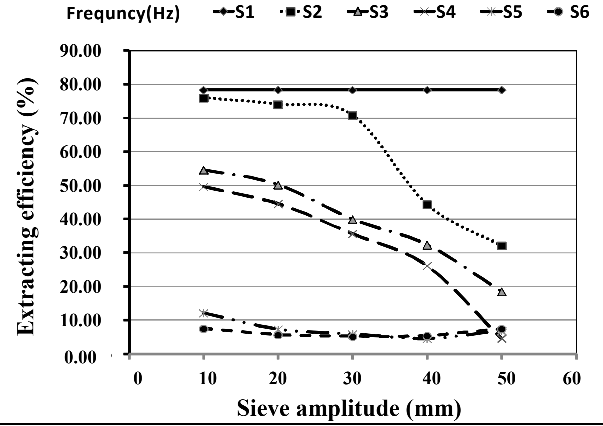
It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses



B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

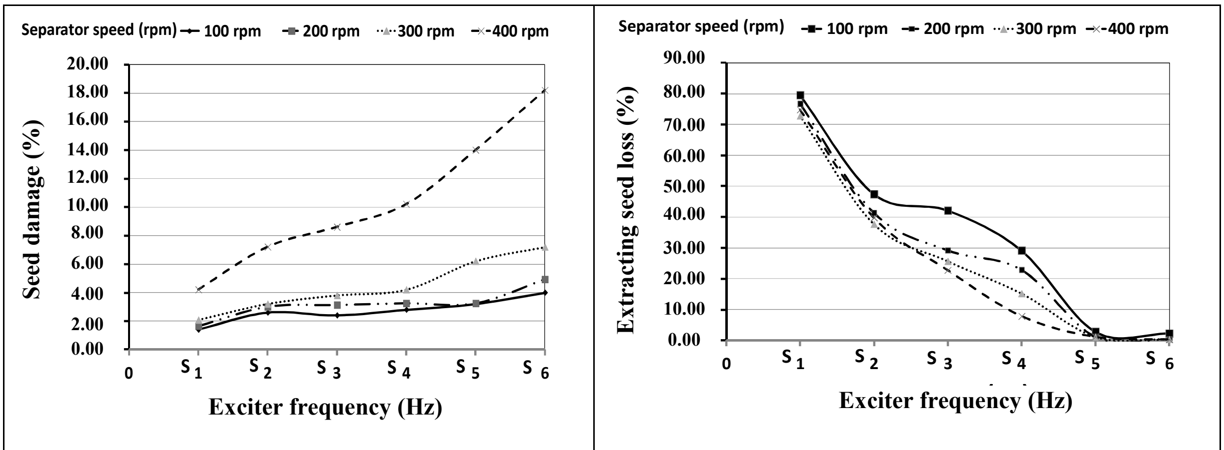
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage	B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

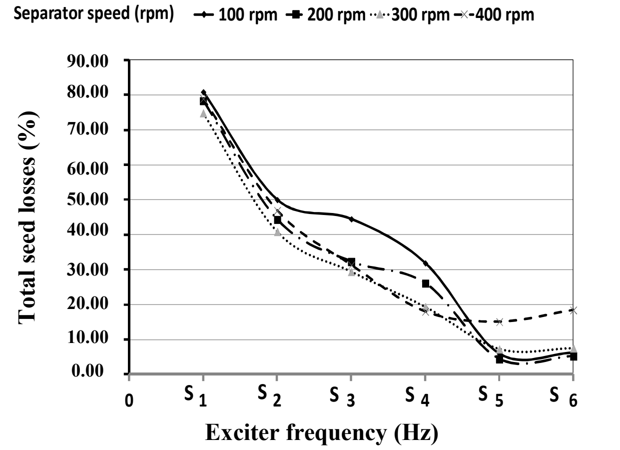
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

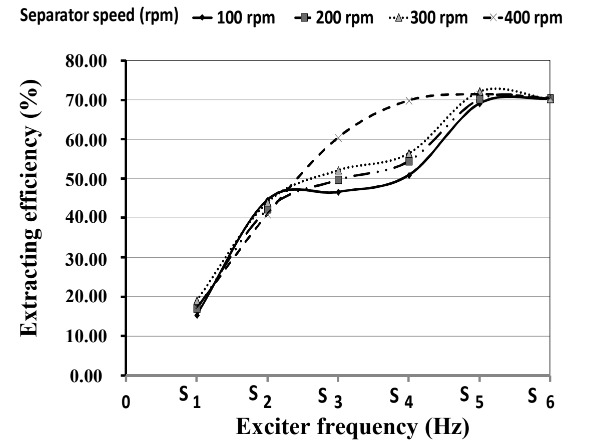
Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses



B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

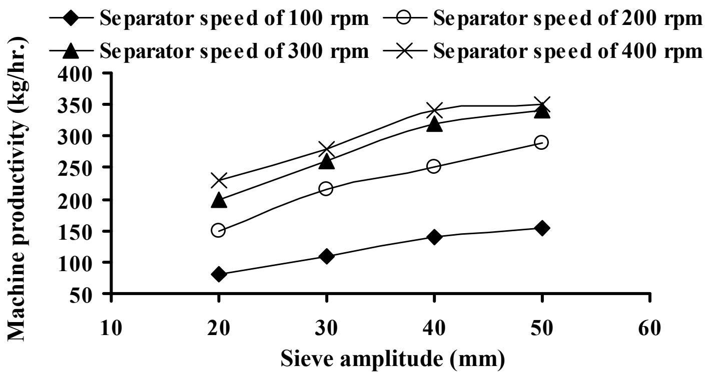


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

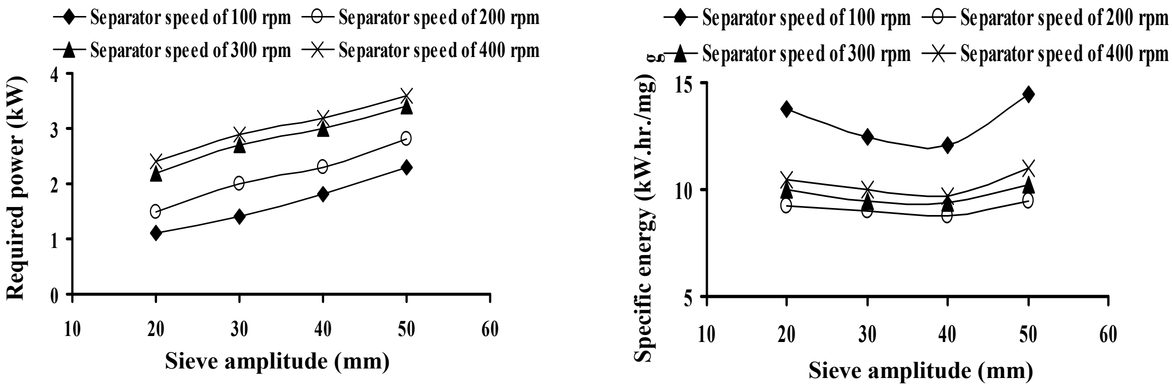


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

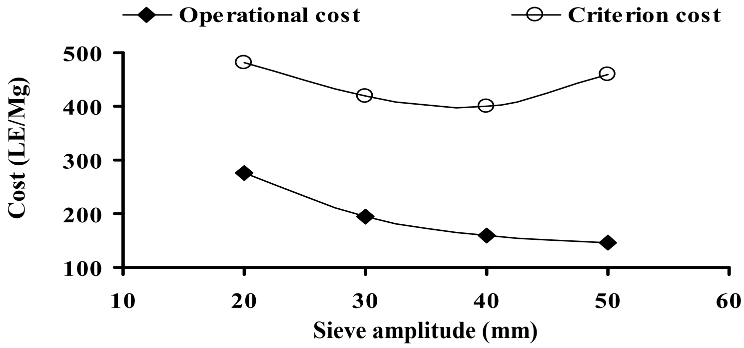


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــــع وتقييـــــــم أداء آلـــــــــــة محليـــــــــة الصنـــــع لتفـــريـط بـــذور الـرمـــــان

نجلاء صلاح أنور[1] - محمد محمد مراد حسن[1] - محب محمد أنيس الشرباصي[2] - طارق حسين على[3]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علـــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt

3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

* **Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

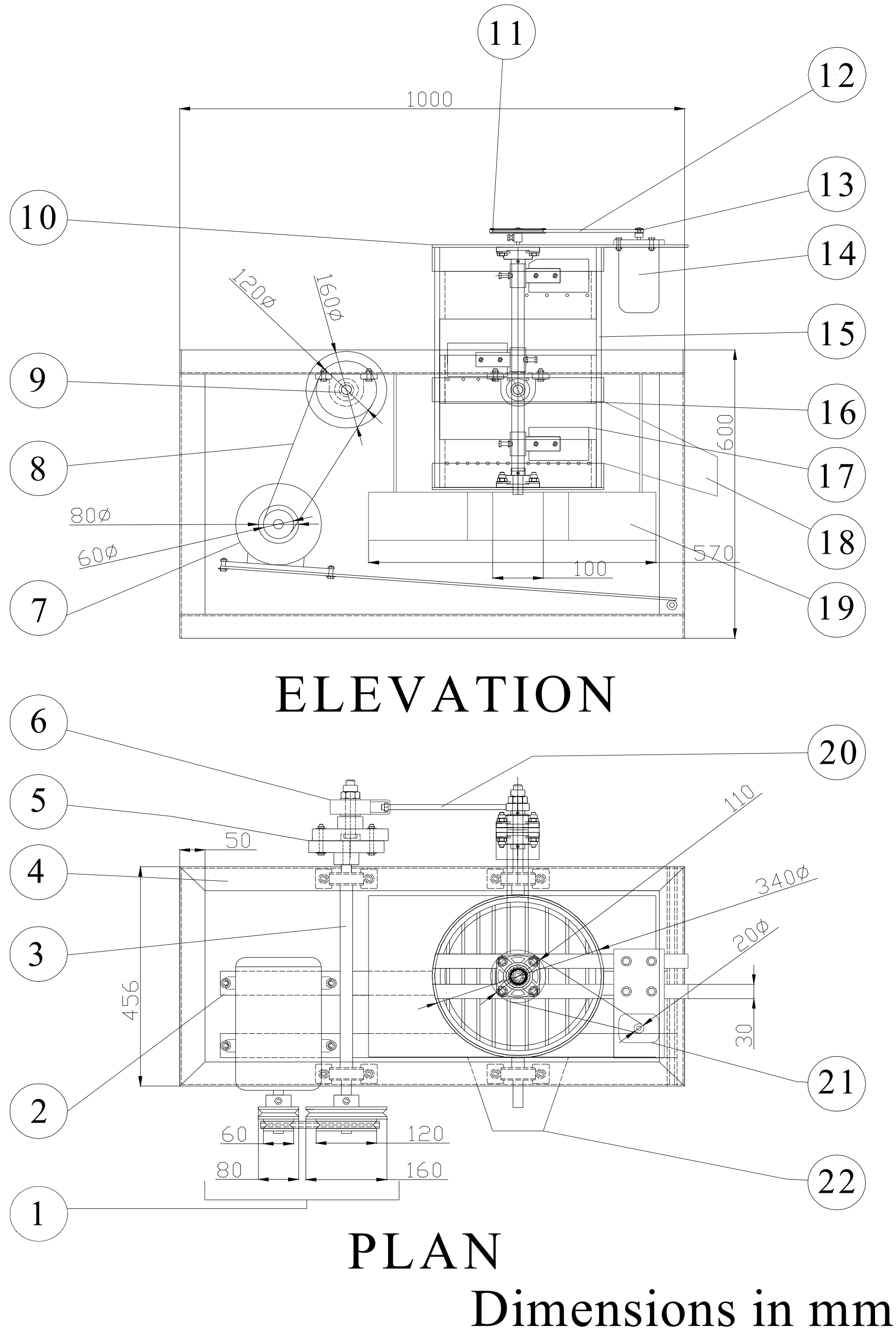
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

$\cos\theta$ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

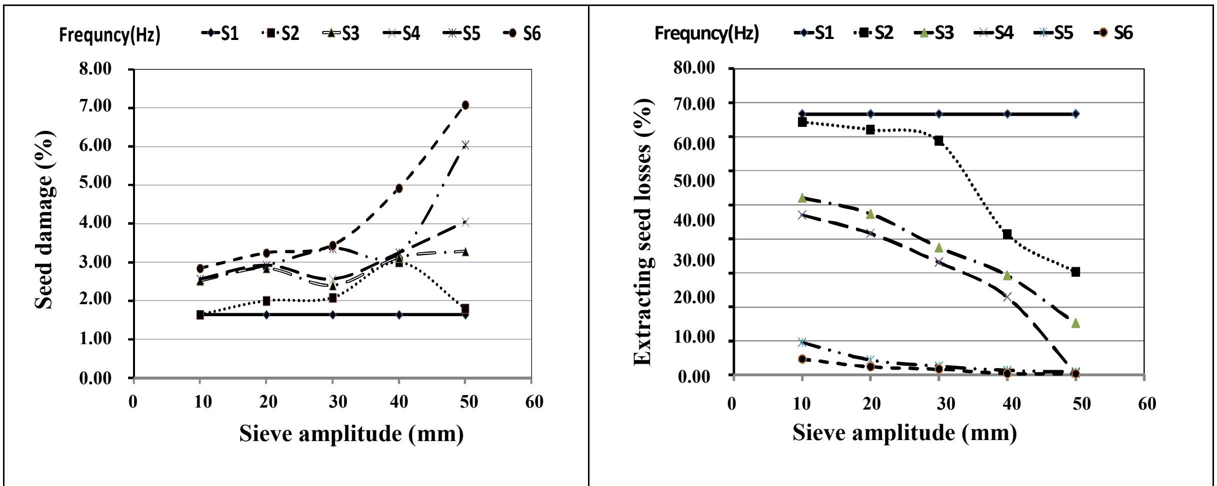
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage

B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

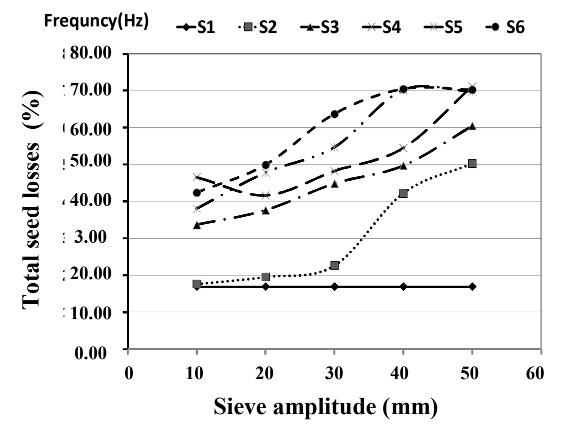
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

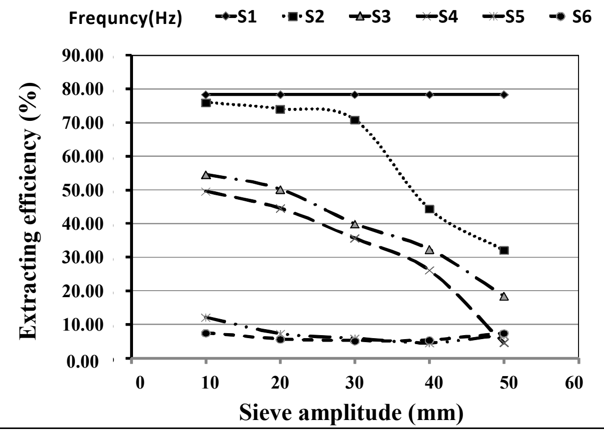
It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses



B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

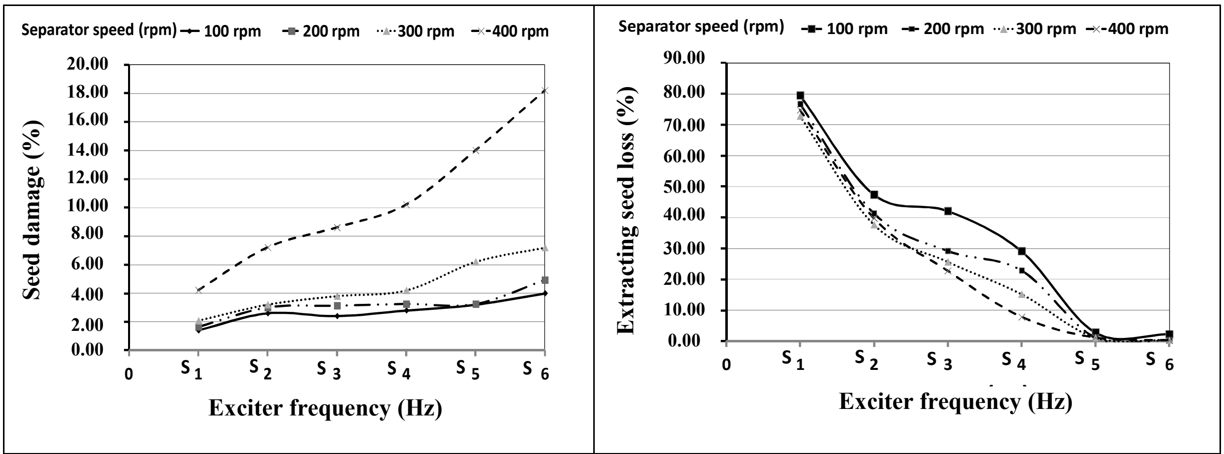
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage	**B. Effect of separator speed and exciter frequency on extracting seed loss**

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

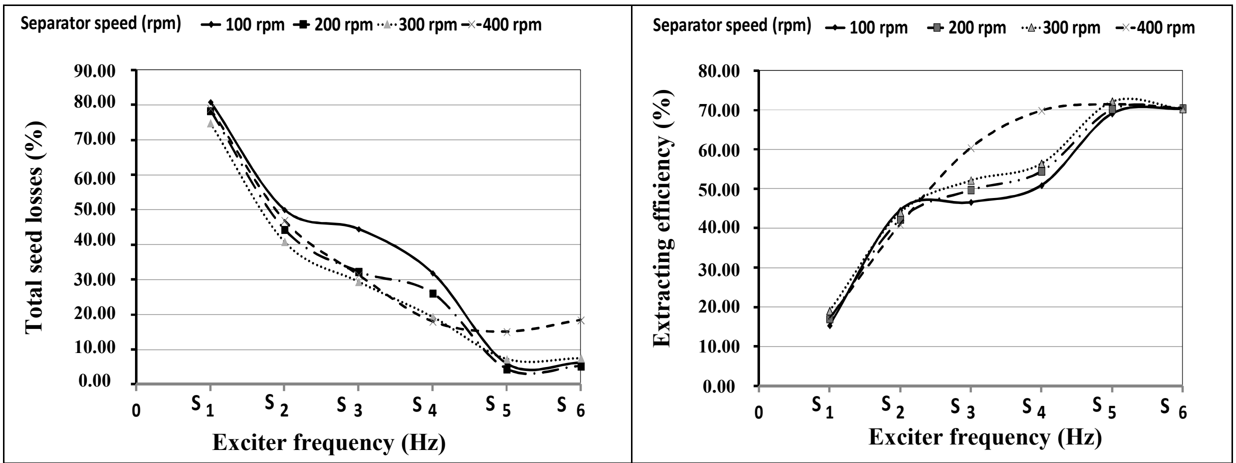
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses

B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

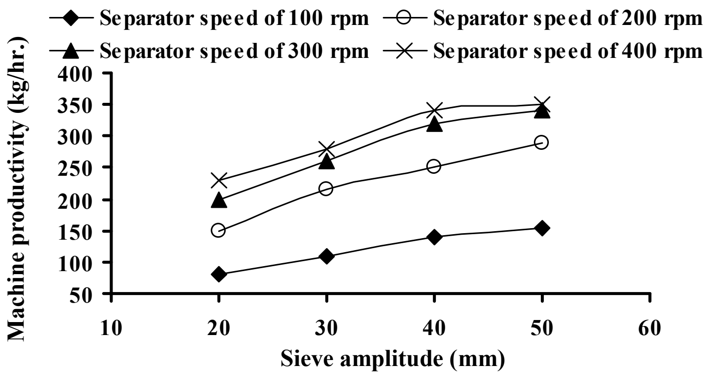


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

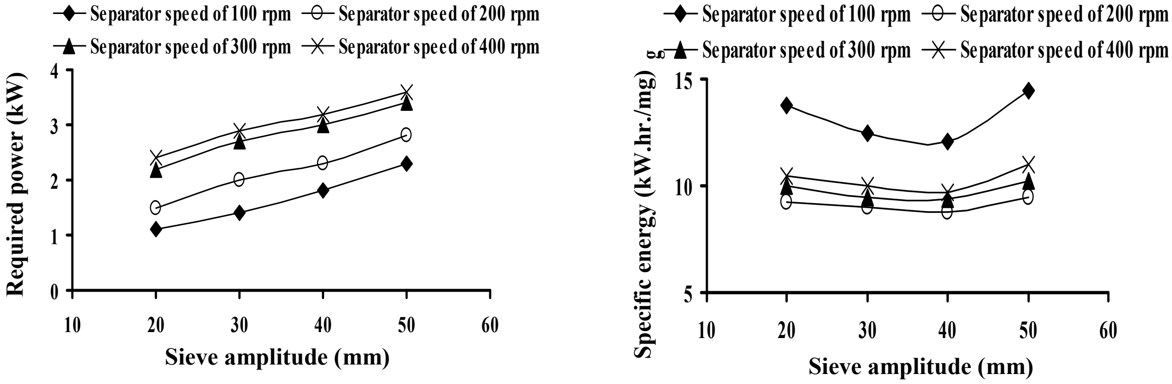


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

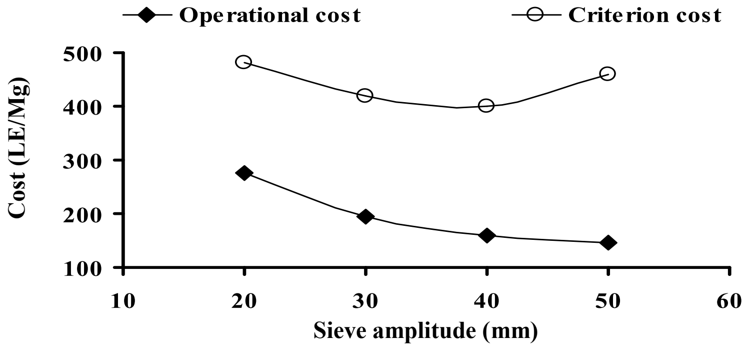


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــــع وتقييـــــــم أداء آلـــــــــة محليـــــــــة الصنـــــع لتفـــريـط بـــذور الـرمــــان

نجلاء صلاح أنور[1] - محمد محمد مراد حسن[1] - محب محمد أنيس الشرباصي[2] - طارق حسين على[3]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt

3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

*** Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

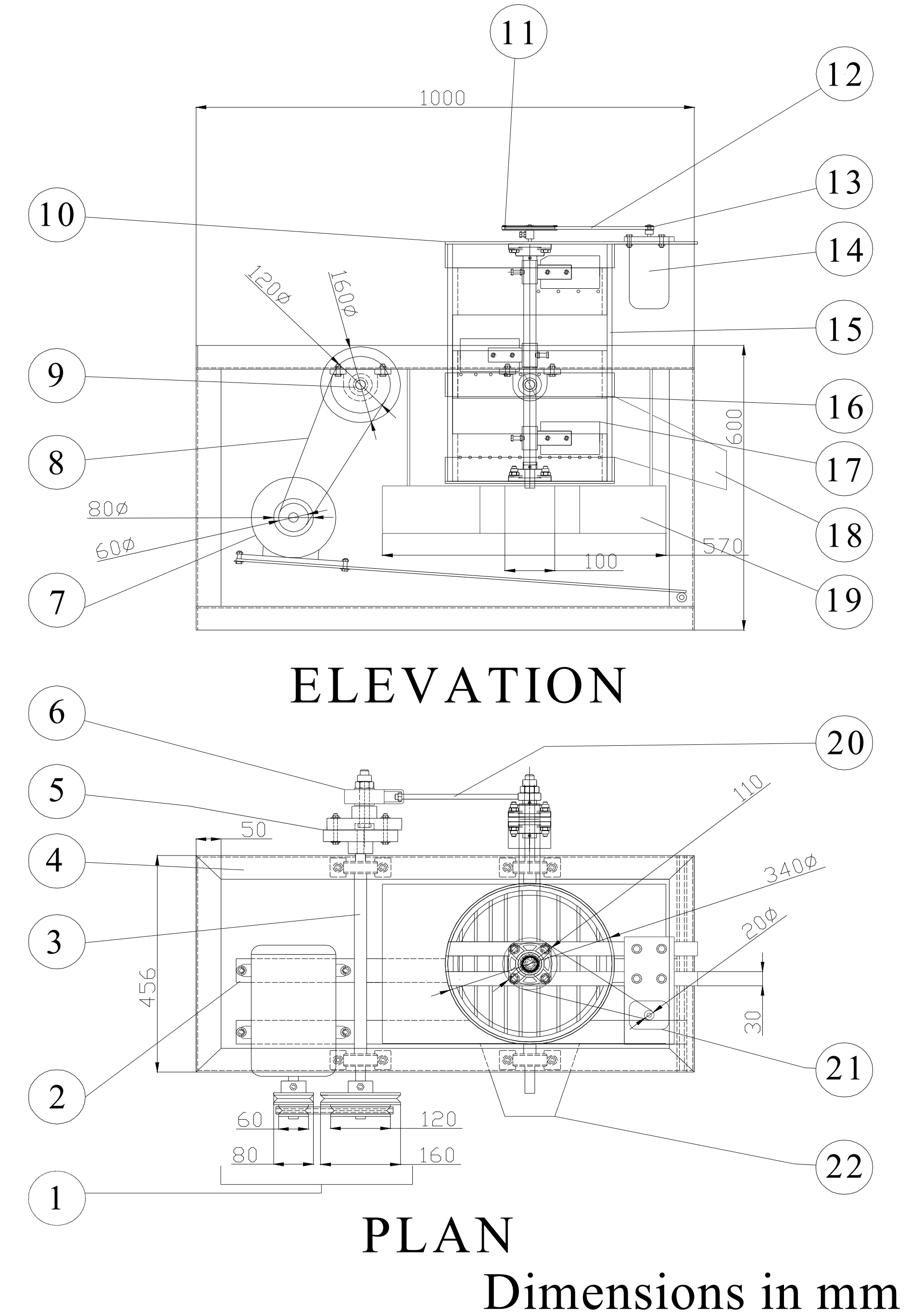
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

$\cos\theta$ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

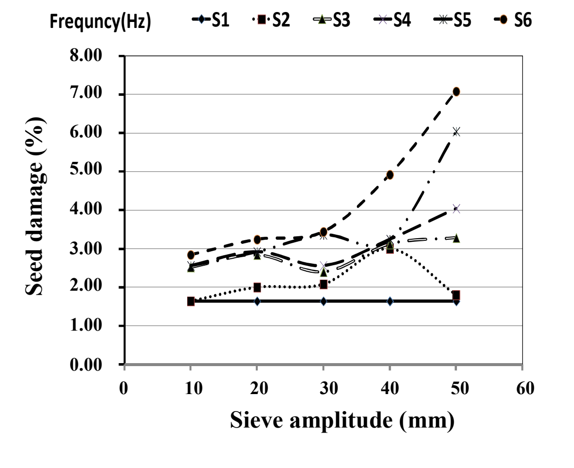
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

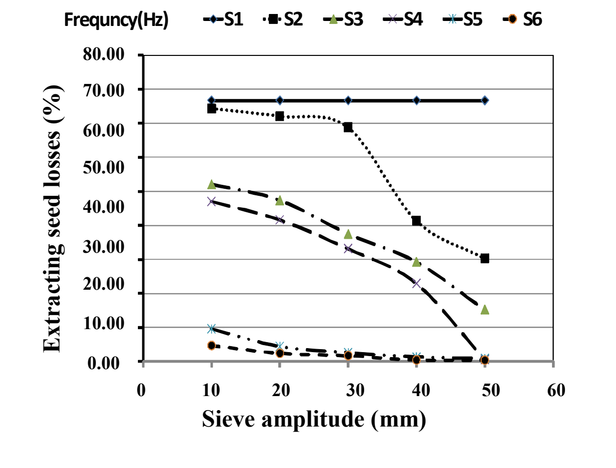
RESULTS AND DISCUSSION

The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and





A. Effect of sieve amplitude and exciter frequency on seed damage	B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

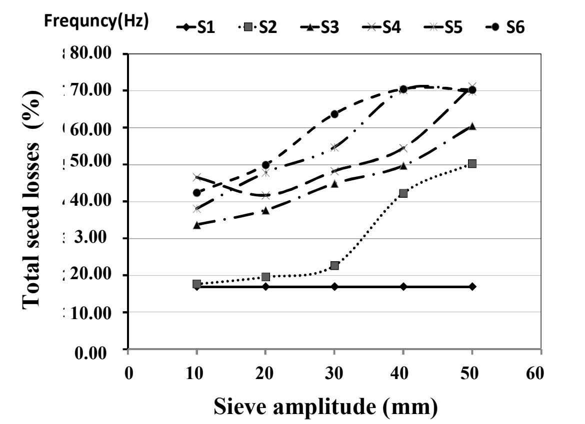
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

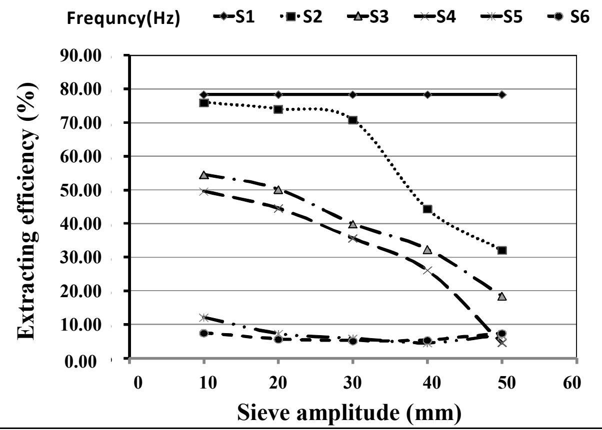
It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses



B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

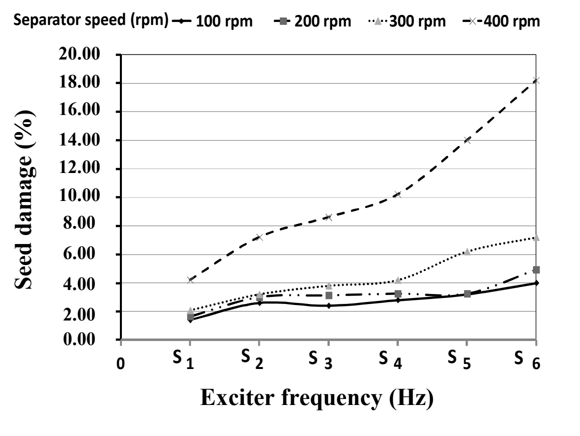
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

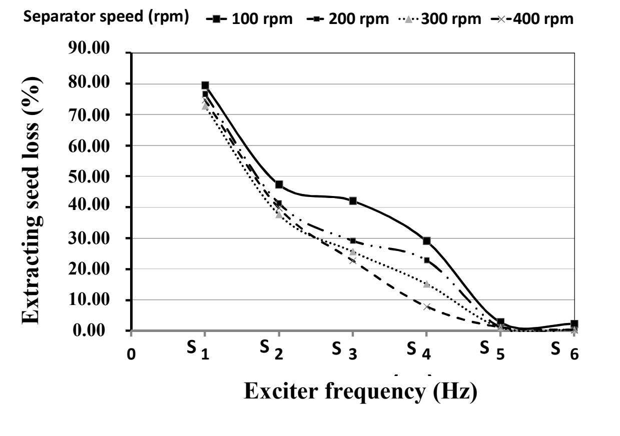
At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage



B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

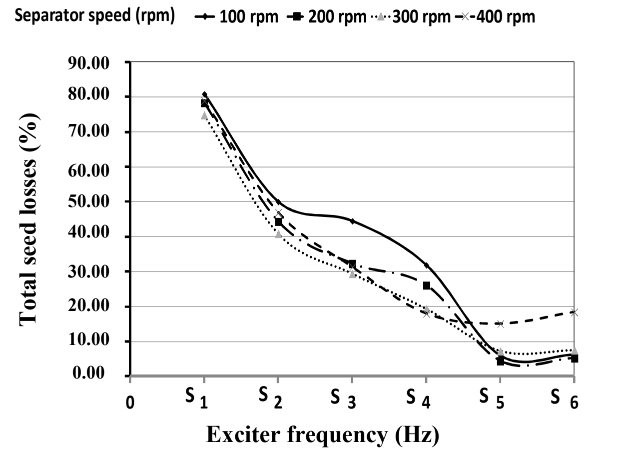
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

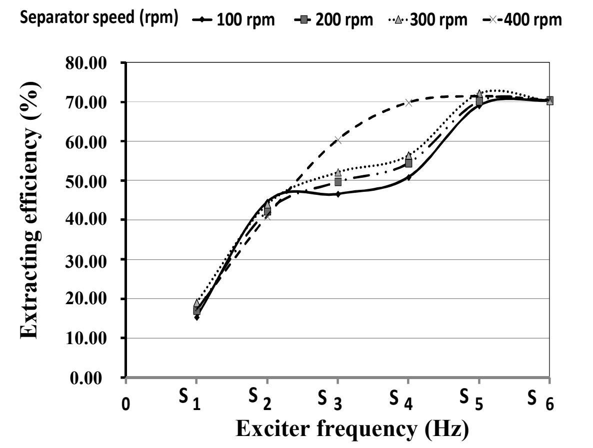
Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses



B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

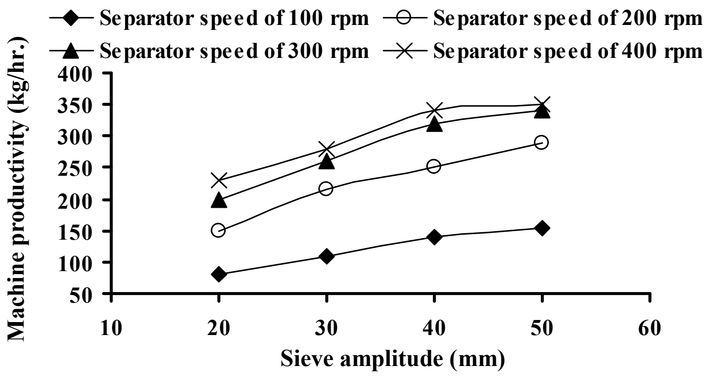


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

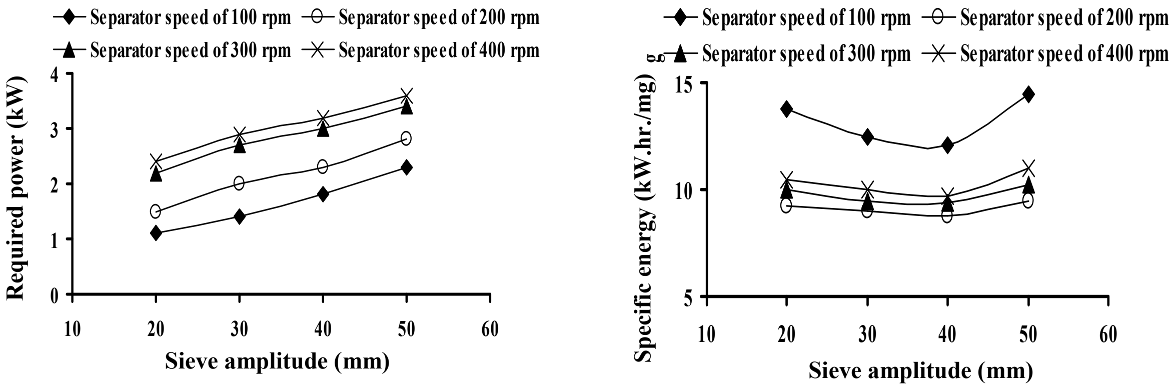


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

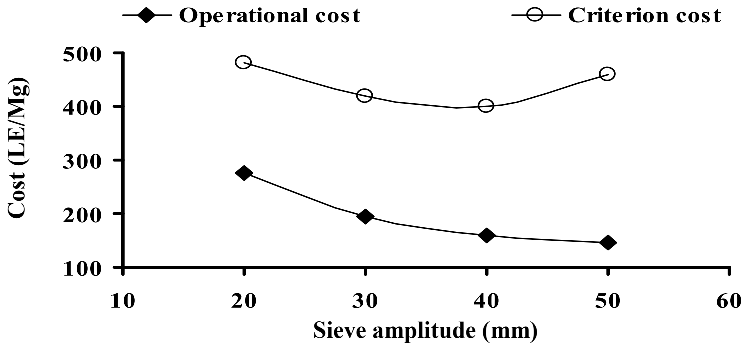


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــــع وتقييـــــــــم أداء آلـــــــــــــة محليـــــــــــة الصنـــــع لتفـــريـط بـــذور الـرمـــــان

نجلاء صلاح أنور[1] - محمد محمد مراد حسن[1] - محب محمد أنيس الشرباصي[2]- طارق حسين على[3]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوراني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt

3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

* **Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

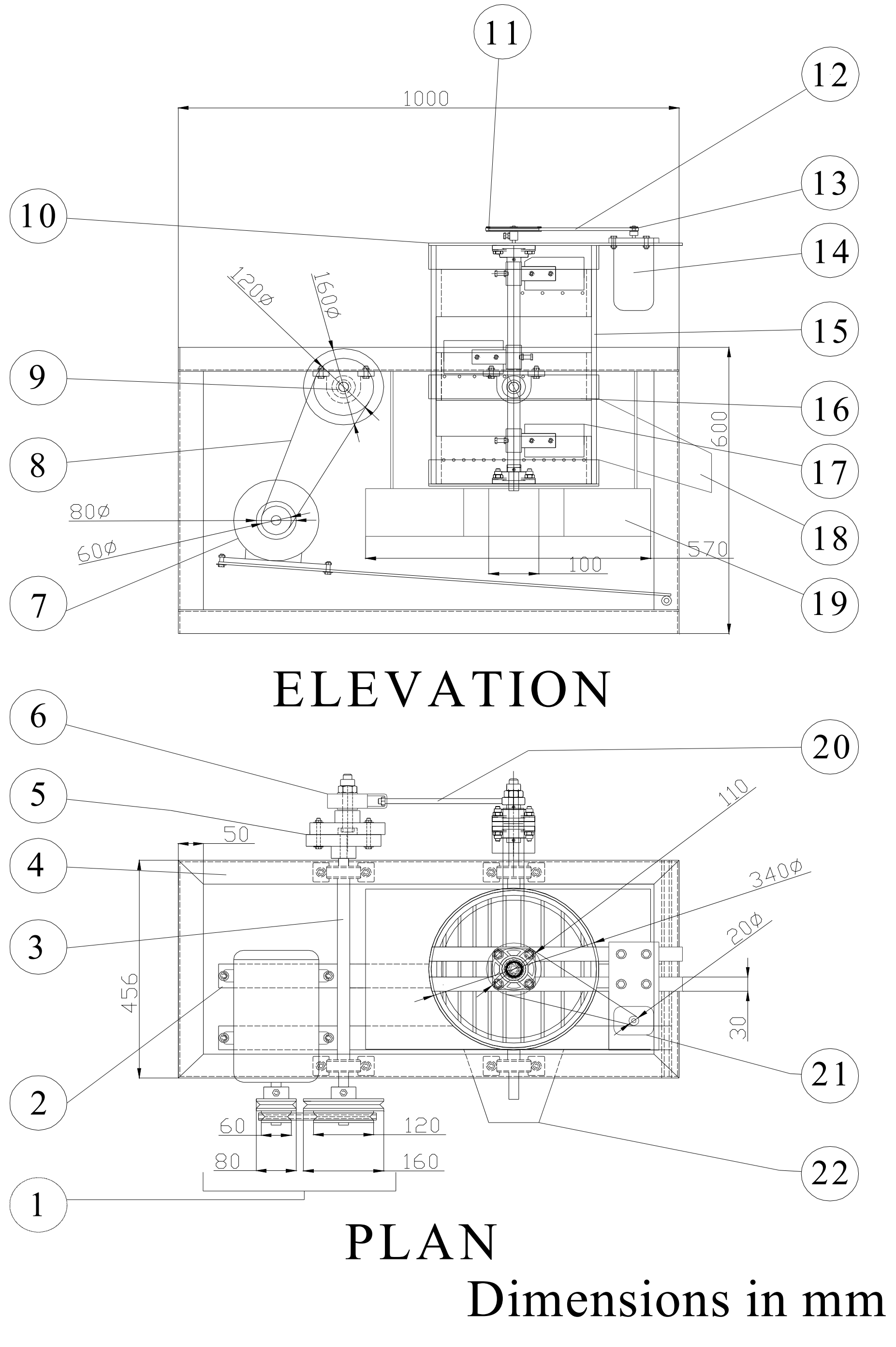
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

cos θ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

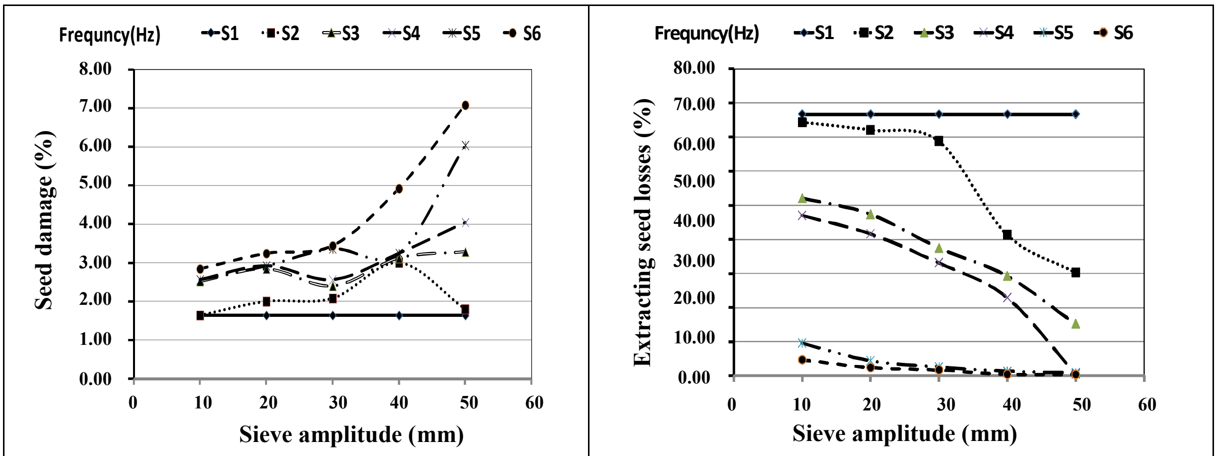
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage	**B. Effect of sieve amplitude and exciter frequency on extracting losses**

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

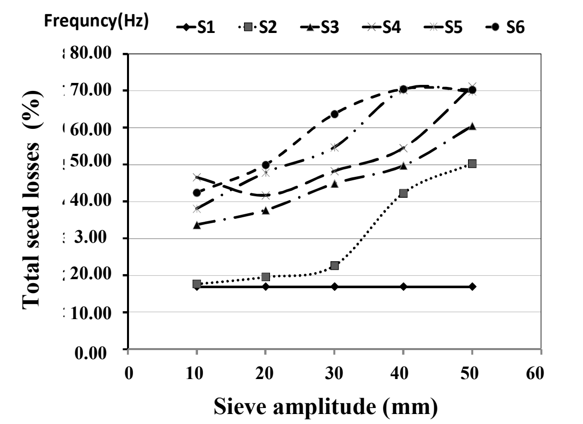
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

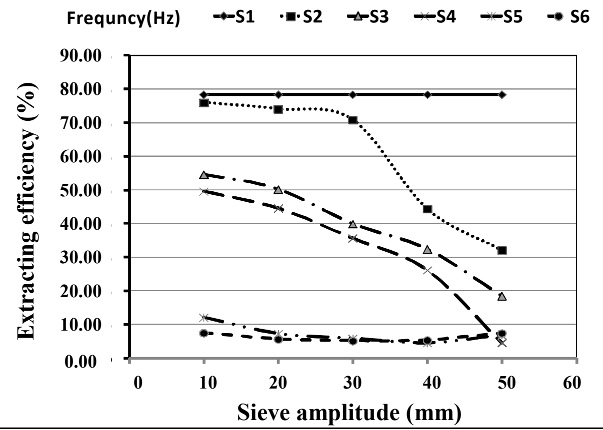
It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses



B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

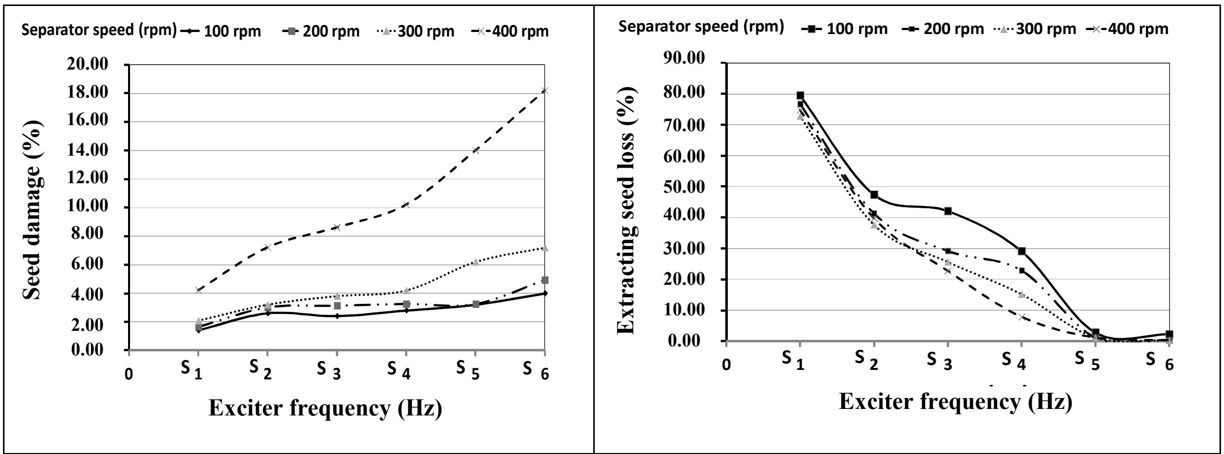
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage	B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

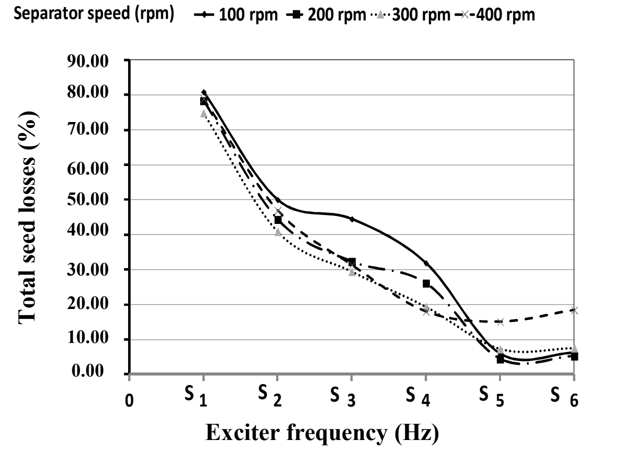
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

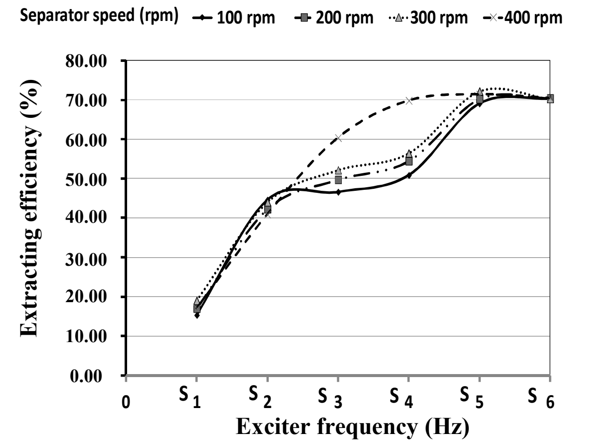
Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses



B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

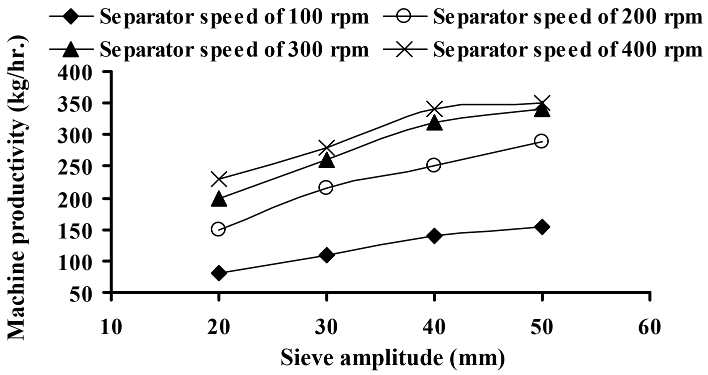


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

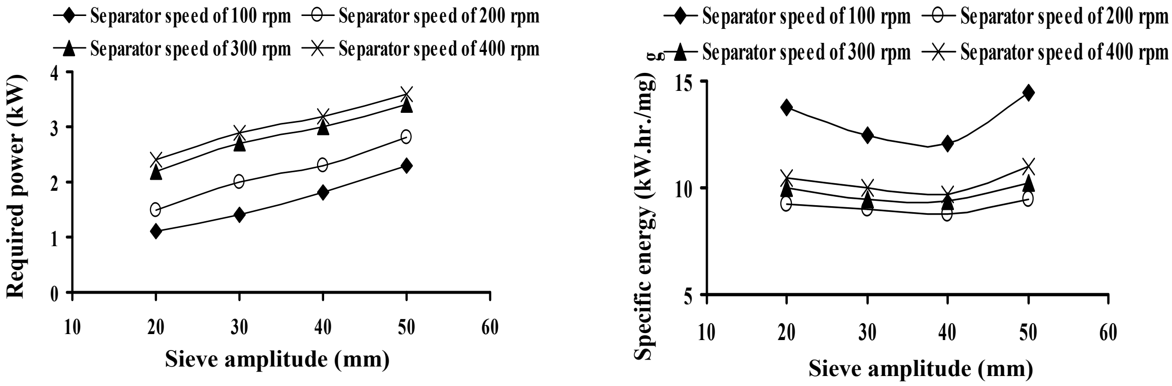


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

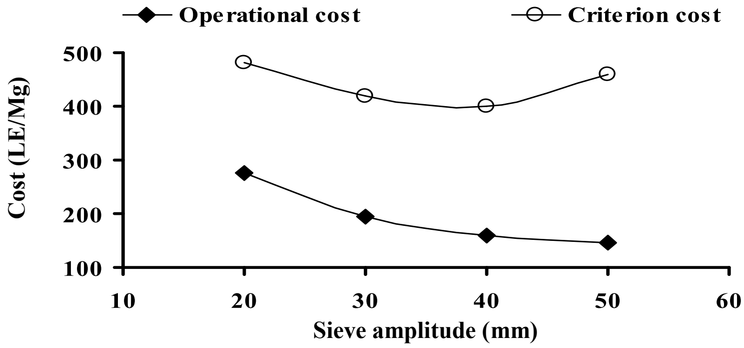


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــع وتقييـــــم أداء آلـــــــة محليـــــــة الصنــــع لتفــريـط بـــذور الـرمــــان

نجلاء صلاح أنور[١] - محمد محمد مراد حسن[١] - محب محمد أنيس الشرباصي[٢] - طارق حسين على[٣]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علـــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt

3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

* **Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

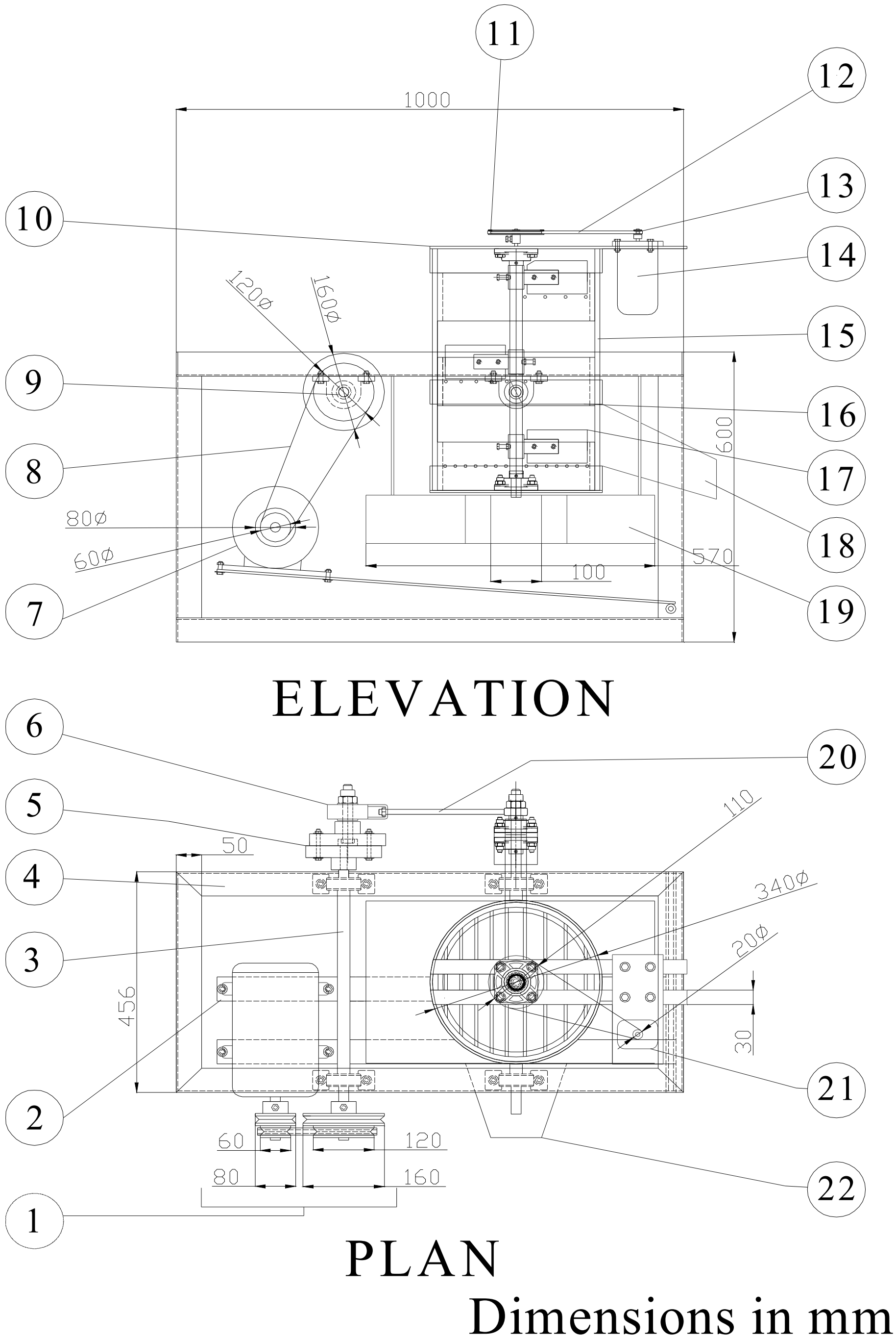
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

cos θ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

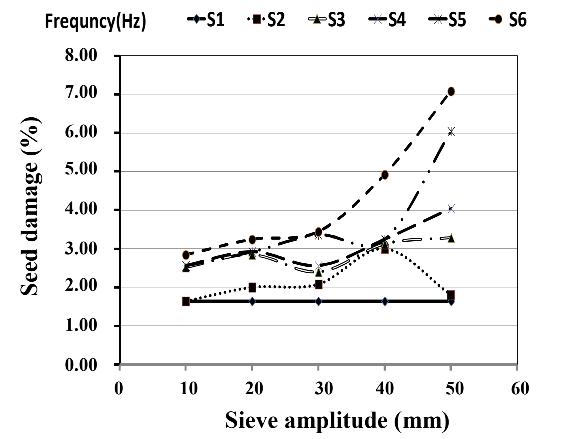
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

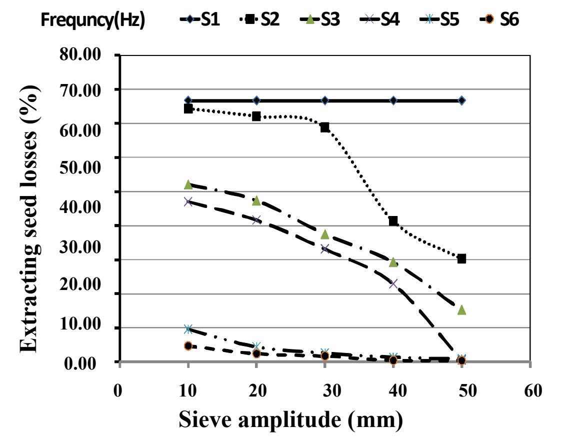
The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage



B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

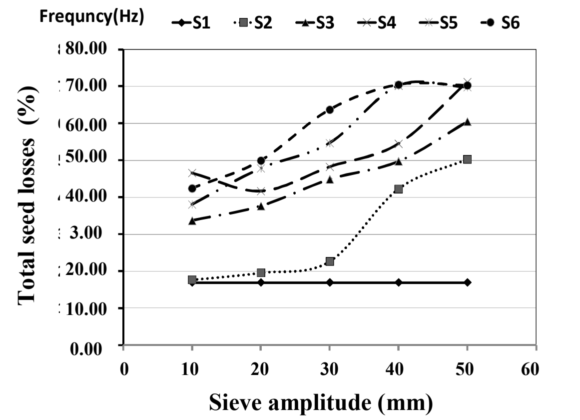
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

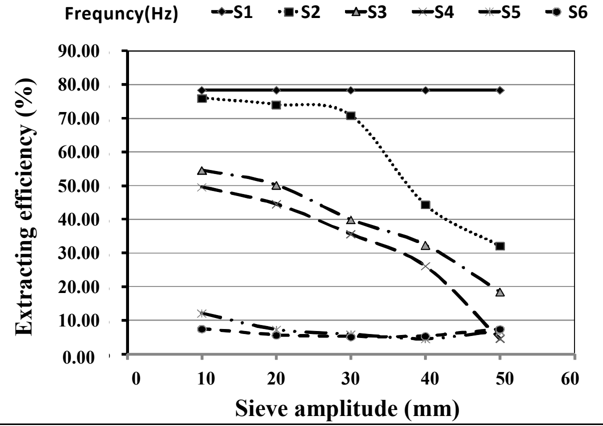
It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses



B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

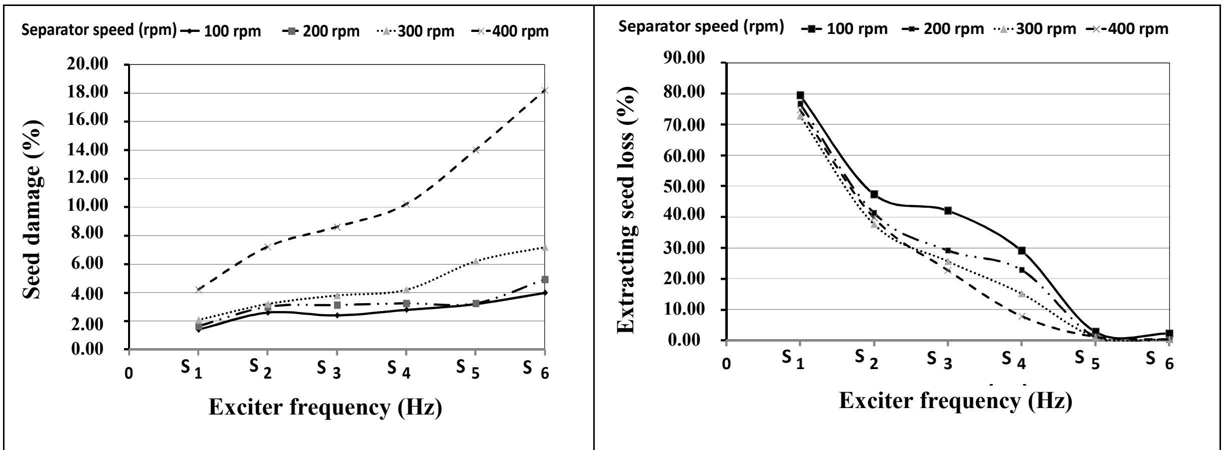
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage	B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

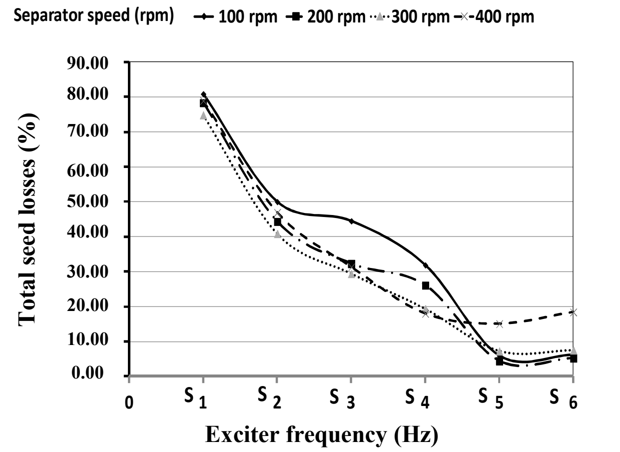
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

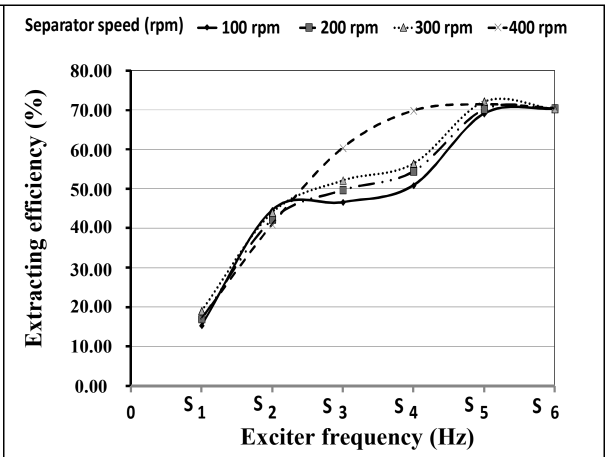
Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses



B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

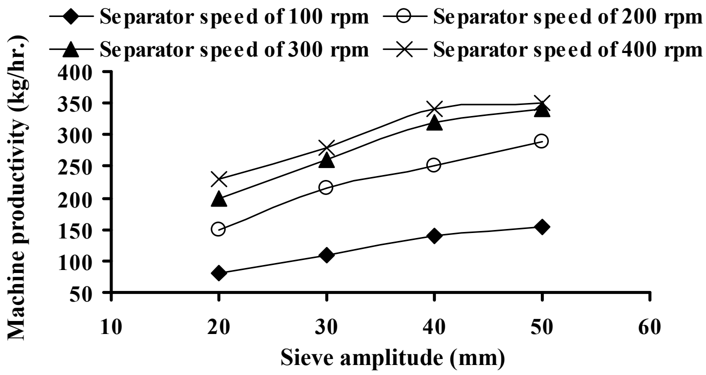


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

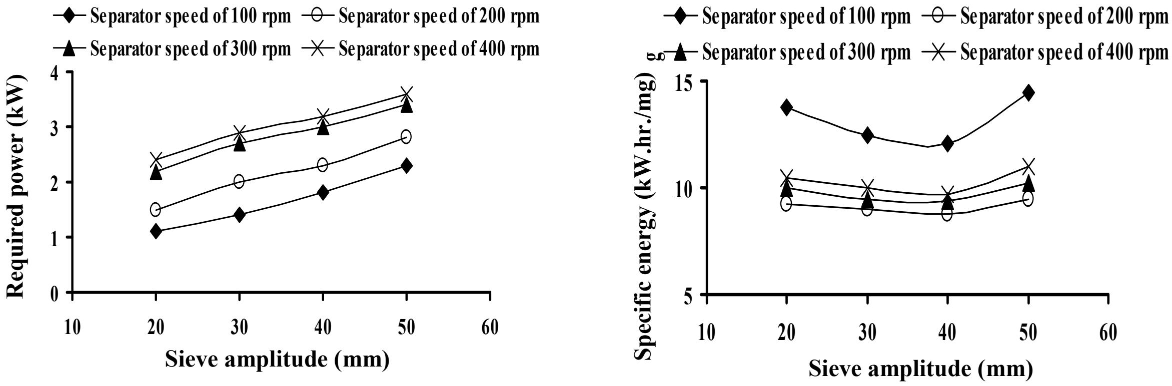


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

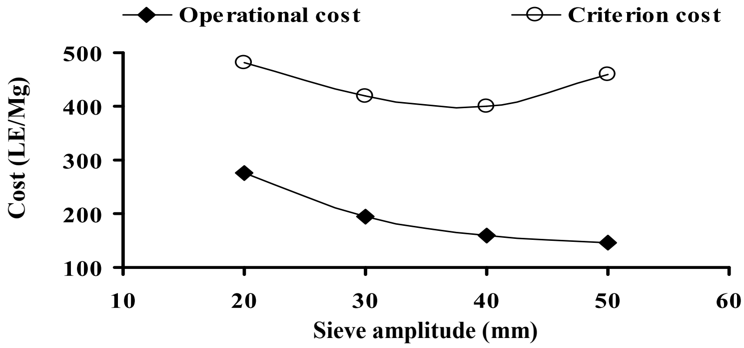


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــــع وتقييـــــــم أداء آلـــــــــــة محليـــــــــــة الصنـــــع لتفـــــريـط بـــذور الـرمــــــان

نجلاء صلاح أنور[1] - محمد محمد مراد حسن[1] - محب محمد أنيس الشرباصي[2]- طارق حسين على[3]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علـــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt
2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt
3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

* **Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

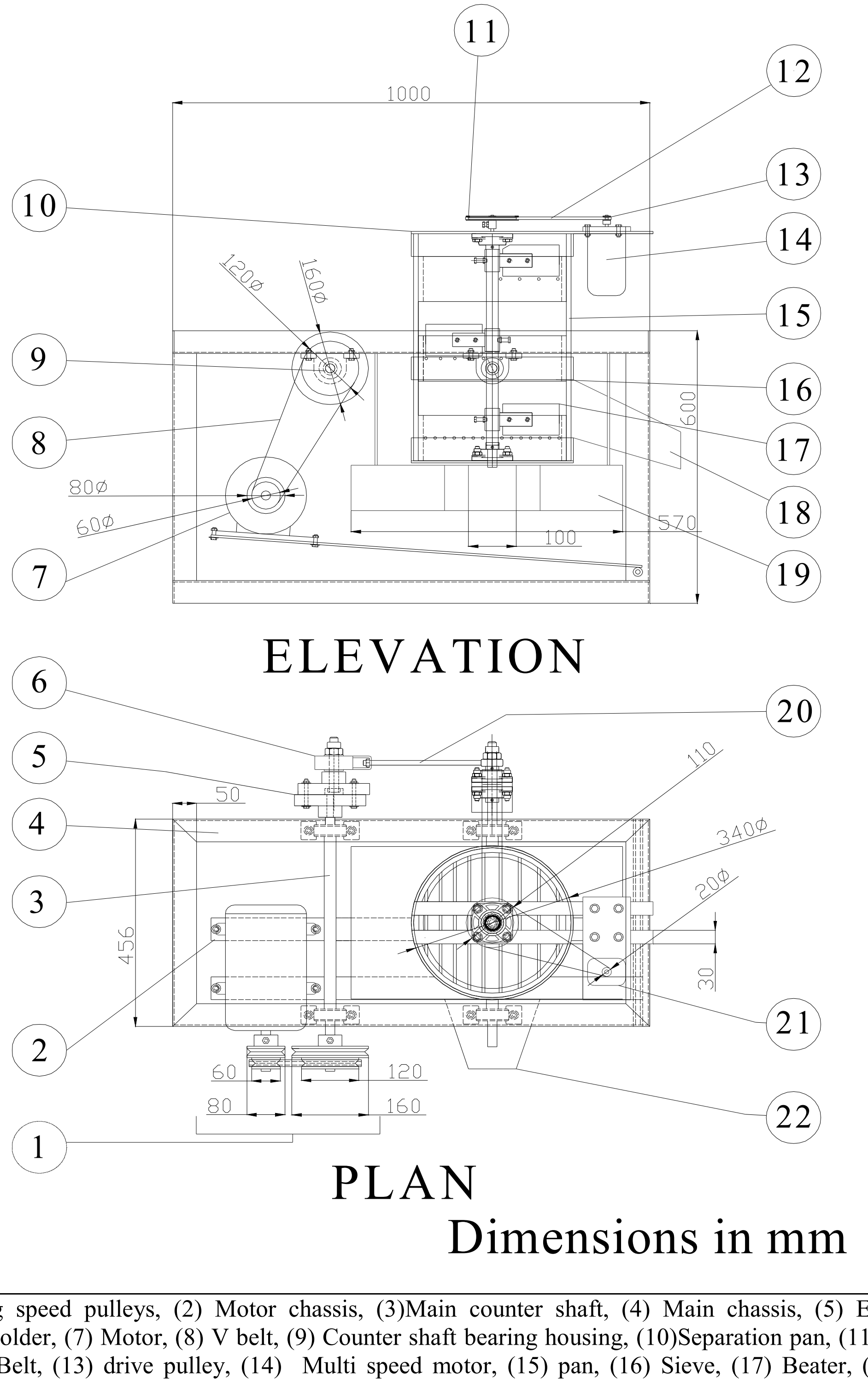
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%)=\frac{M_u}{M_u+M_c}\times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

cos θ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

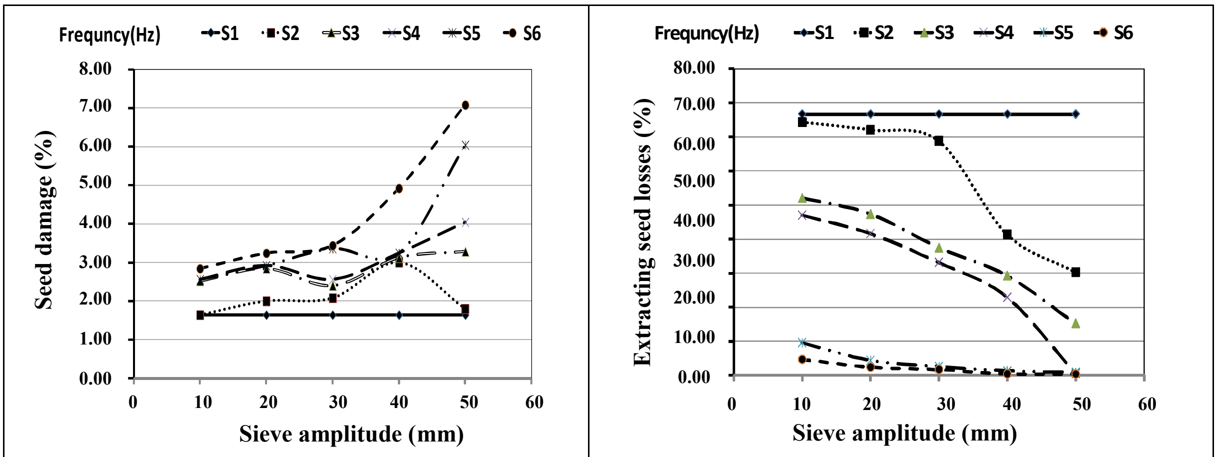
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage

B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

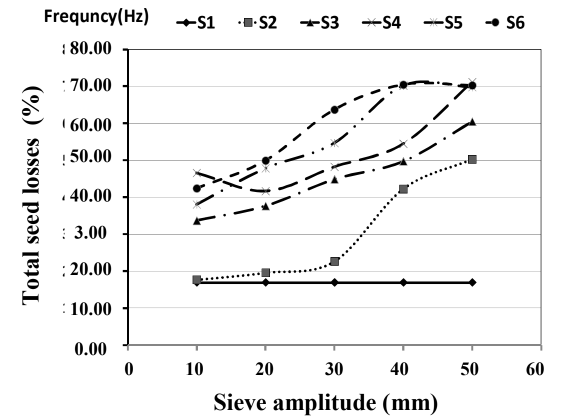
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

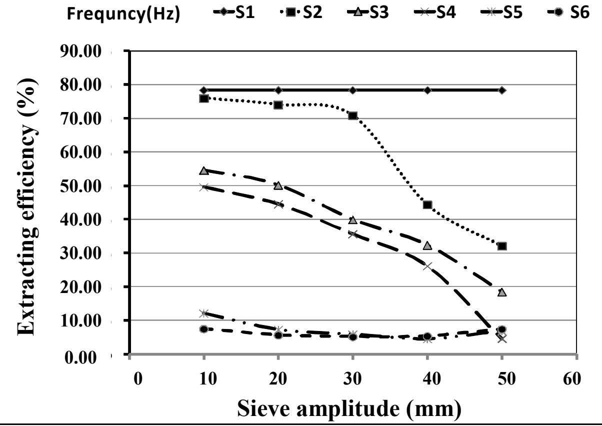
It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses



B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

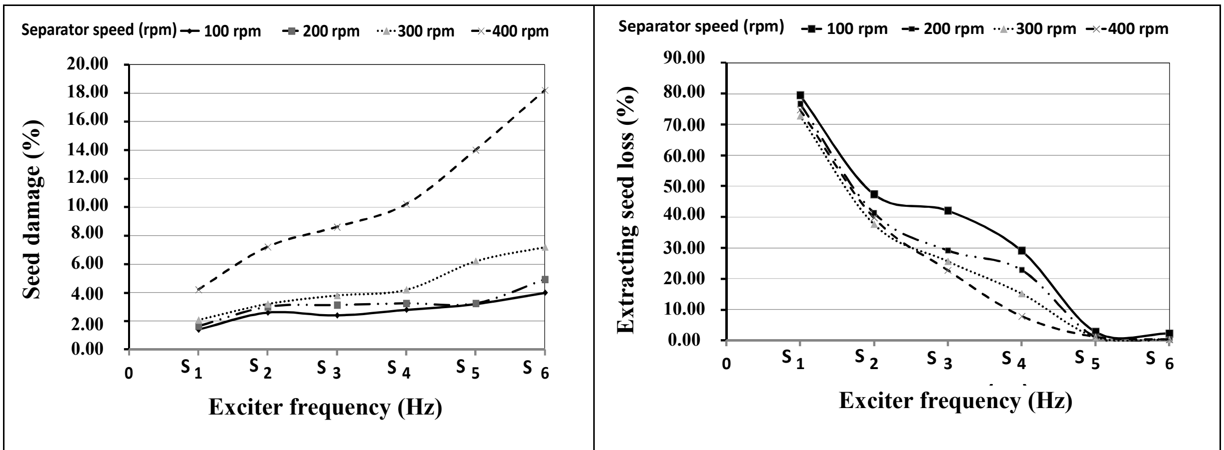
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage	**B. Effect of separator speed and exciter frequency on extracting seed loss**

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

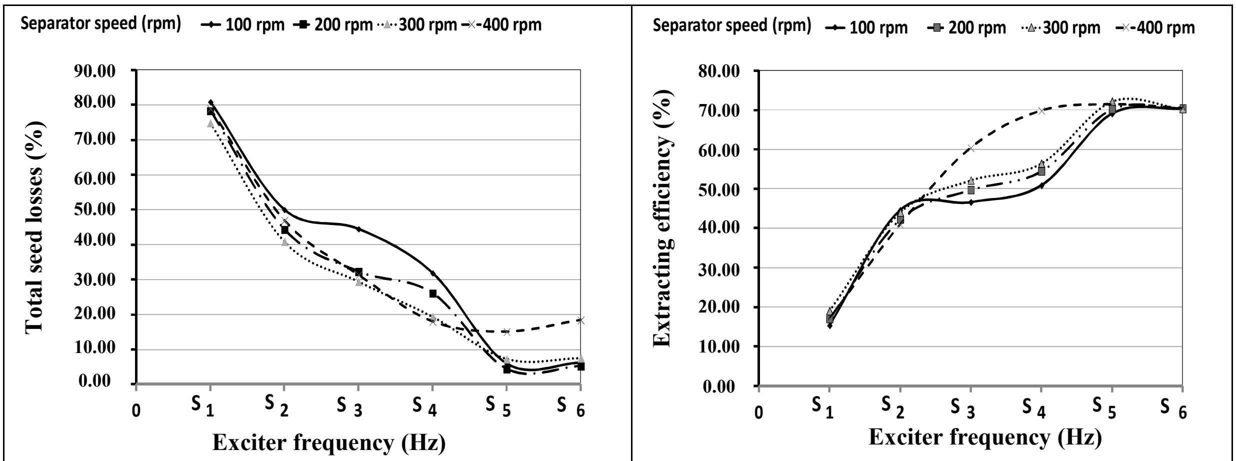
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses

B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

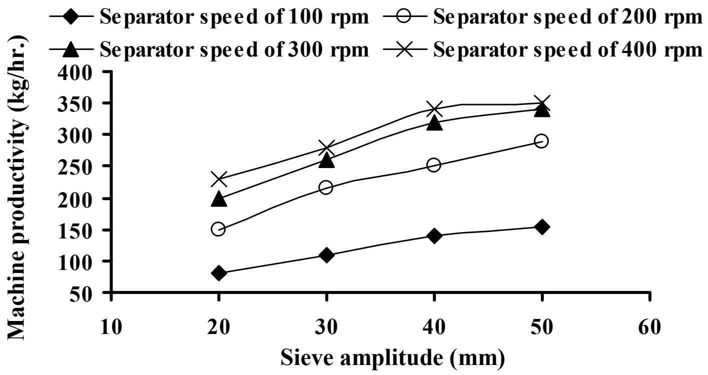


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

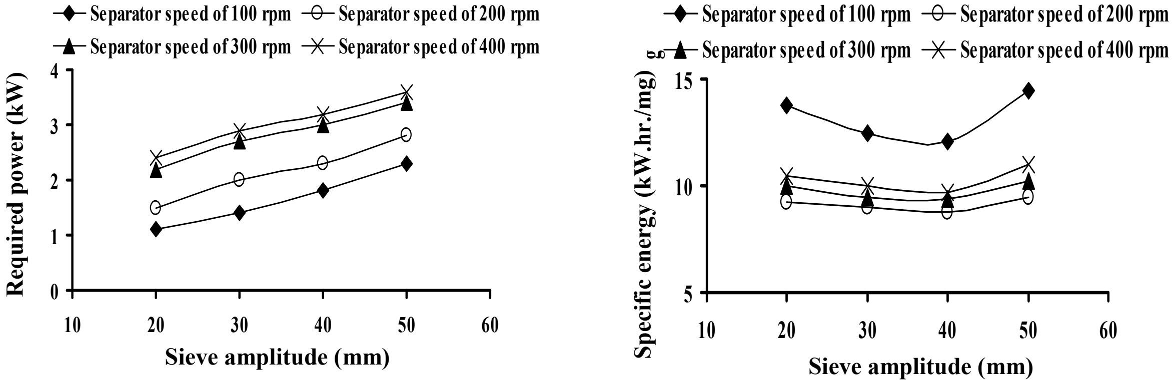


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

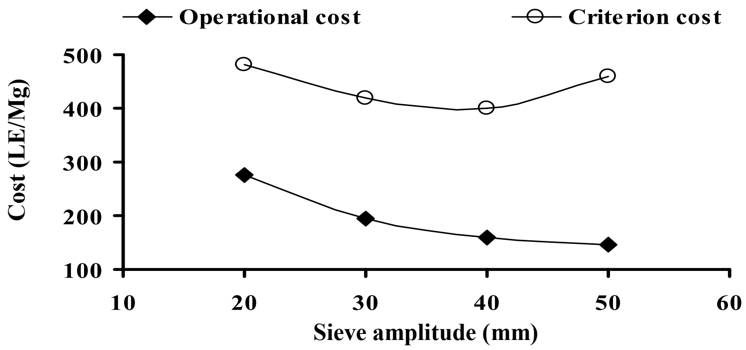


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــــع وتقييـــــــم أداء آلـــــــــــة محليـــــــــة الصنـــــع لتفـــريـط بـــذور الـرمــــــان

نجلاء صلاح أنور[1] - محمد محمد مراد حسن[1] - محب محمد أنيس الشرباصي[2]- طارق حسين على[3]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt
2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt
3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

* **Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

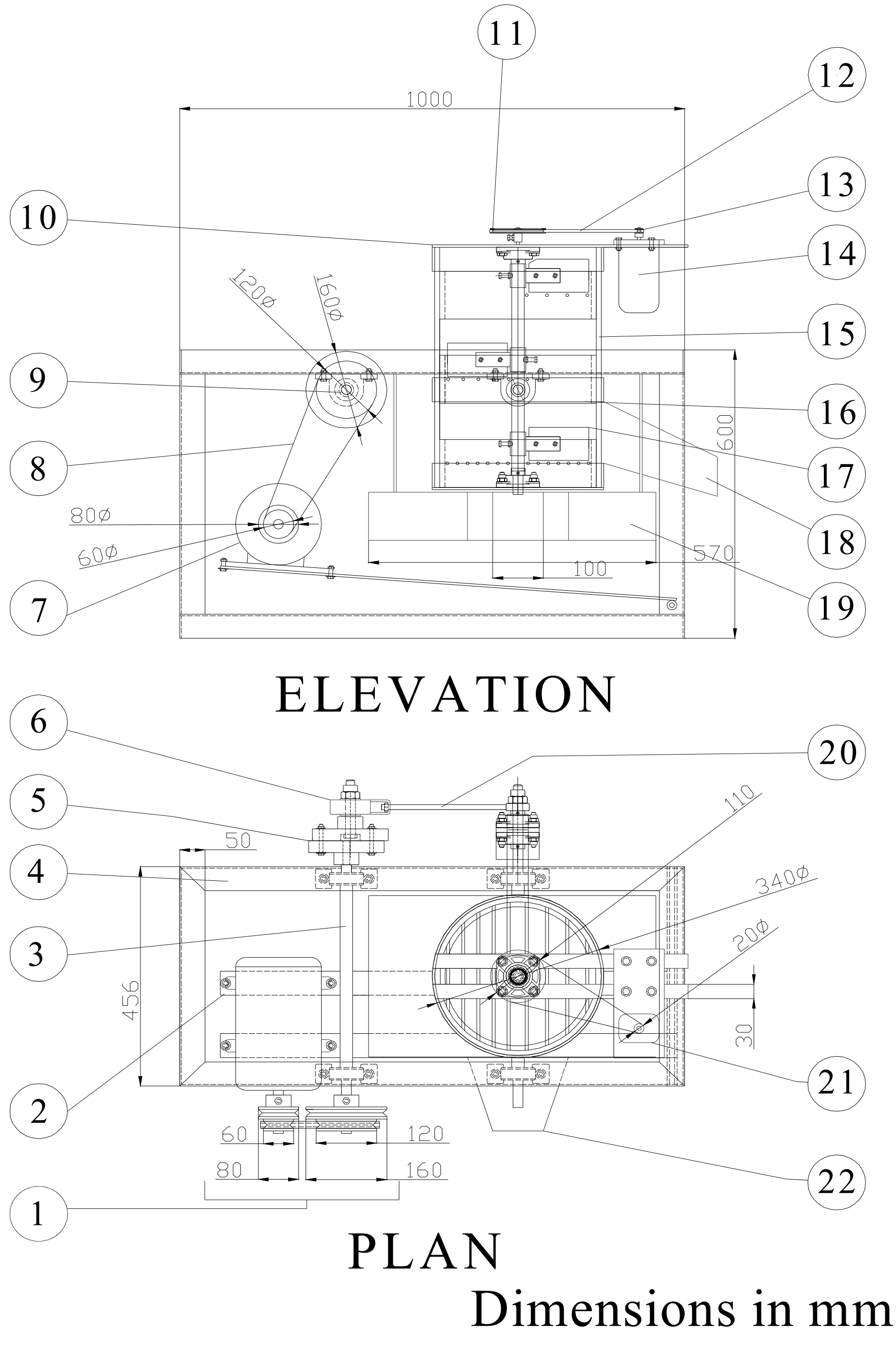
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

cos θ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

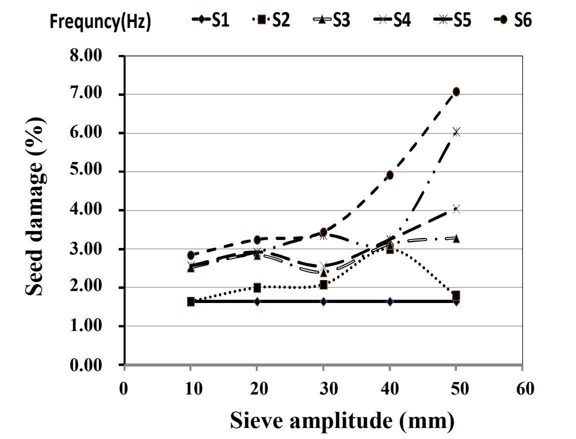
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

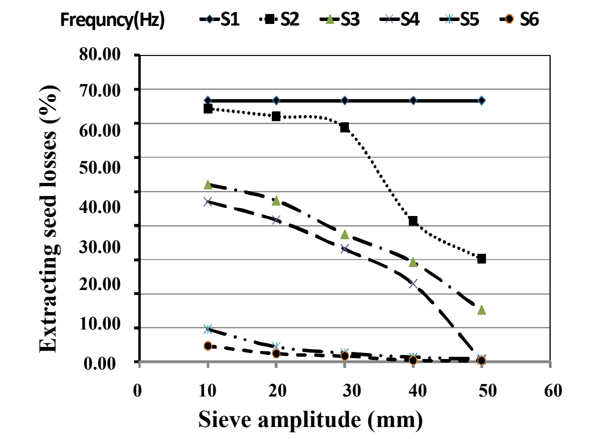
The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage



B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

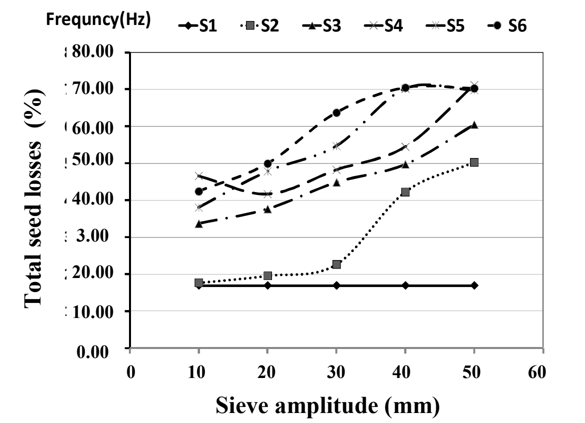
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

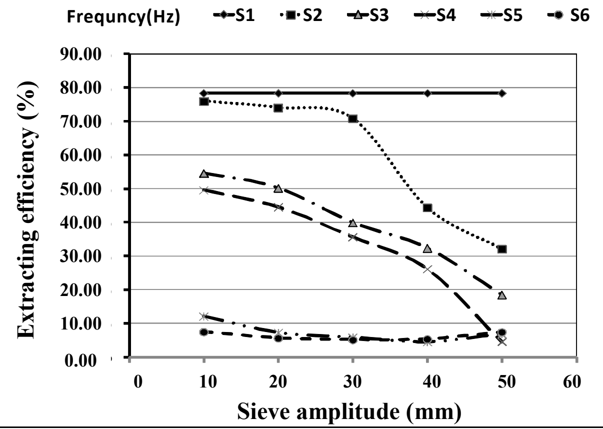
It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses



B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

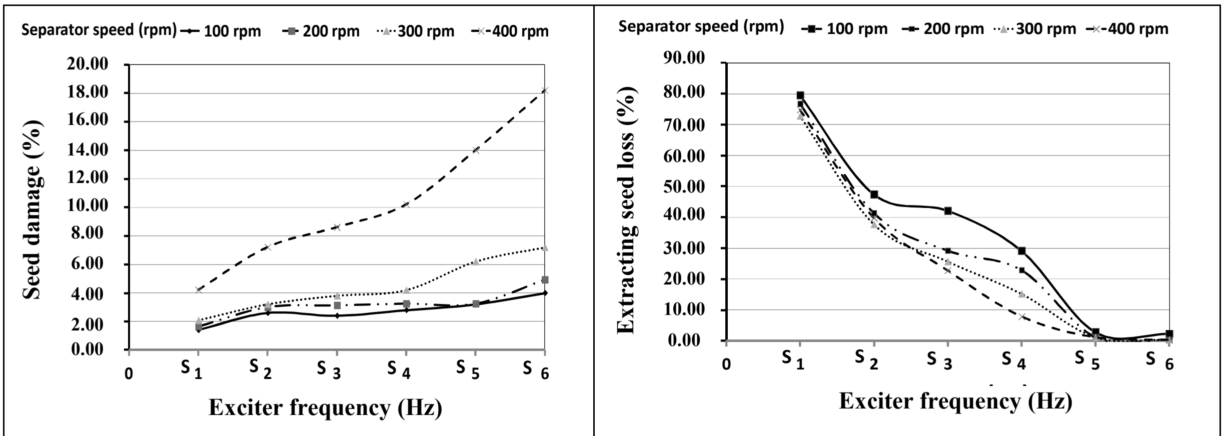
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage	B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

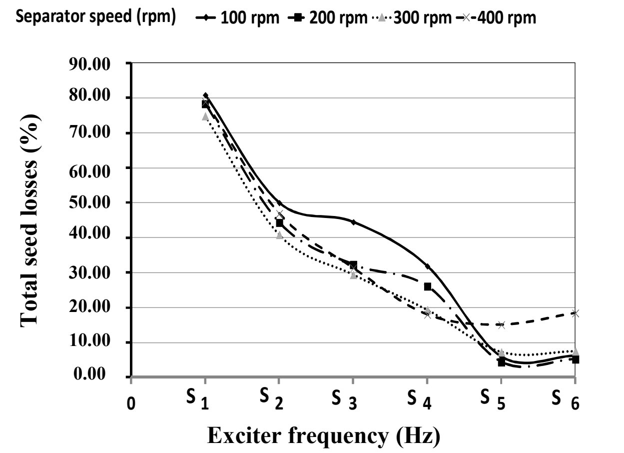
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

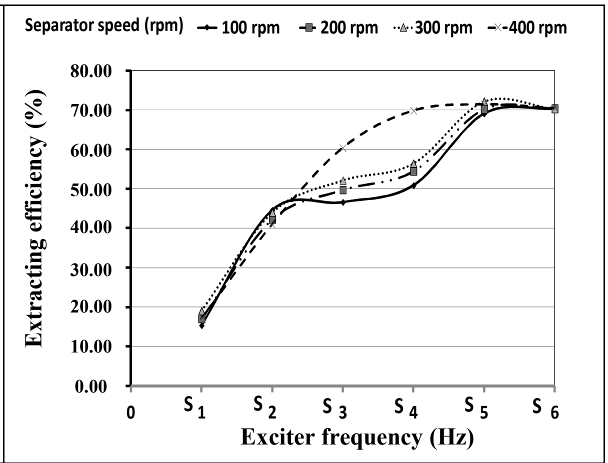
Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses



B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

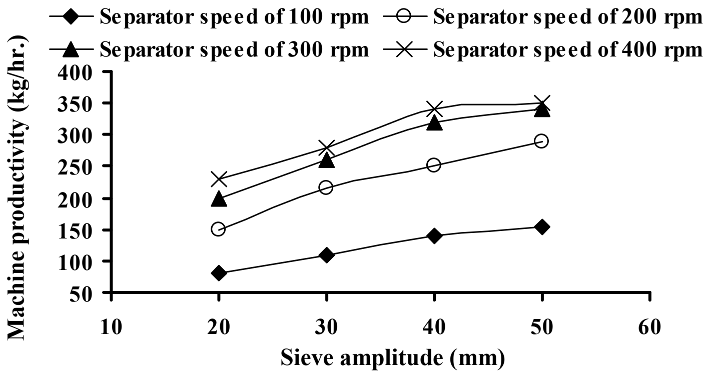


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

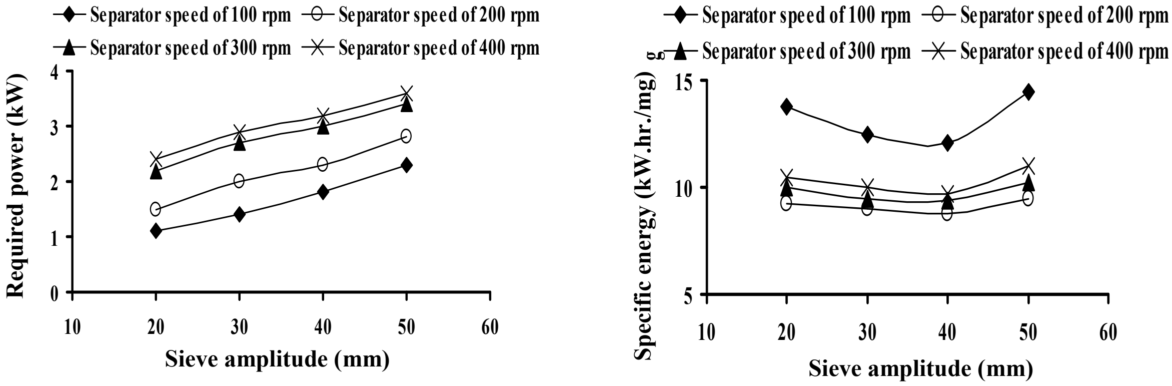


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

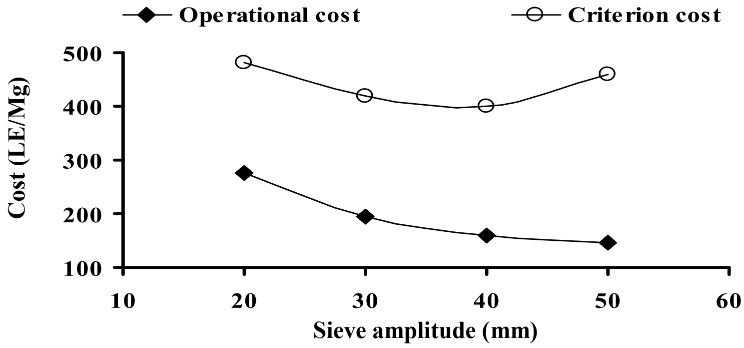


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــــع وتقييـــــــم أداء آلـــــــــــة محليـــــــــة الصنـــــع لتفـــريـط بـــذور الـرمـــــان

نجلاء صلاح أنور[1] - محمد محمد مراد حسن[1] - محب محمد أنيس الشرباصي[2] - طارق حسين على[3]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علـــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt
2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt
3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

*** Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

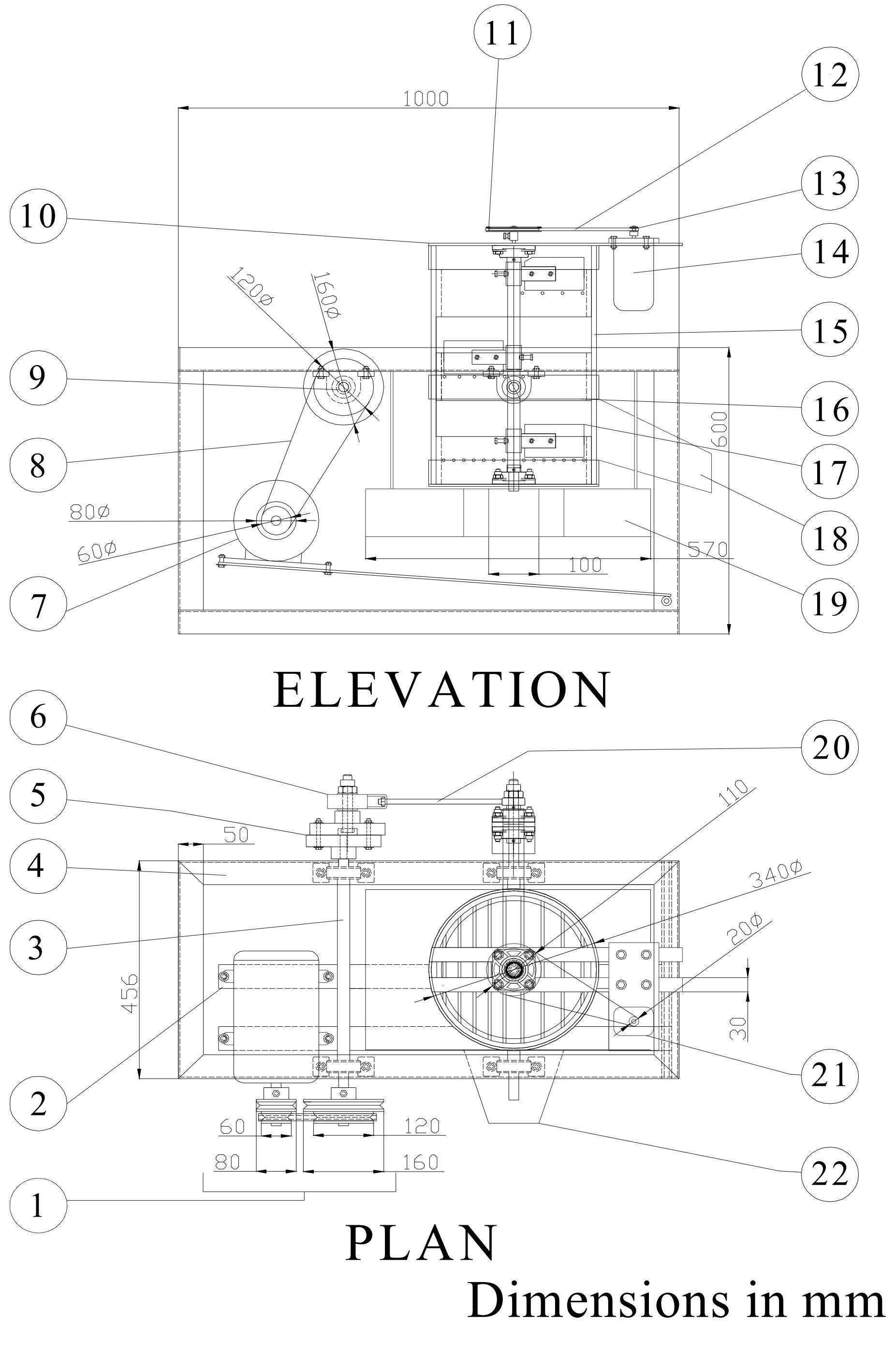
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

$\cos\theta$ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

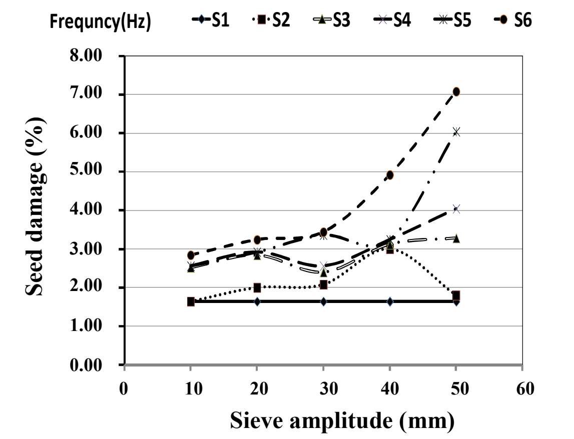
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

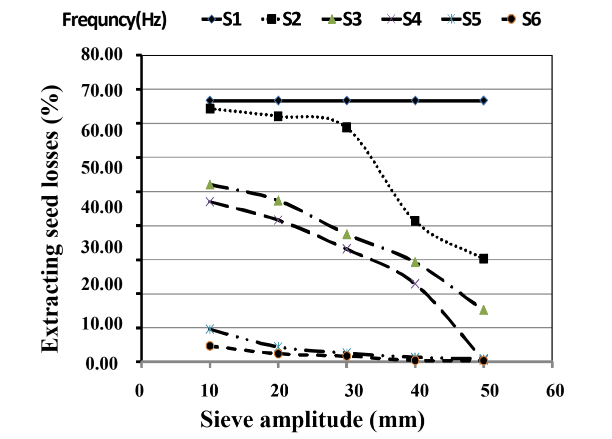
RESULTS AND DISCUSSION

The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and





A. Effect of sieve amplitude and exciter frequency on seed damage	B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

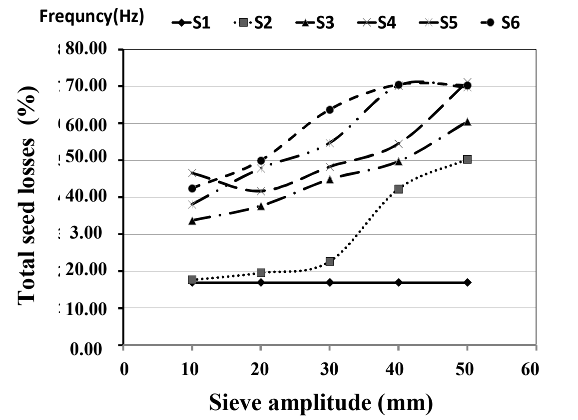
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

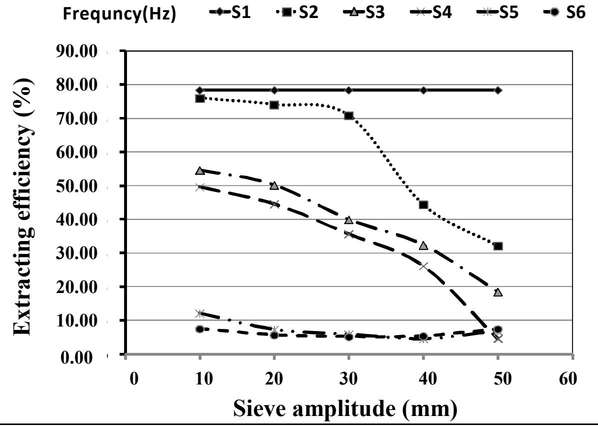
It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses



B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

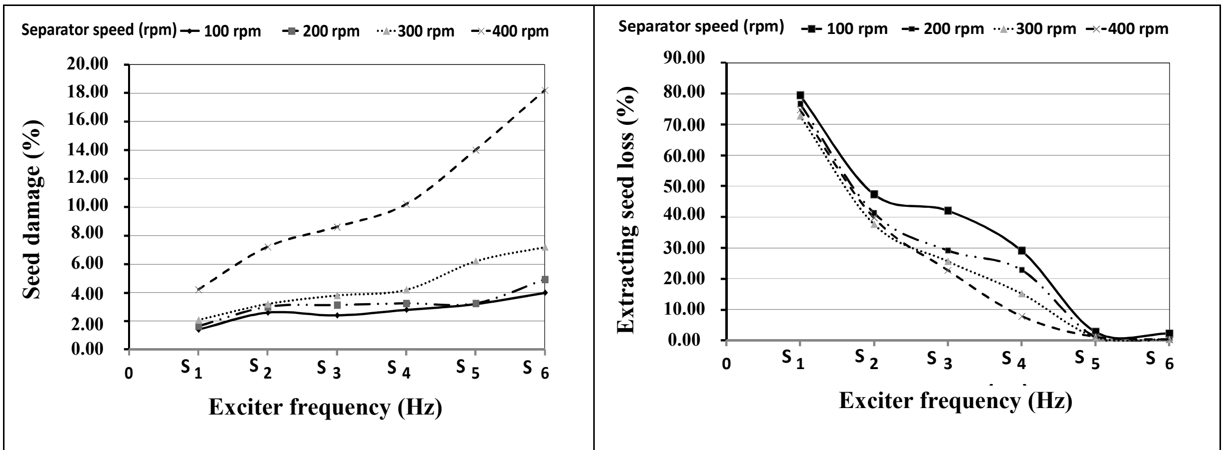
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage	B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

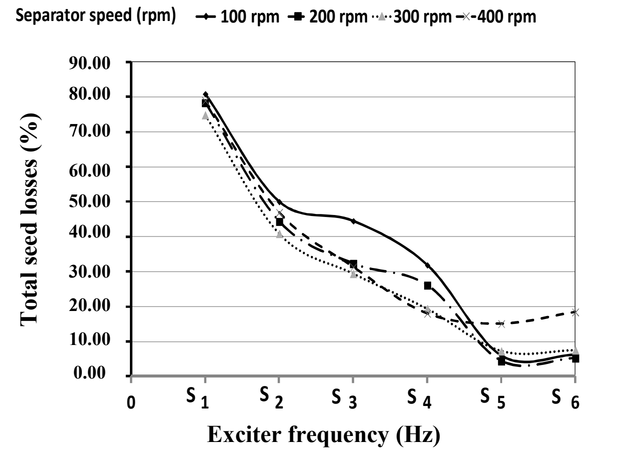
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

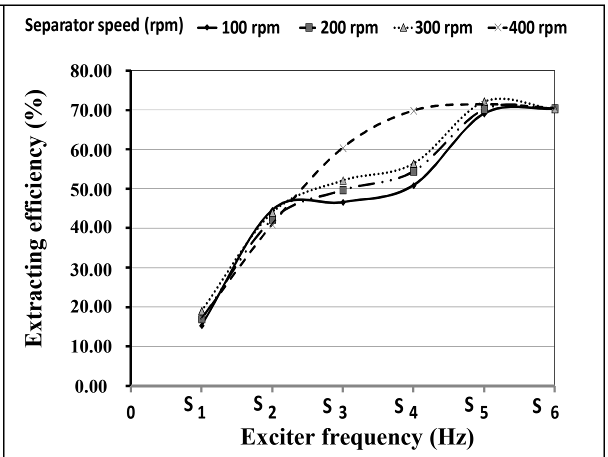
Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses



B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

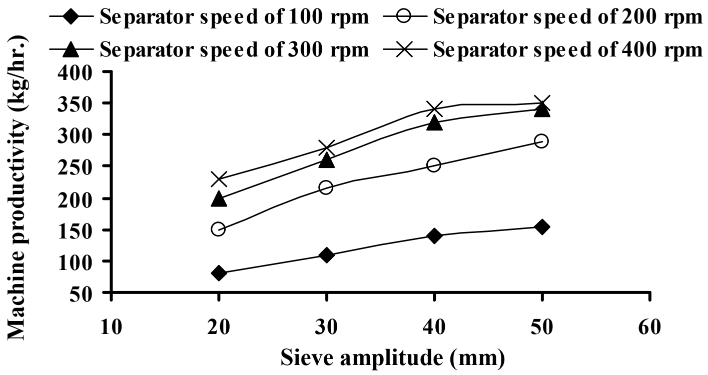


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

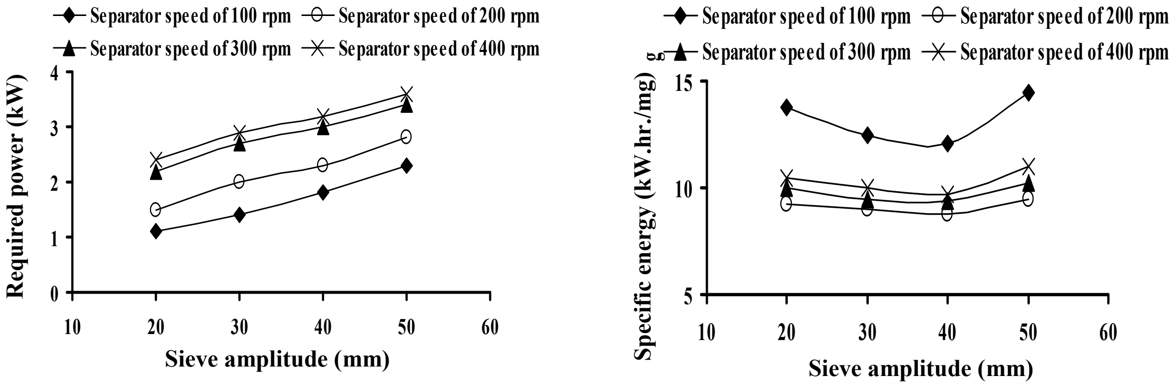


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

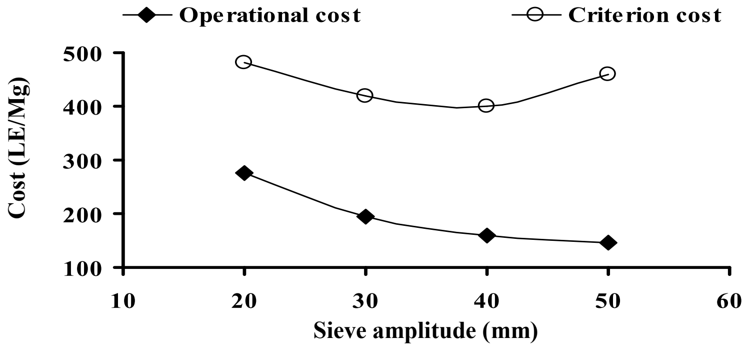


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــــع وتقييـــــــم أداء آلـــــــــــة محليــــــــــة الصنــــع لتفـــريـط بـــذور الـرمــــان

نجلاء صلاح أنور[1] - محمد محمد مراد حسن[1] - محب محمد أنيس الشرباصي[2]- طارق حسين على[3]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علـــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt

3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

* **Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

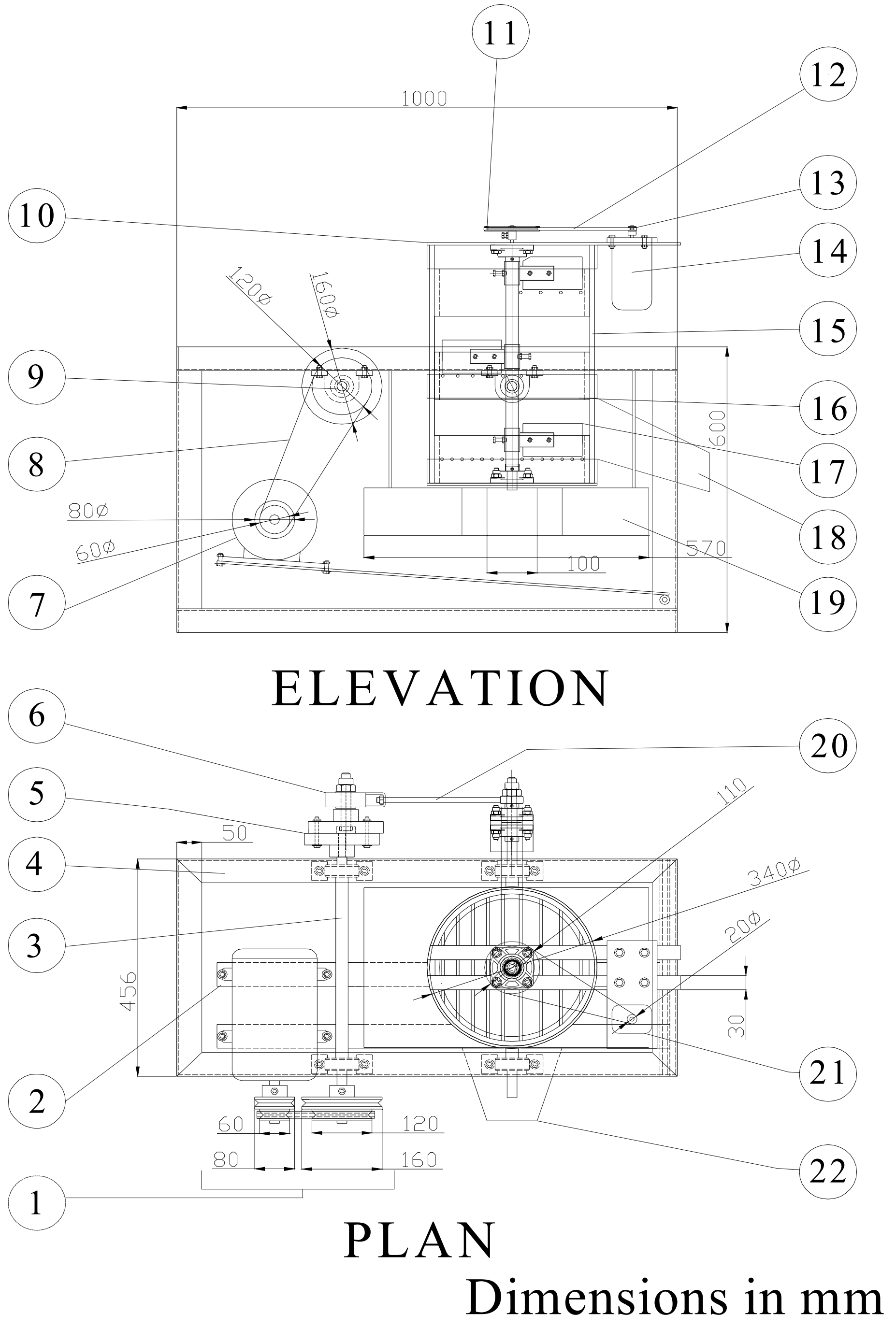
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

cos θ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

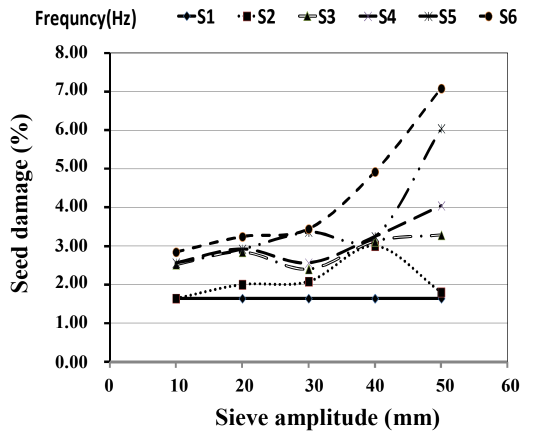
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

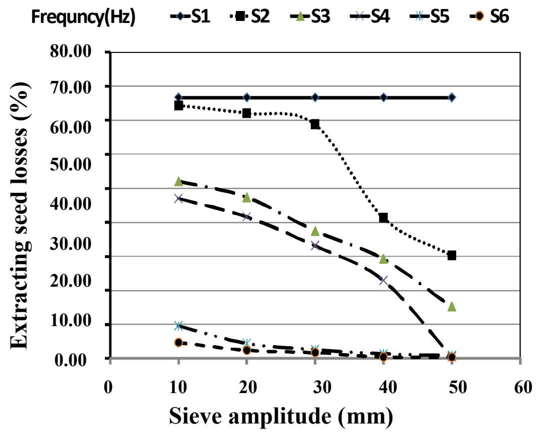
The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage



B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

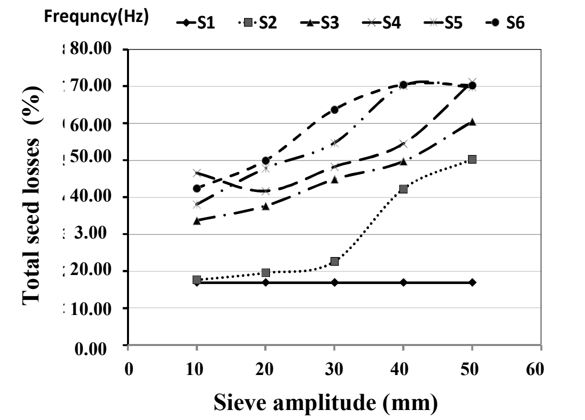
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

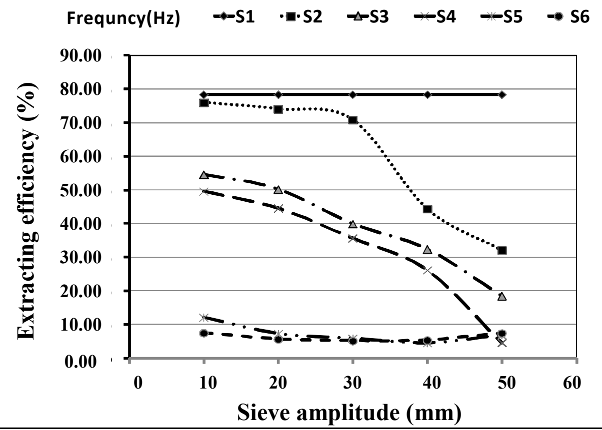
It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses



B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

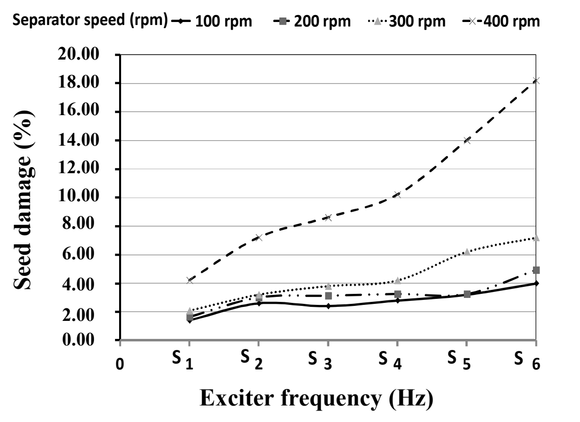
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

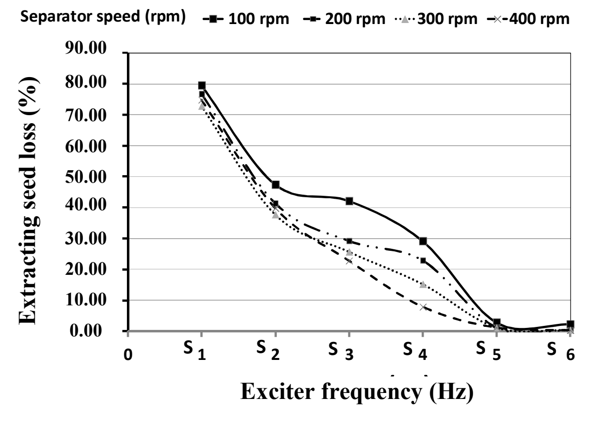
At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage



B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

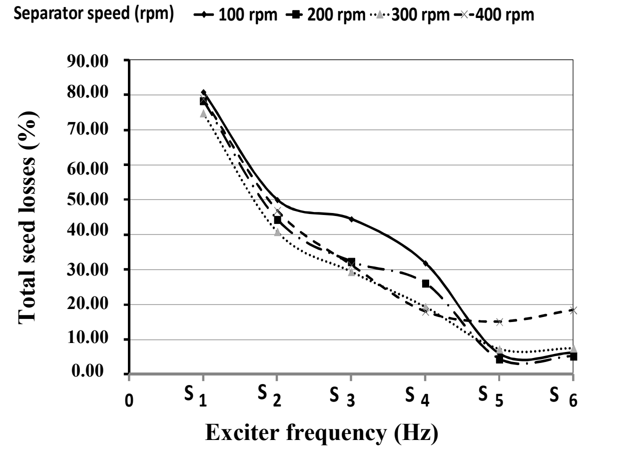
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

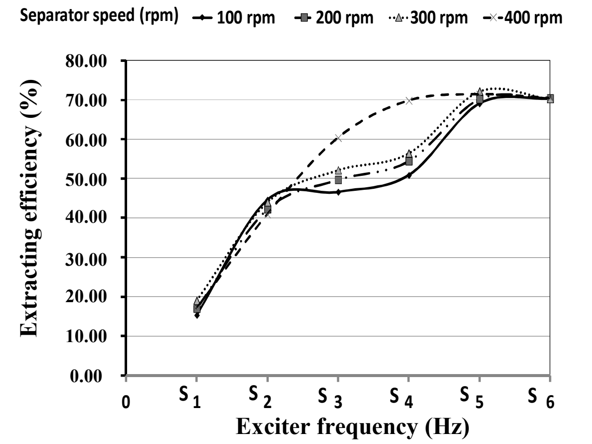
Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses



B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

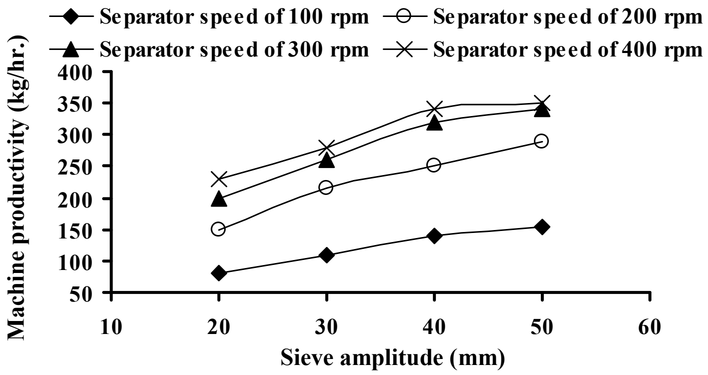


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

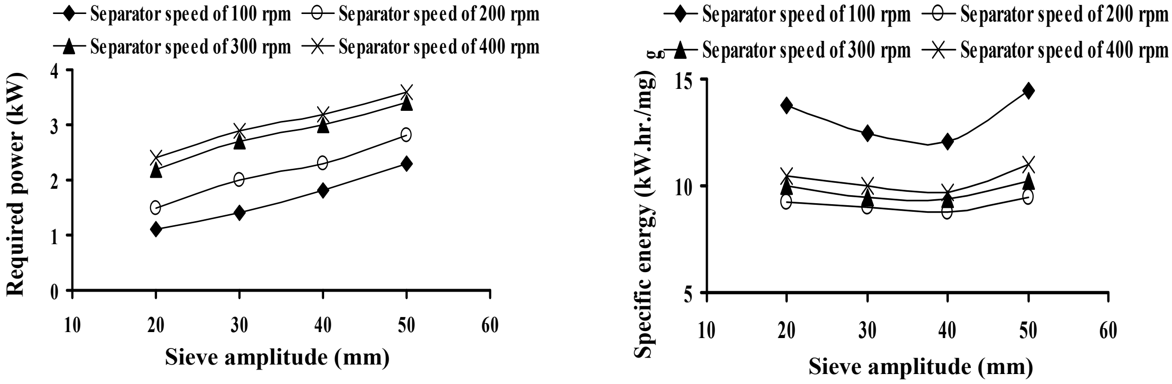


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

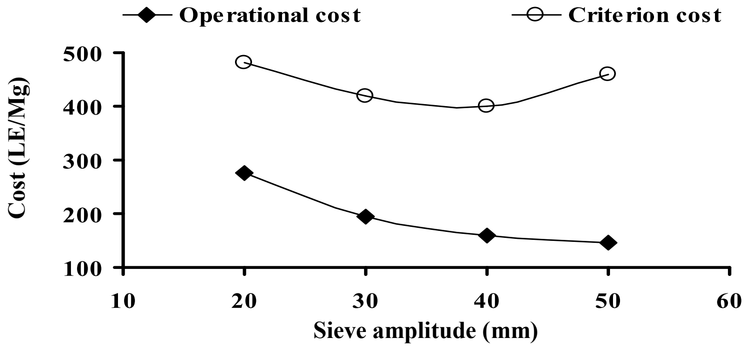


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــــع وتقييـــــــم أداء آلـــــــــــة محليـــــــــة الصنــــــع لتفـــريـط بـــذور الـرمــــــان

نجلاء صلاح أنور[1] - محمد محمد مراد حسن[1] - محب محمد أنيس الشرباصي[2]- طارق حسين على[3]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علـــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt

3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

*** Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

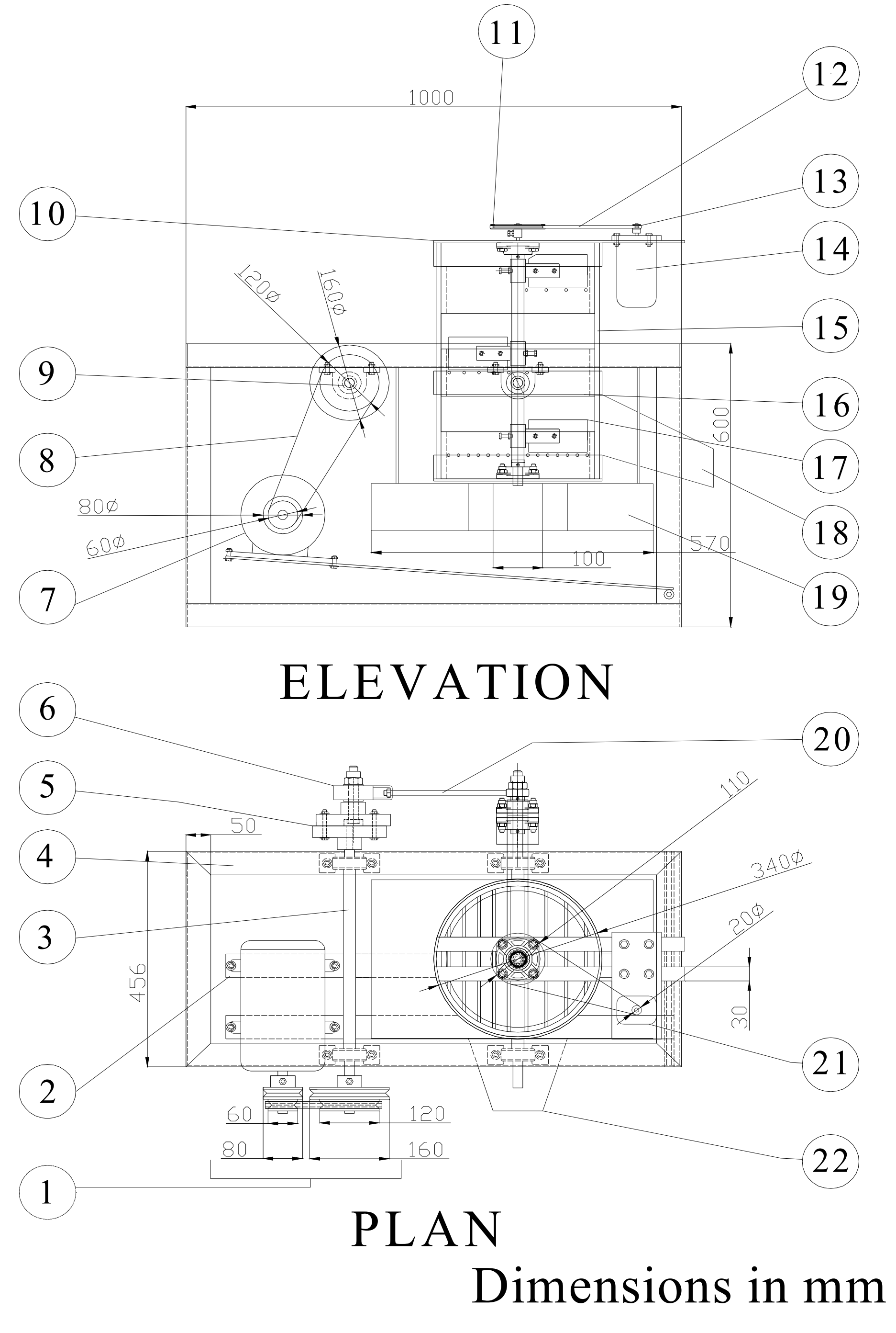
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

$\cos\theta$ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

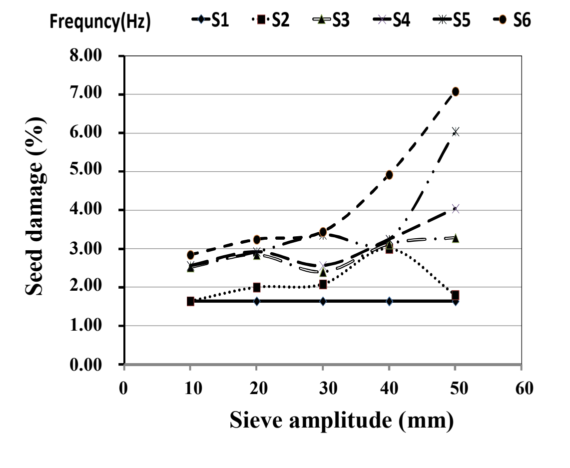
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

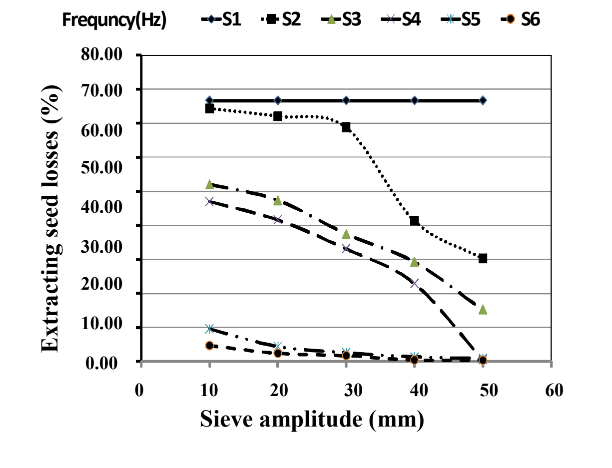
The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage



B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

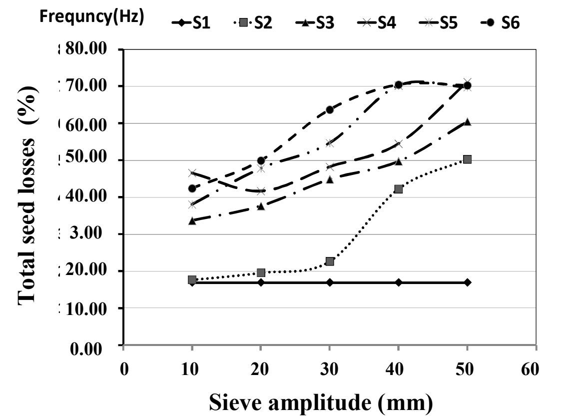
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

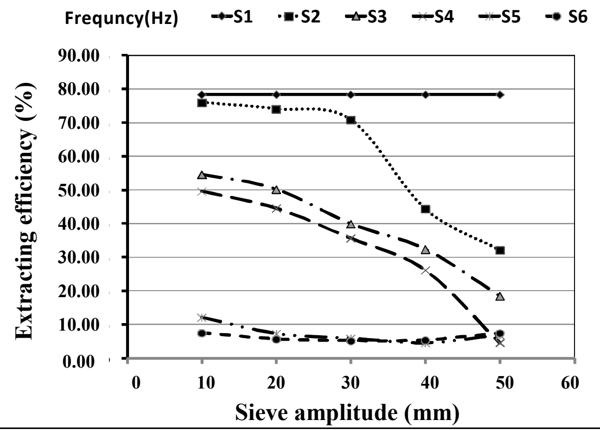
It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses



B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

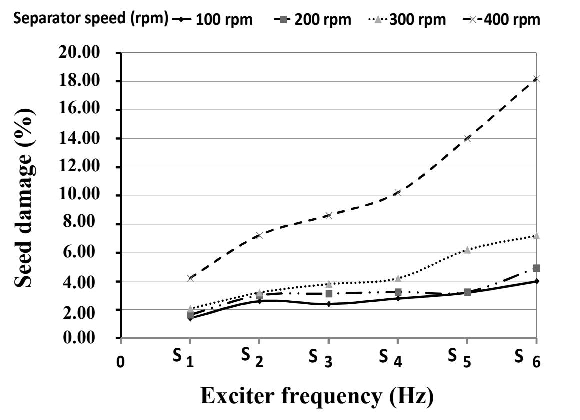
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

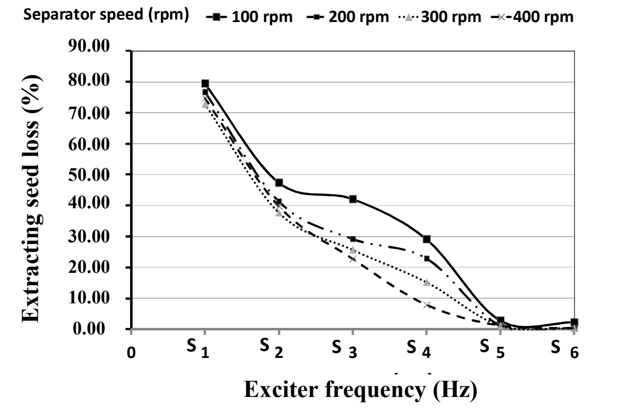
At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage



B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

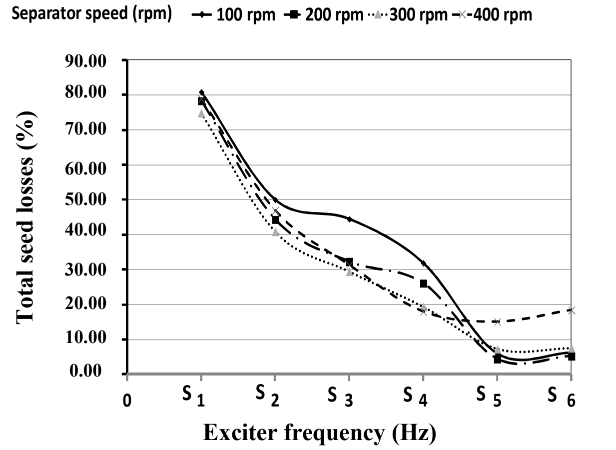
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

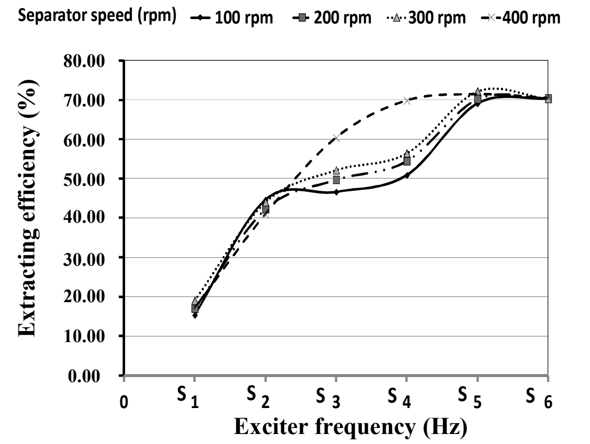
Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses



B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

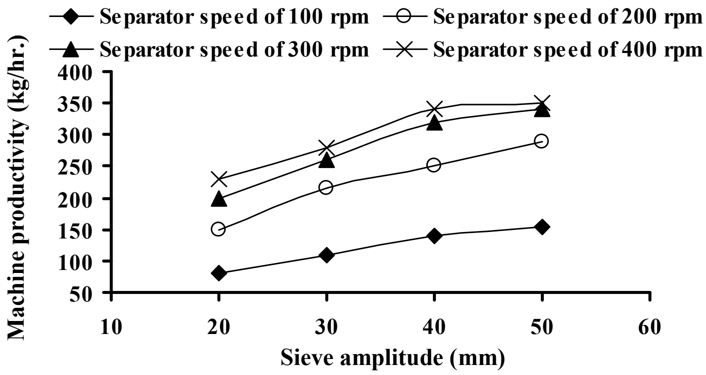


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

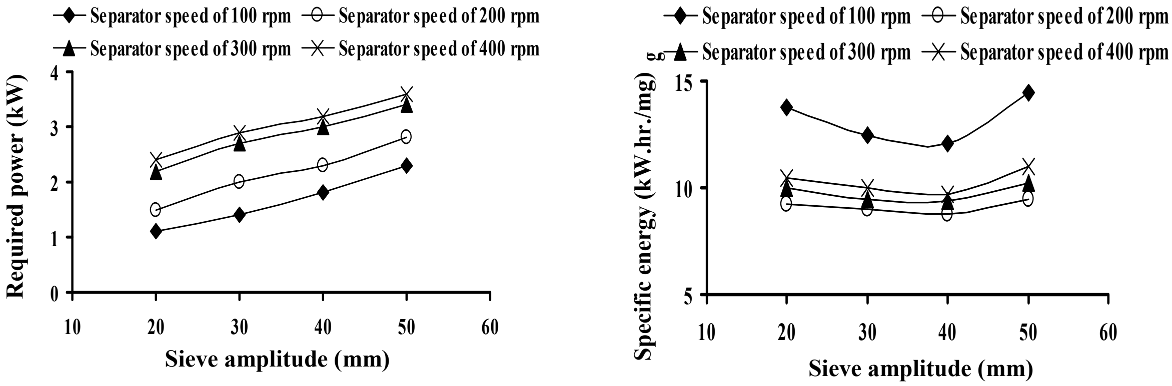


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

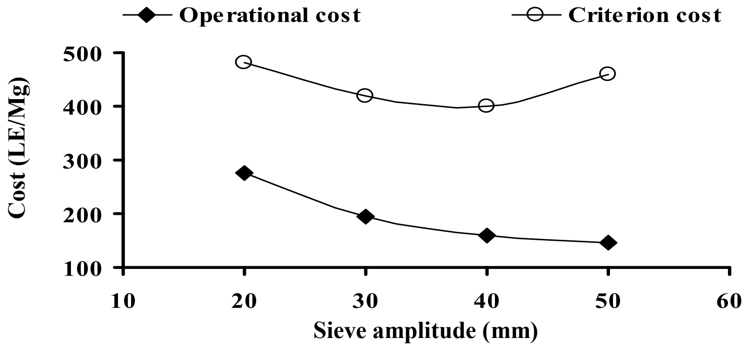


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــع وتقييـــــم أداء آلـــــــــة محليـــــــة الصنـــع لتفـــريـط بـــذور الـرمـــان

نجلاء صلاح أنور[1] - محمد محمد مراد حسن[1] - محب محمد أنيس الشرباصي[2]- طارق حسين على[3]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علـــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt

3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

*** Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

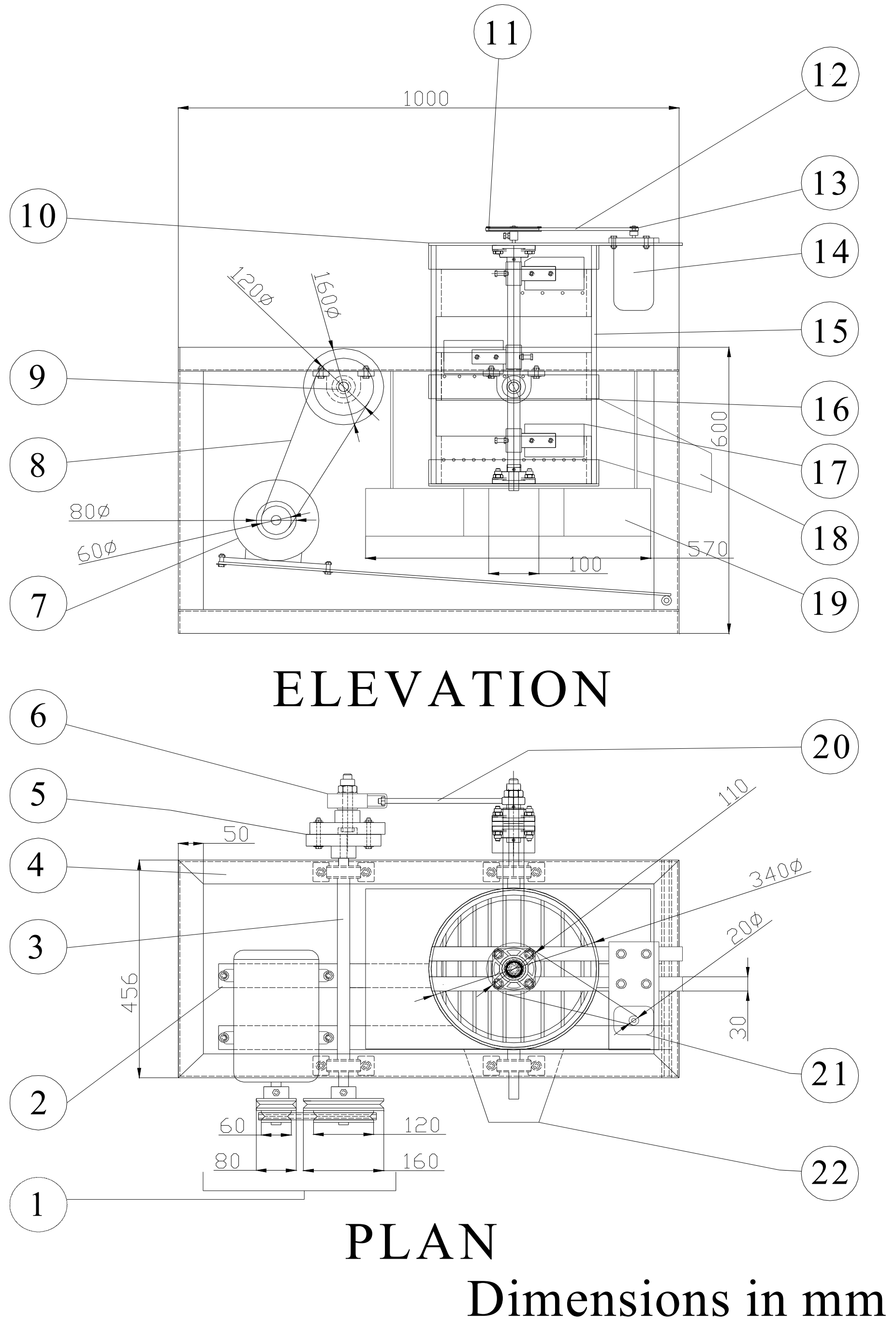
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

cos θ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

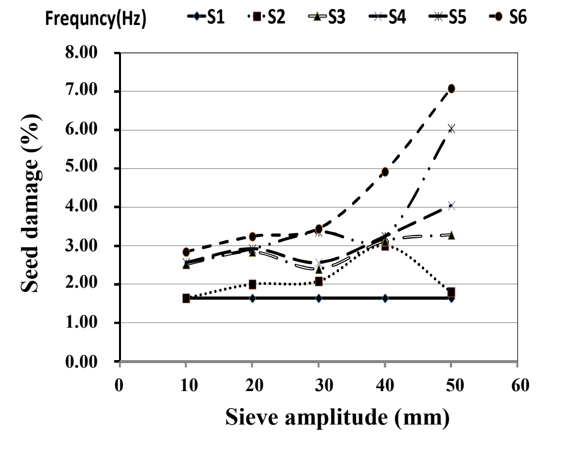
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

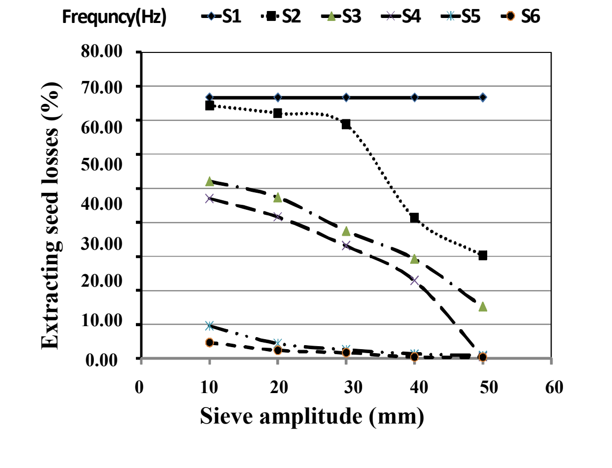
The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage



B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

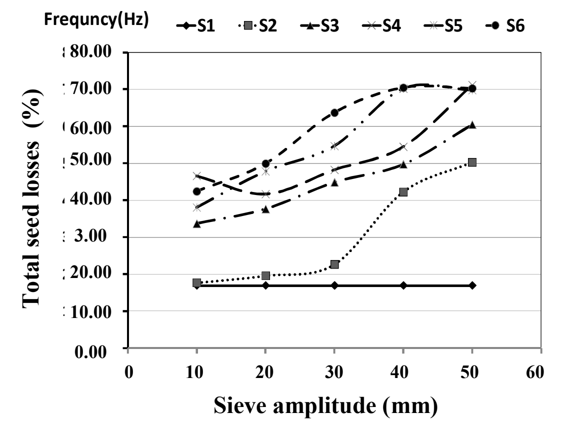
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

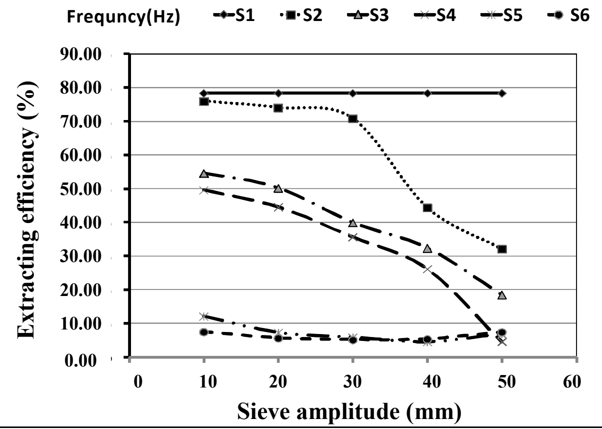
It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses



B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

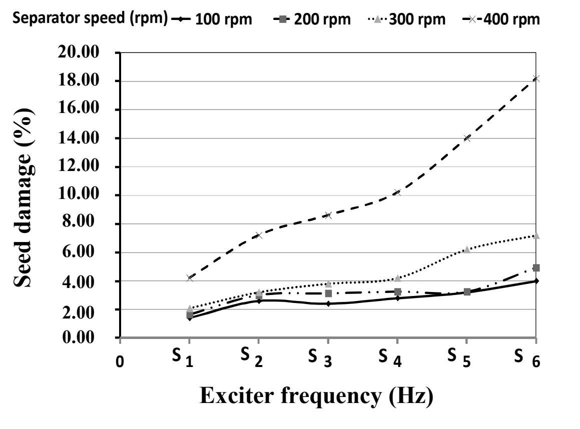
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

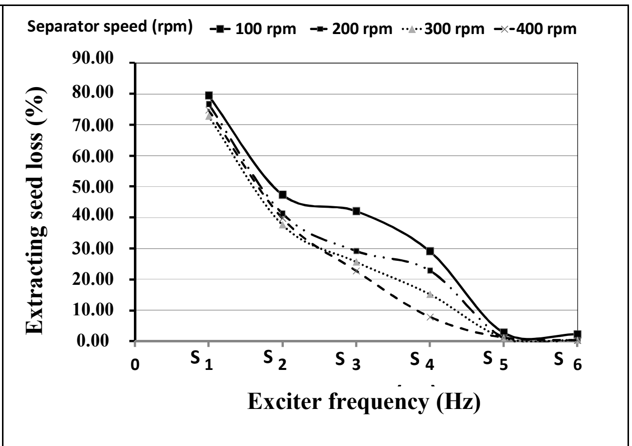
At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage



B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

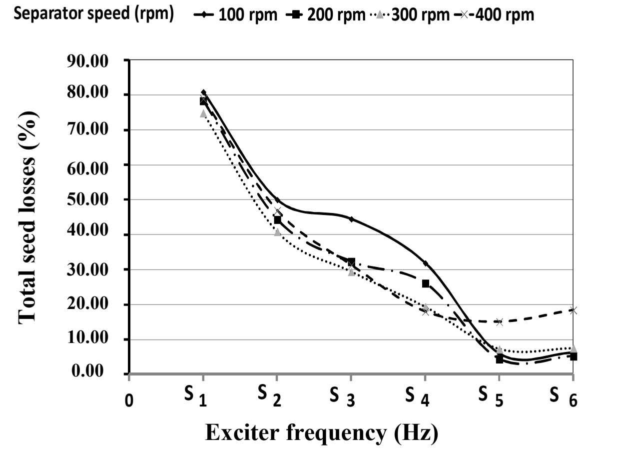
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

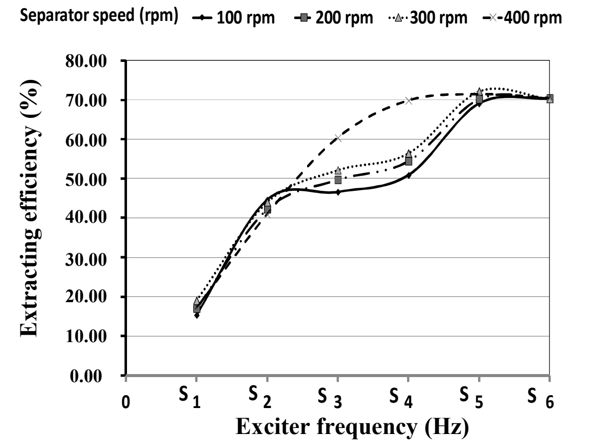
Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses



B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

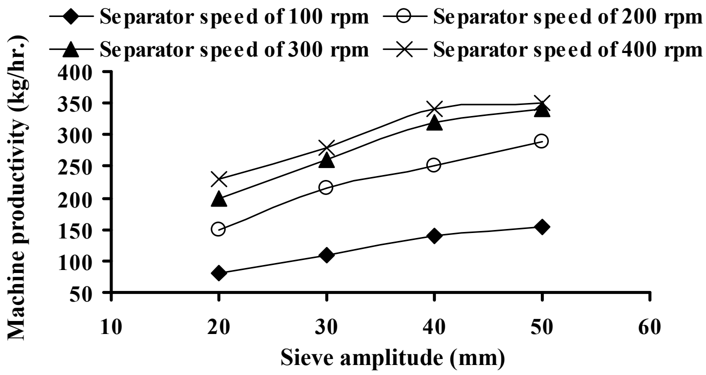
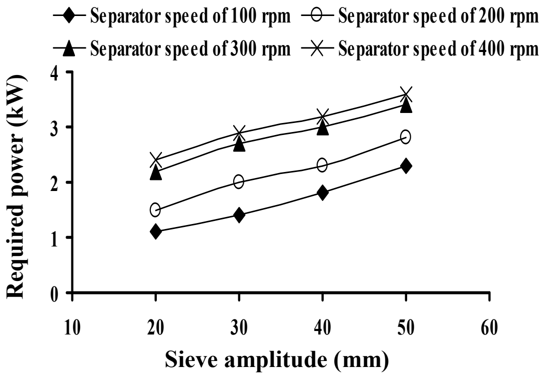


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz



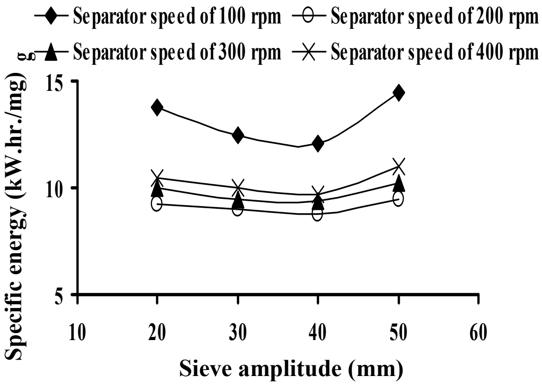


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

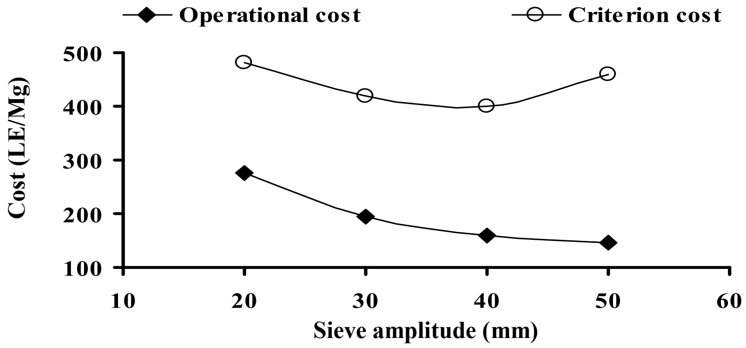


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــــع وتقييـــــــم أداء آلــــــــــة محليـــــــــة الصنـــــع لتفـــريـط بـــذور الـرمــــان

نجلاء صلاح أنور[1] - محمد محمد مراد حسن[1] - محب محمد أنيس الشرباصي[2]- طارق حسين على[3]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt

3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

* **Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

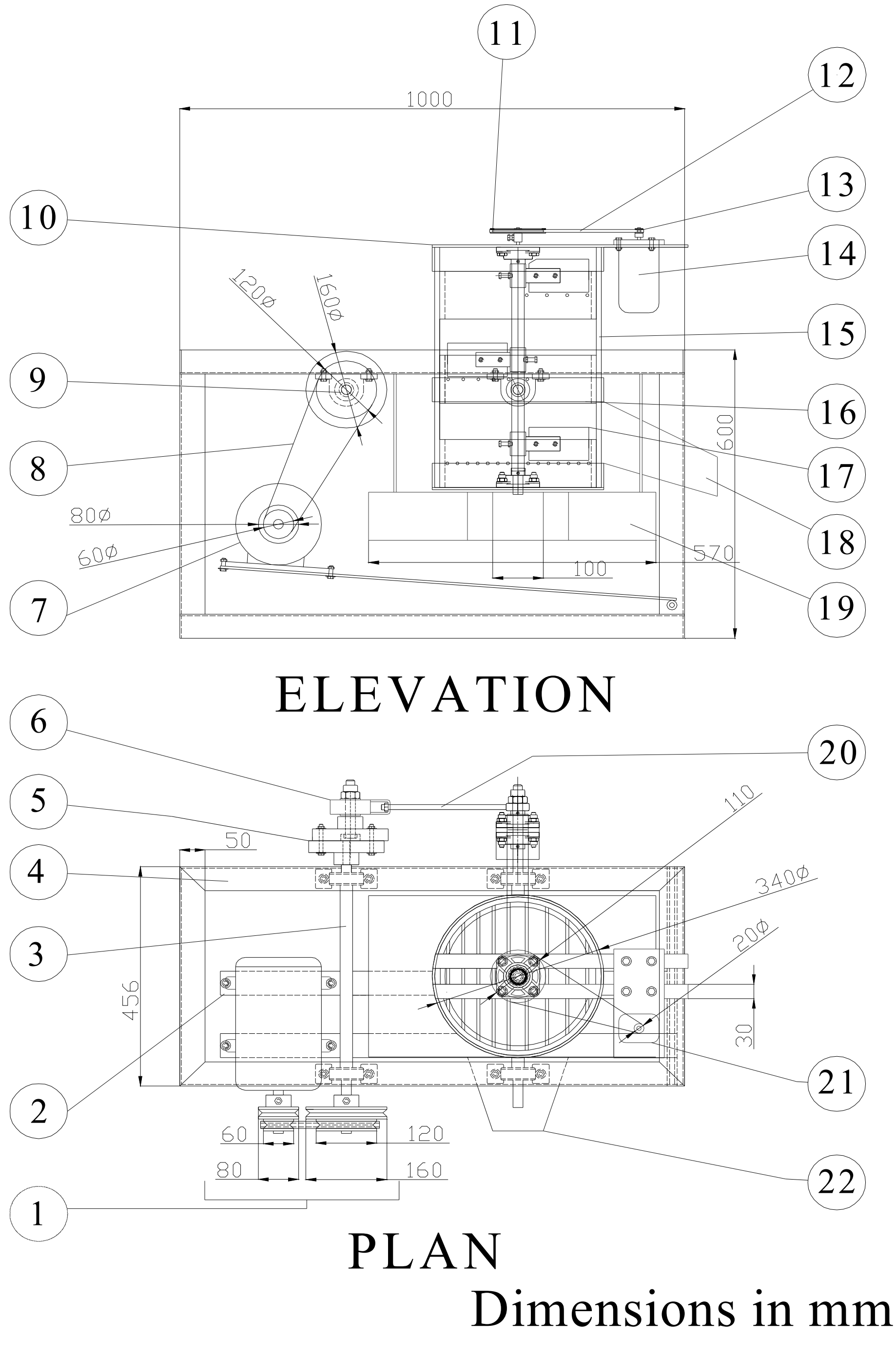
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

$\cos\theta$ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and

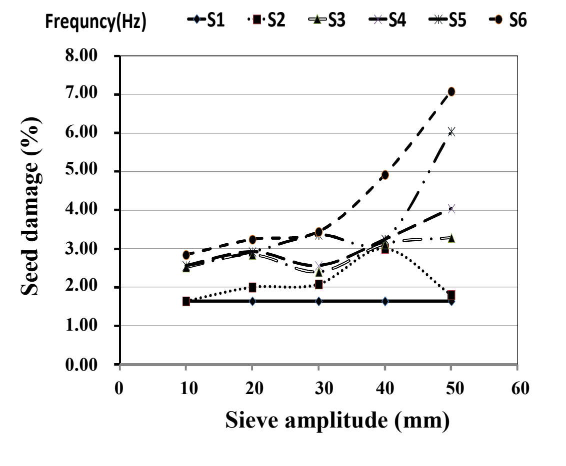
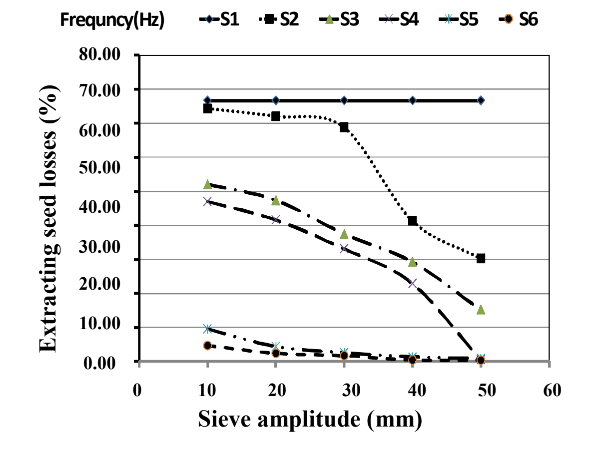
	
A. Effect of sieve amplitude and exciter frequency on seed damage	**B. Effect of sieve amplitude and exciter frequency on extracting losses**

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

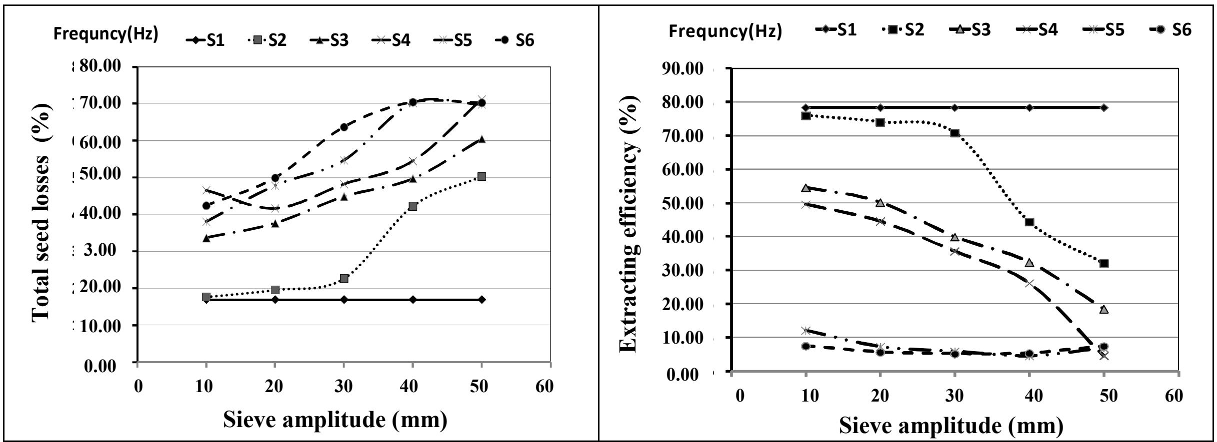
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses	B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

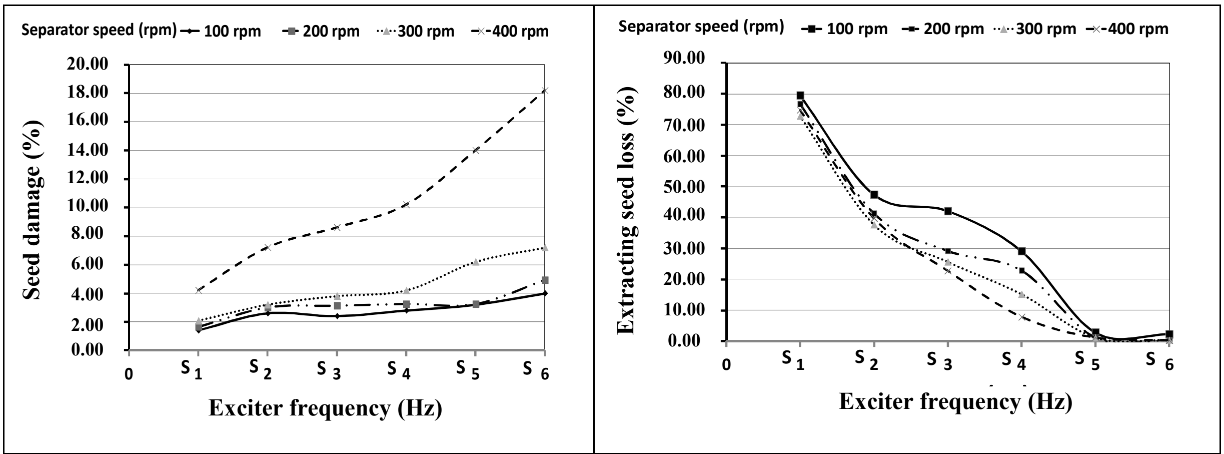
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage	B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

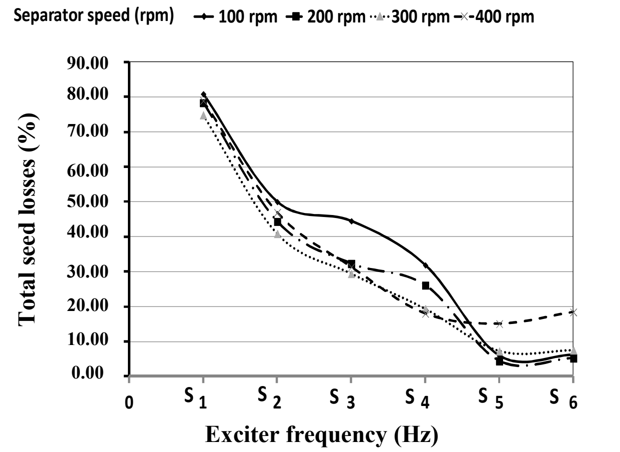
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

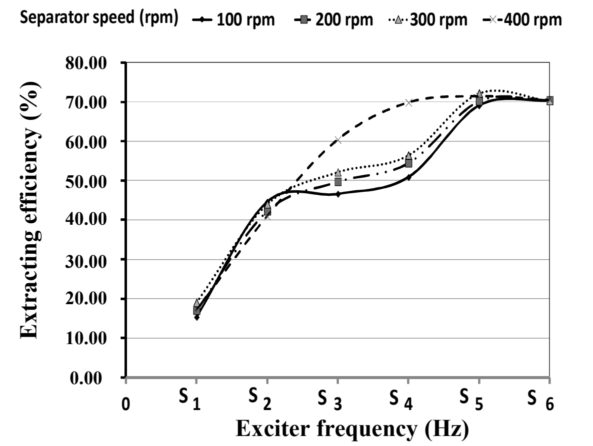
Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses



B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

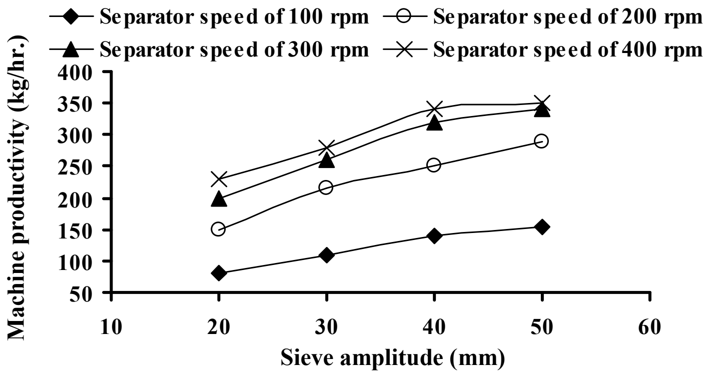


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

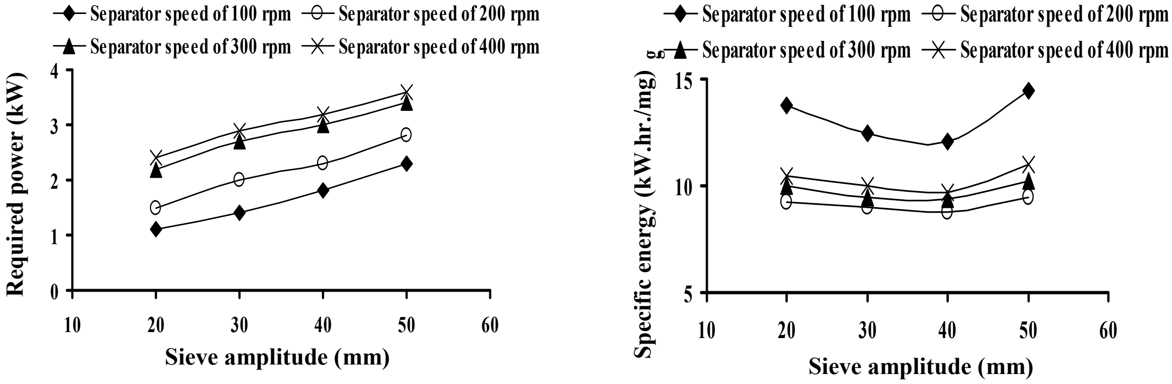


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

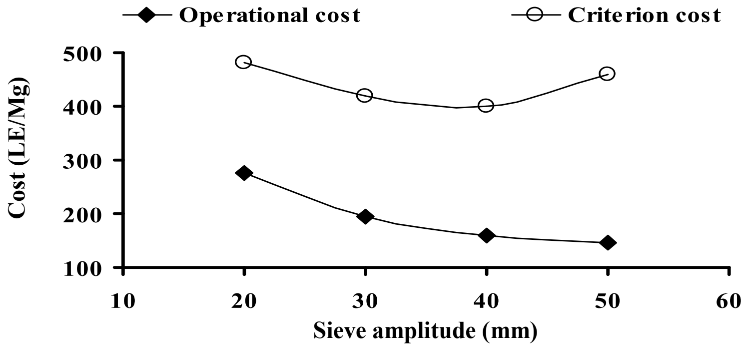


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــــع وتقييـــــــم أداء آلـــــــــــة محليـــــــــة الصنـــــع لتفـــريـط بــــذور الـرمــــــان

نجلاء صلاح أنور[١] - محمد محمد مراد حسن[١] - محب محمد أنيس الشرباصي[٢]- طارق حسين على[٣]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر	أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.
٢- أ.د. محمود مصطفى علـــي	أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt

3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

* **Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

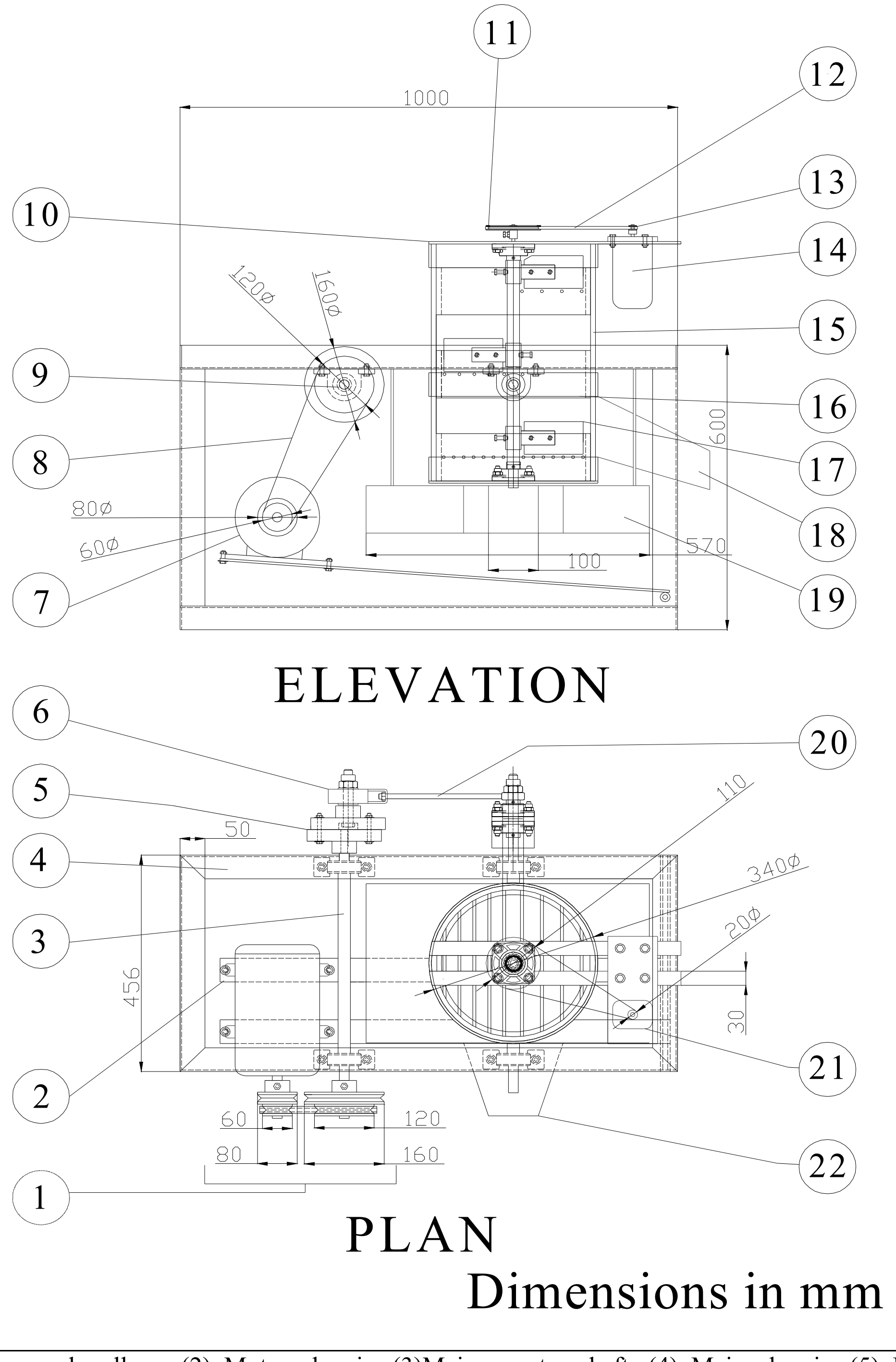
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

$\cos\theta$ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

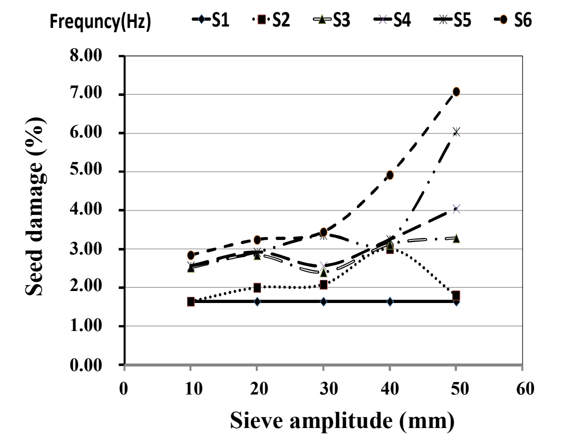
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

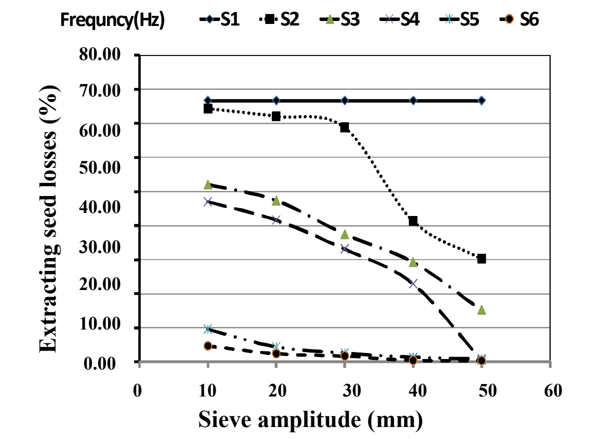
The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage



B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

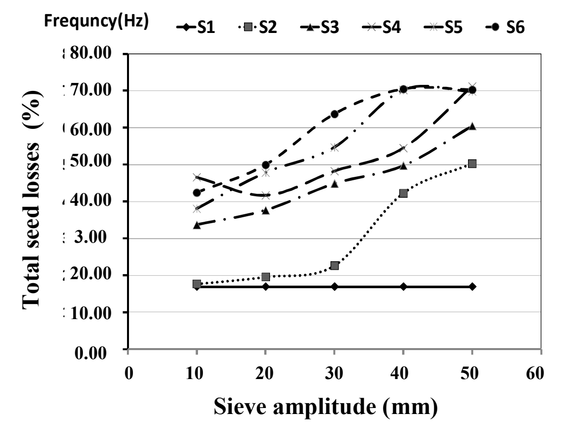
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

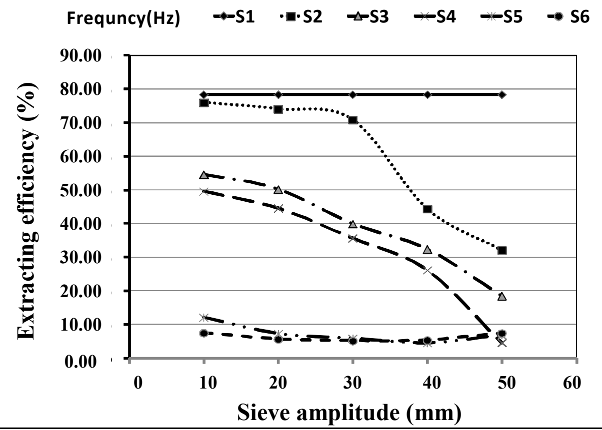
It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses



B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

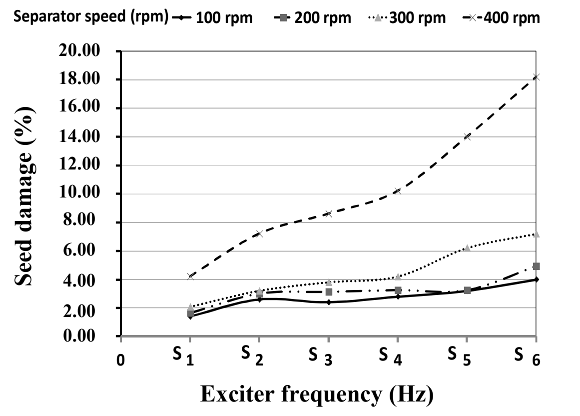
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

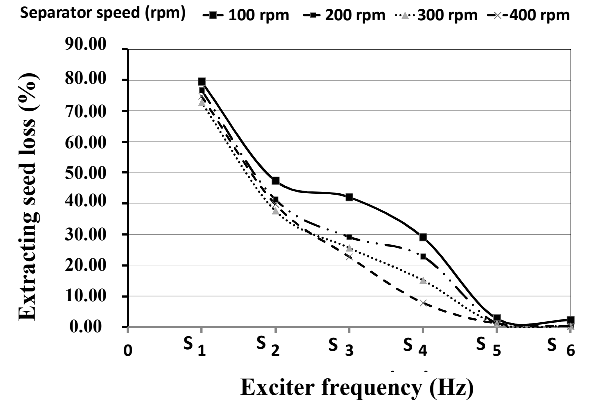
The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.





A. Effect of separator speed and exciter frequency on seed damage	B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

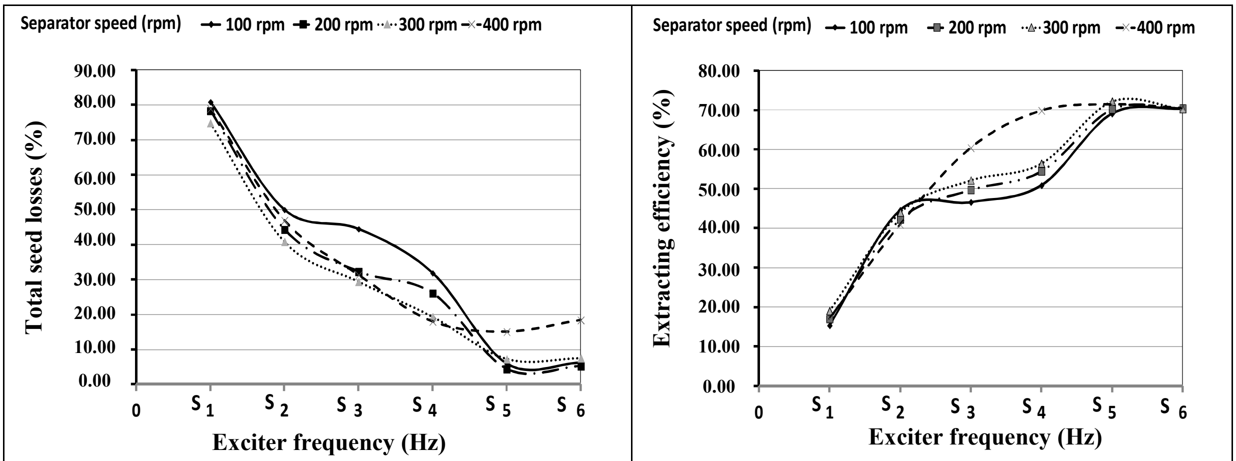
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses

B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

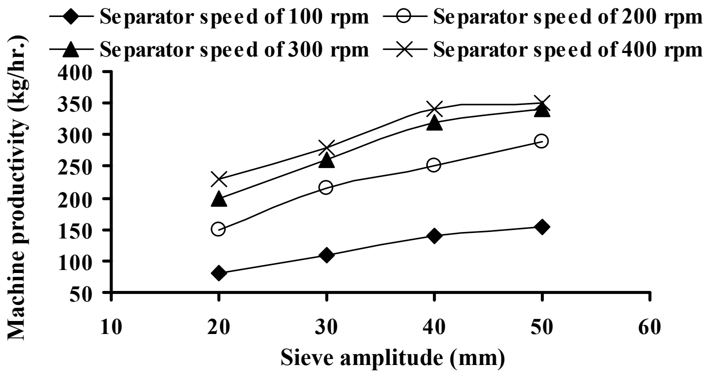


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

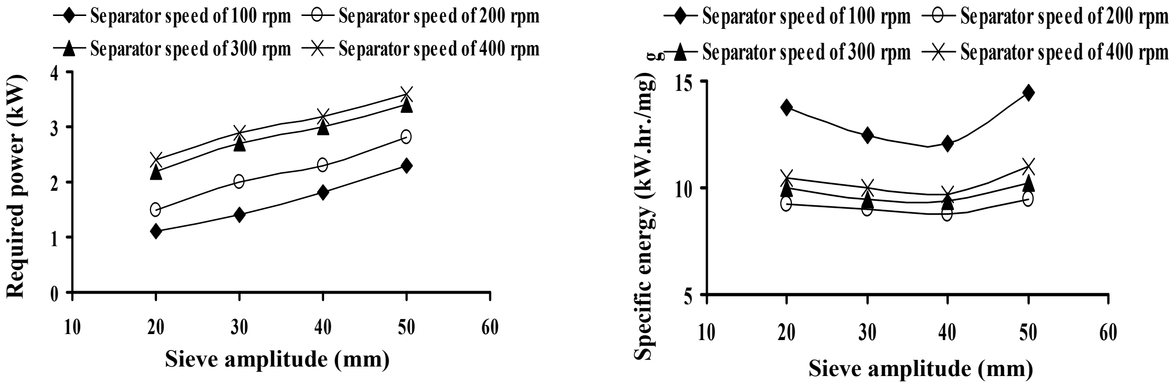


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

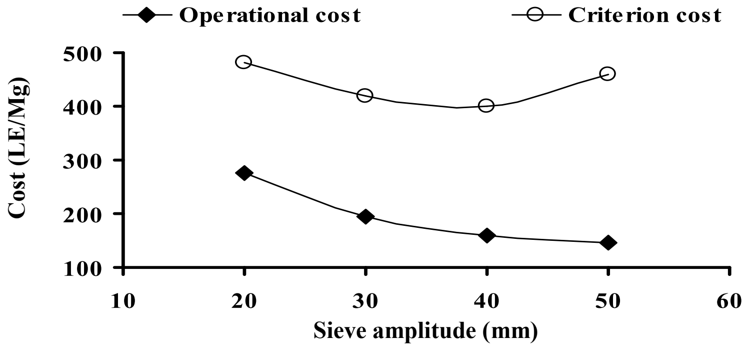


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــــع وتقييـــــــم أداء آلـــــــــة محليـــــــــة الصنـــــع لتفـــريـط بـــذور الـرمـــــان

نجلاء صلاح أنور[١] - محمد محمد مراد حسن[١] - محب محمد أنيس الشرباصي[٢]- طارق حسين على[٣]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علـــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt

3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

* **Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

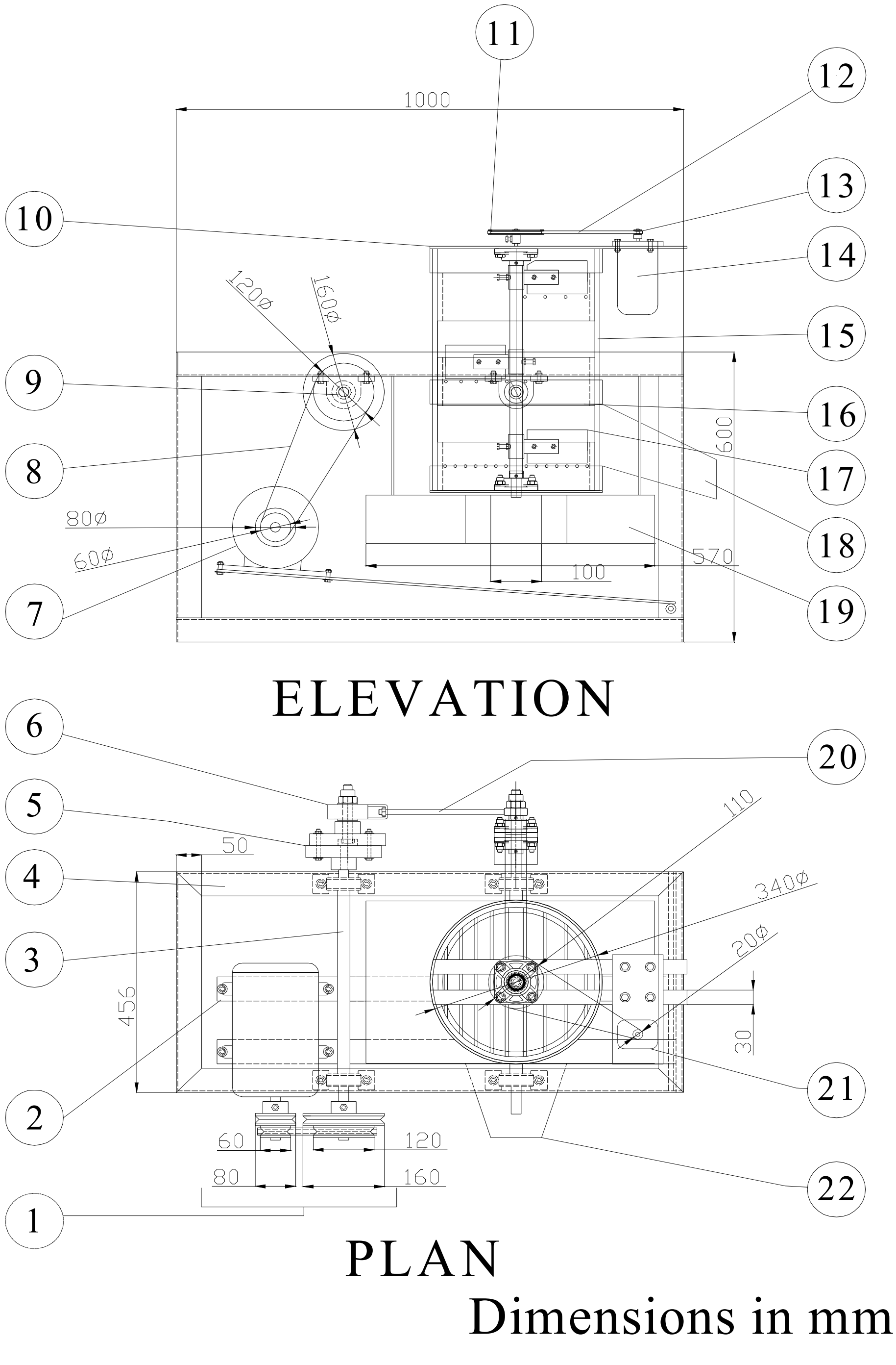
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

$\cos\theta$ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

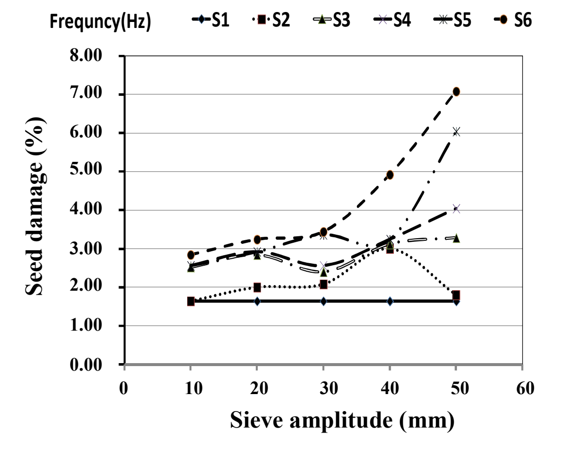
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

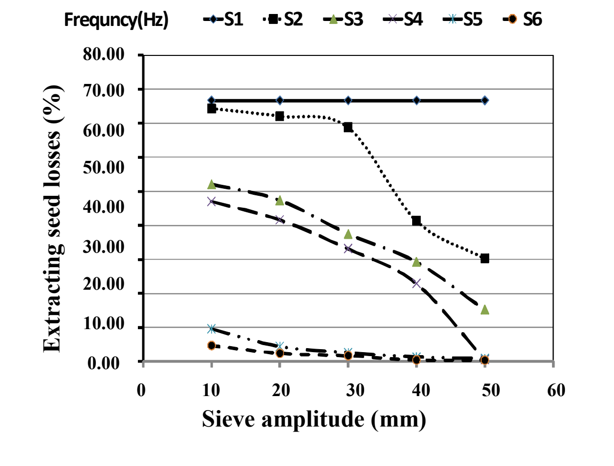
The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage



B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

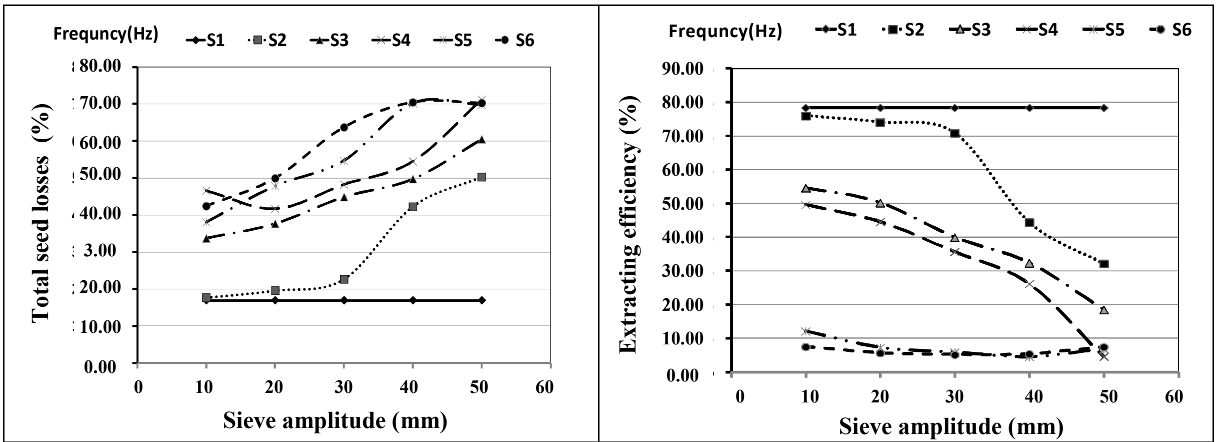
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses

B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

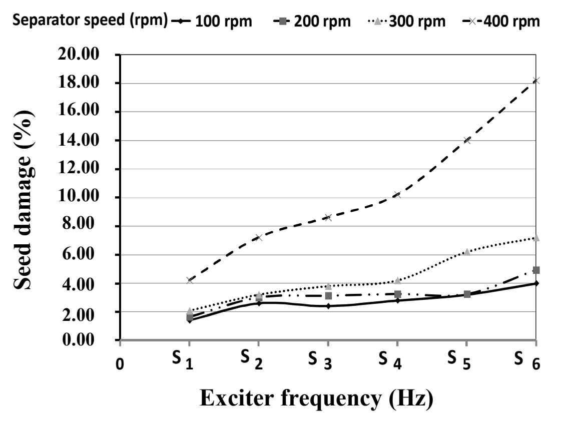
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

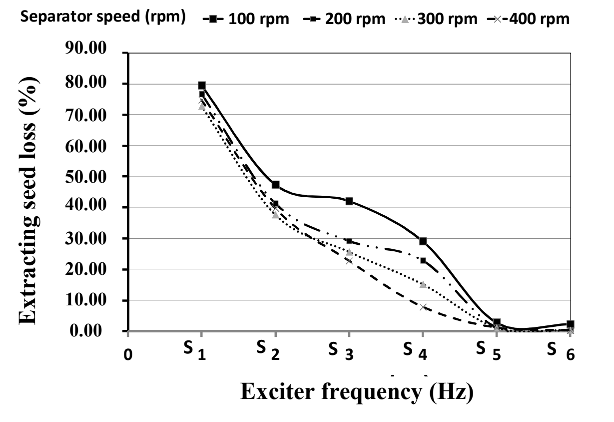
The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.





A. Effect of separator speed and exciter frequency on seed damage	B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

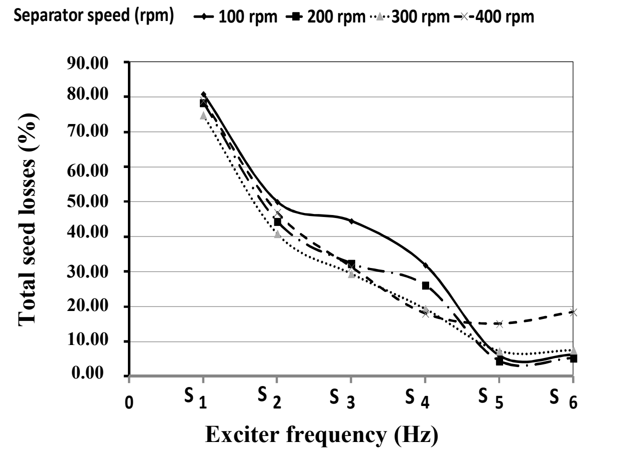
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

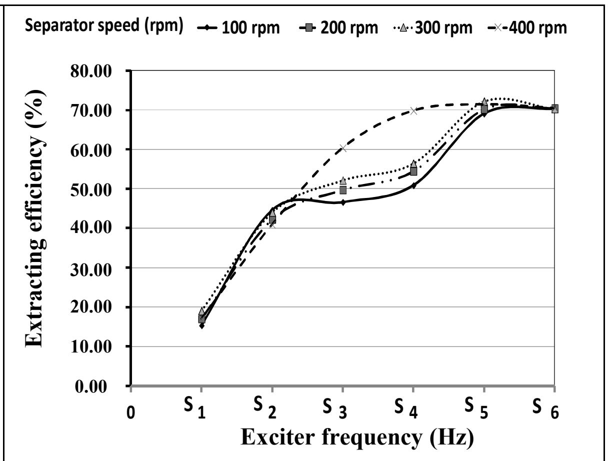
Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses



B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

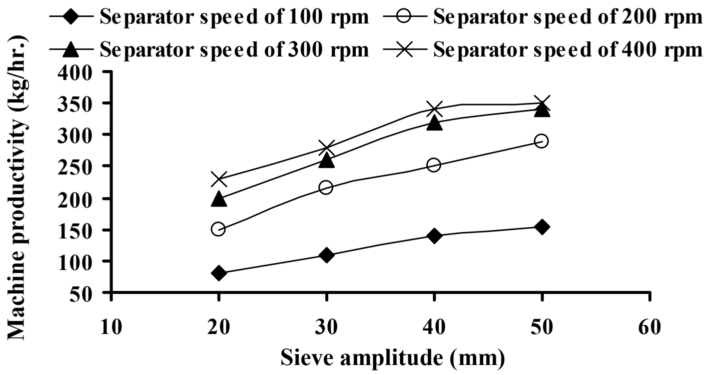


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

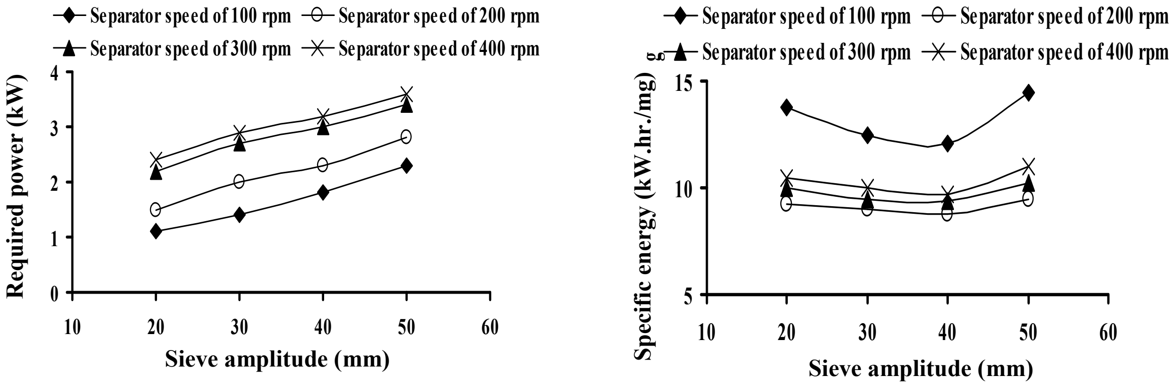


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

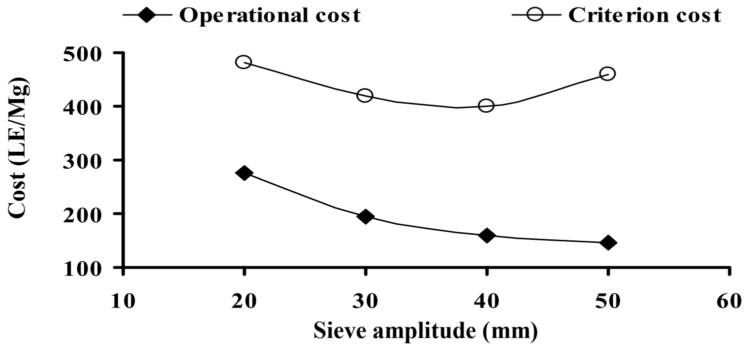


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــع وتقييـــم أداء آلـــة محليـــة الصنـــع لتفـــريـط بـــذور الرمـــان

نجلاء صلاح أنور[1] - محمد محمد مراد حسن[1] - محب محمد أنيس الشرباصي[2]- طارق حسين على[3]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علـي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt

3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

* **Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

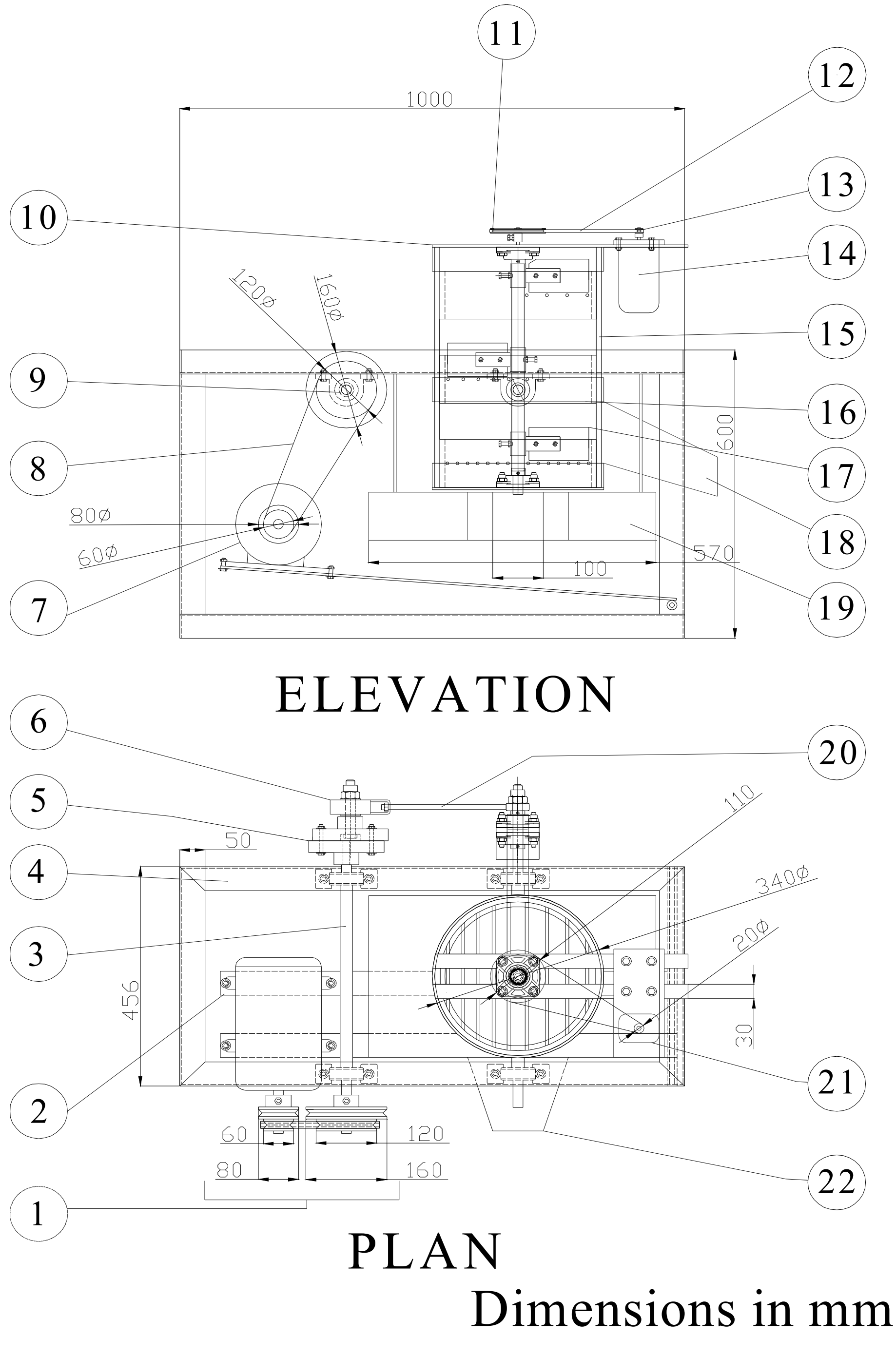
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

$\cos\theta$ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

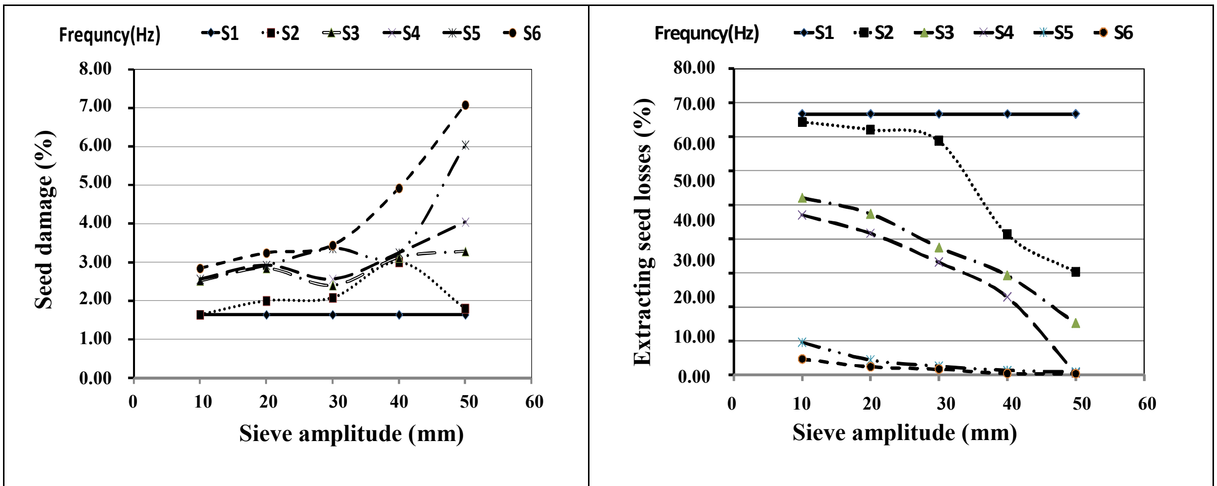
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage	B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

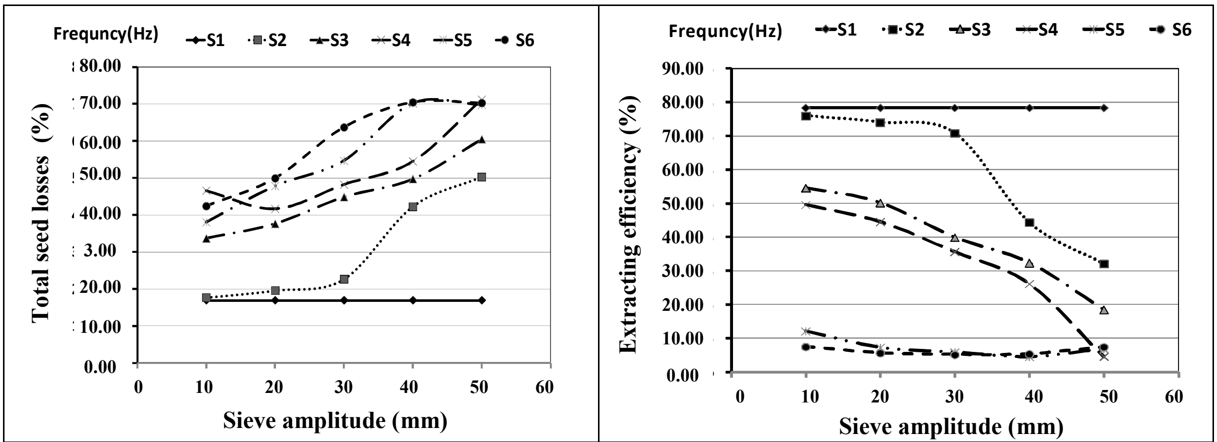
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses

B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

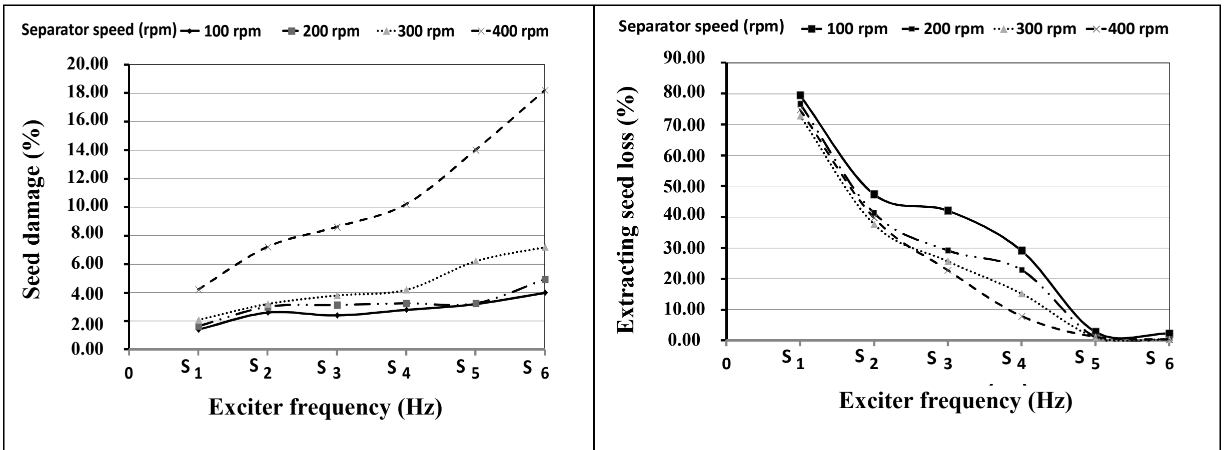
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage

B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

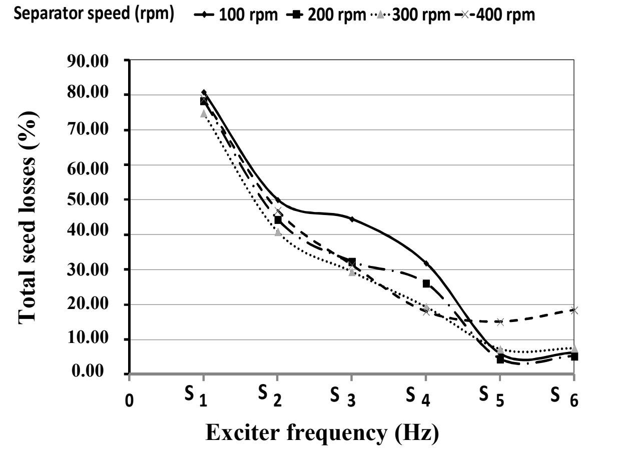
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

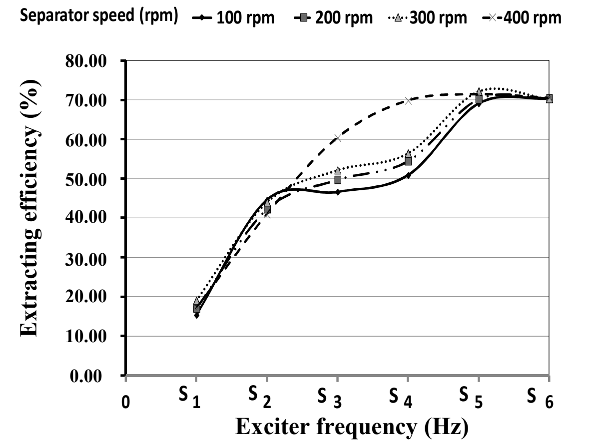
Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses



B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

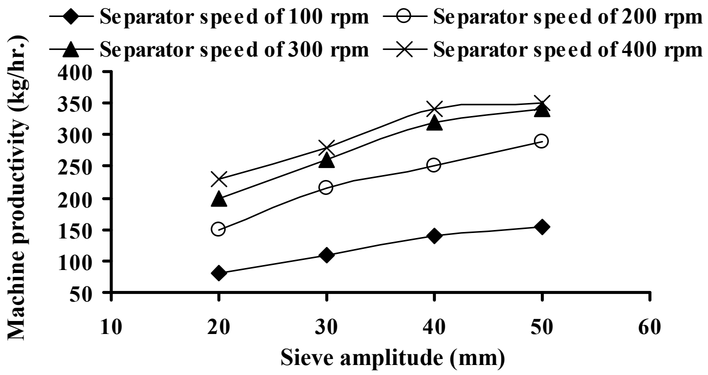


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

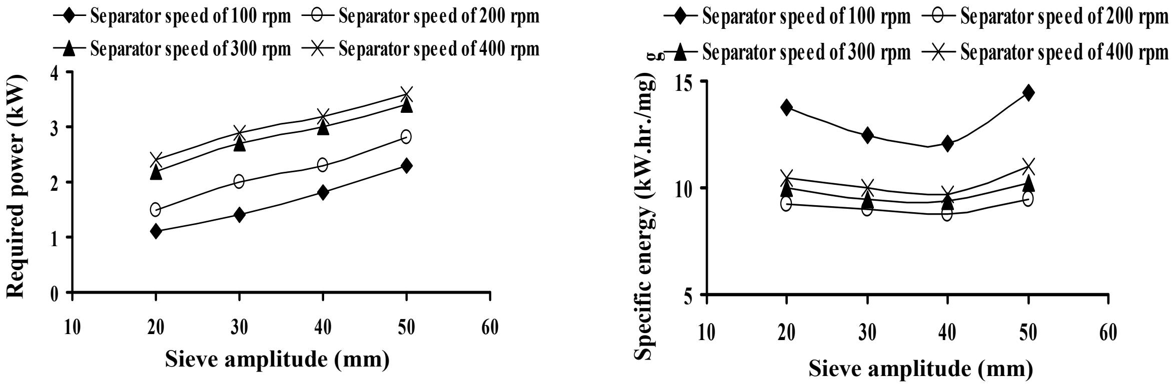


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

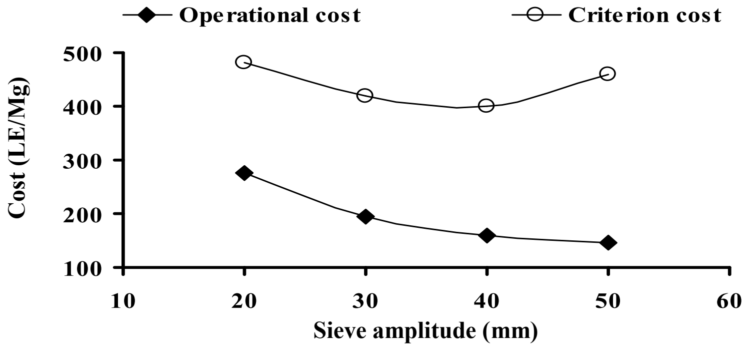


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيــــع وتقييــــــم أداء آلـــــــــــة محليــــــــــة الصنـــــع لتفـــريــط بـــذور الـرمــــان

نجلاء صلاح أنور[1] - محمد محمد مراد حسن[1] - محب محمد أنيس الشرباصي[2]- طارق حسين على[3]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علـــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt

3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

*** Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

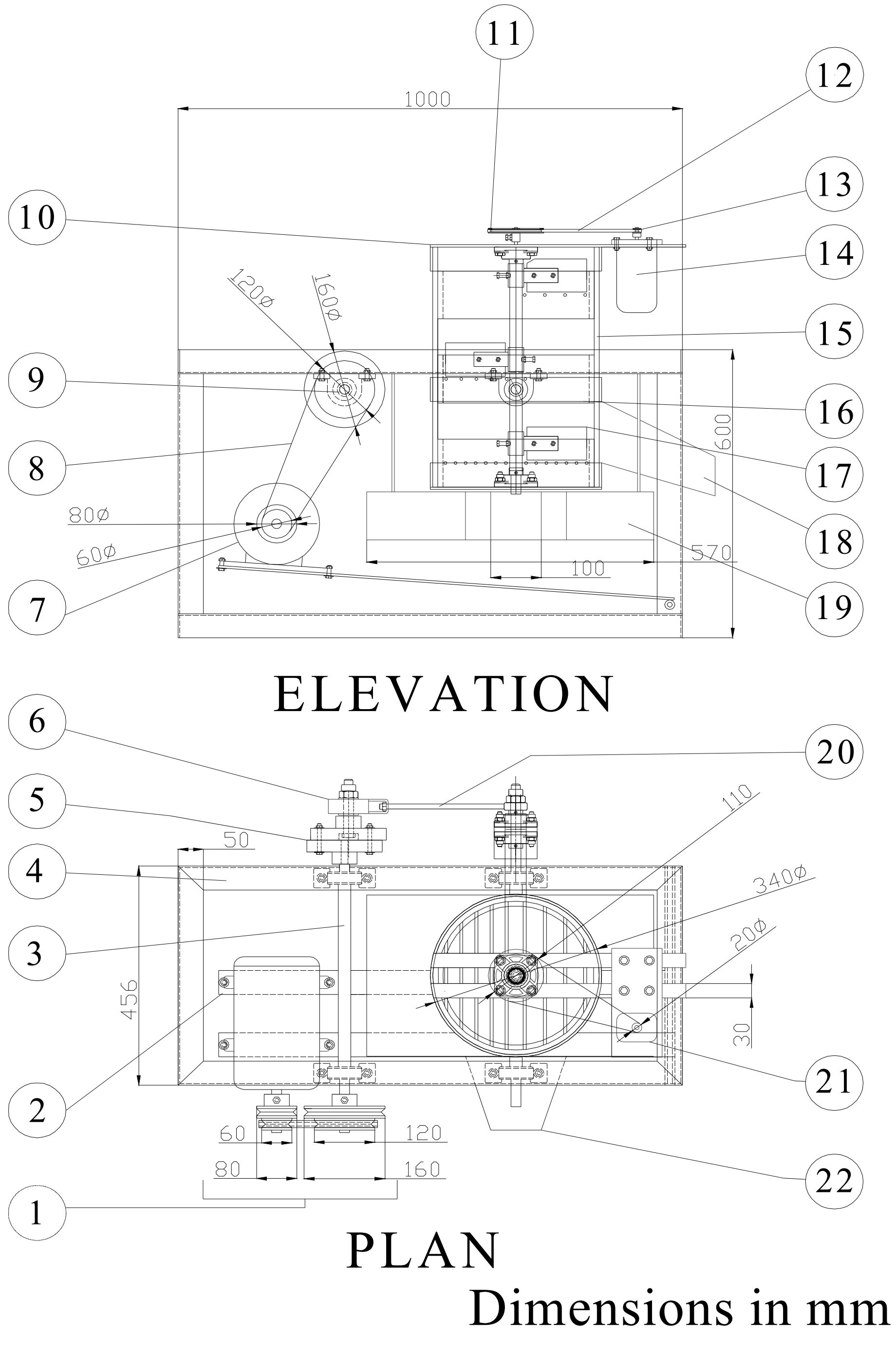
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

$\cos\theta$ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

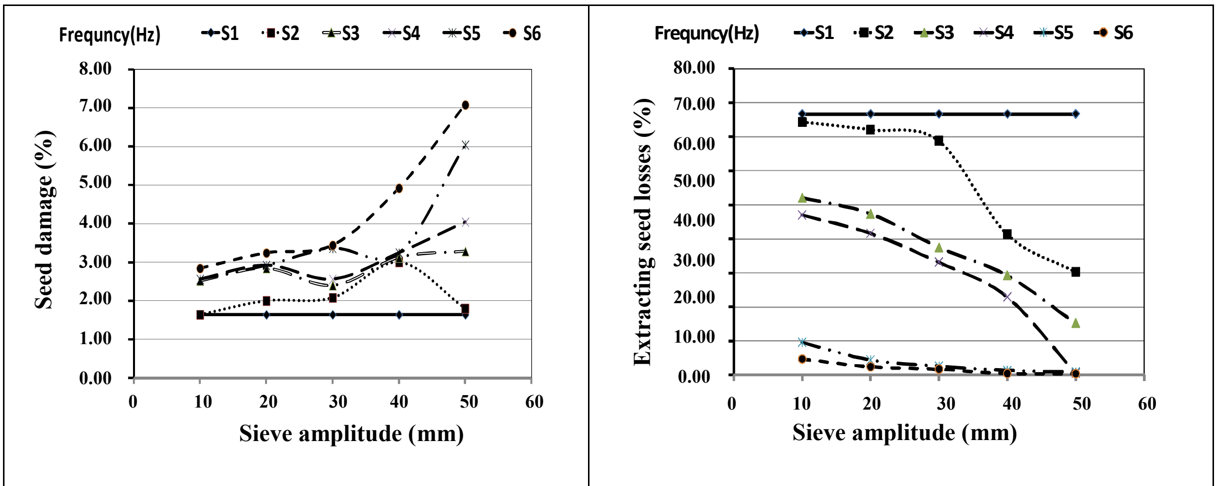
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage	B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

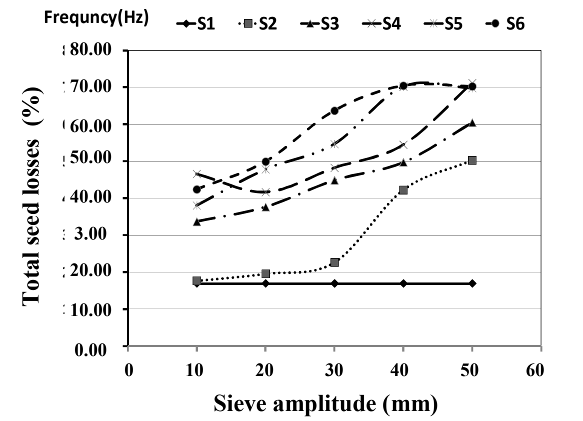
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

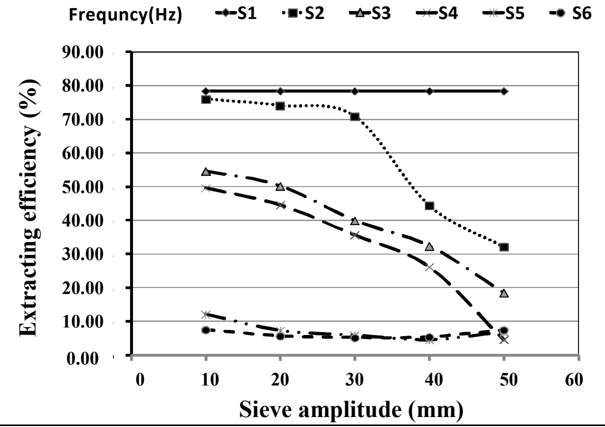
It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses



B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

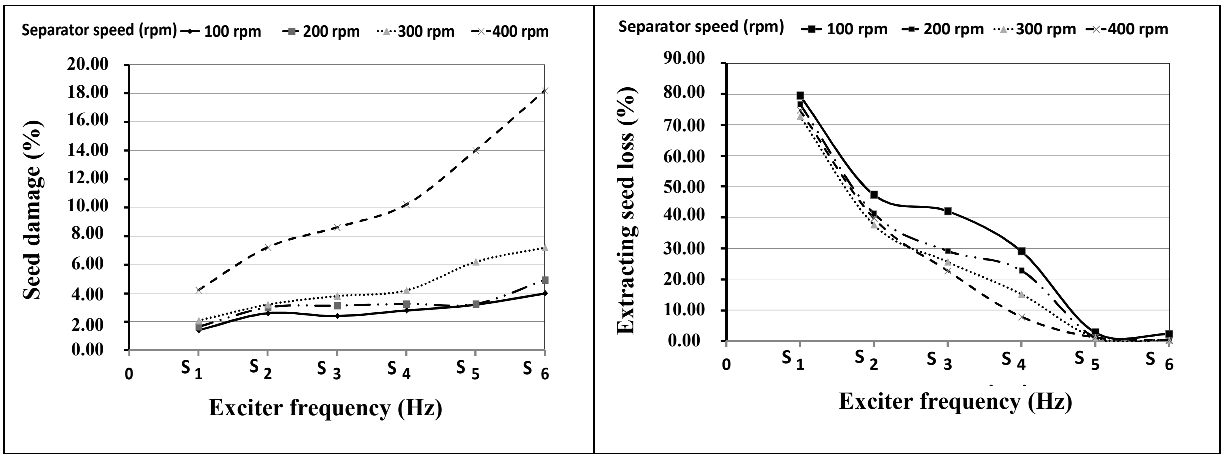
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage	B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

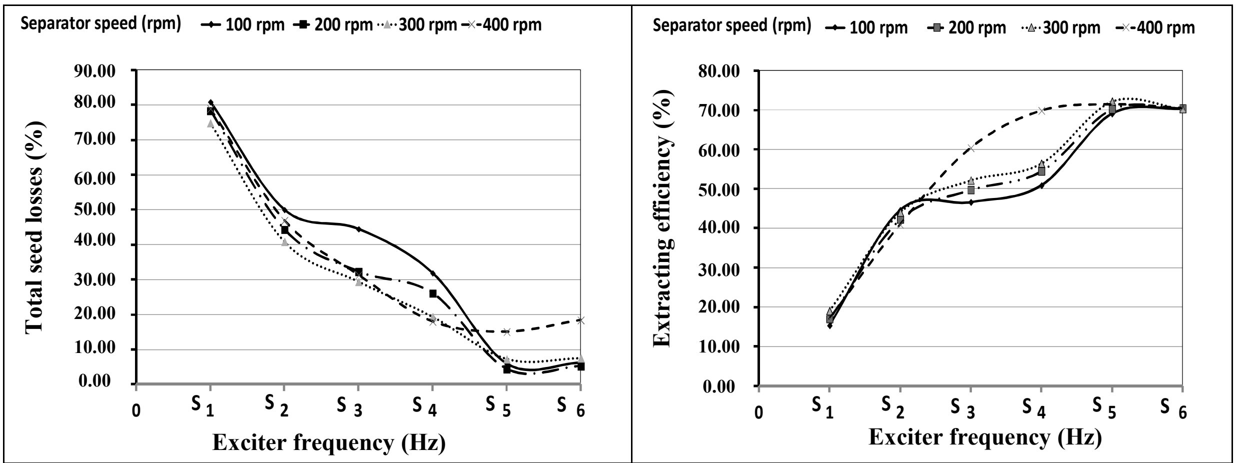
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses	B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

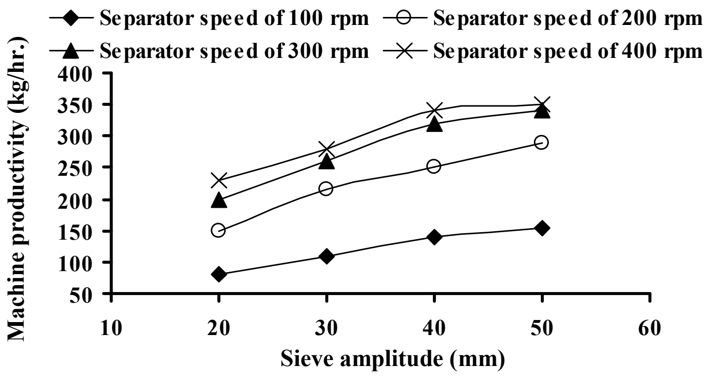
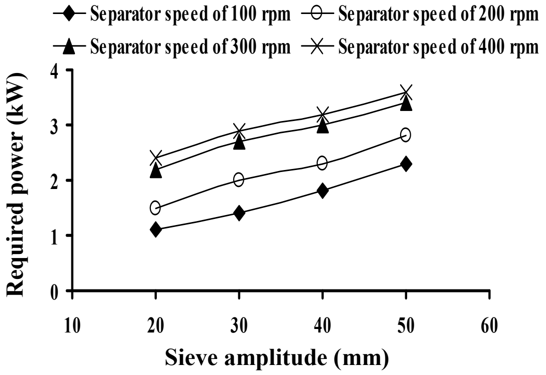


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz



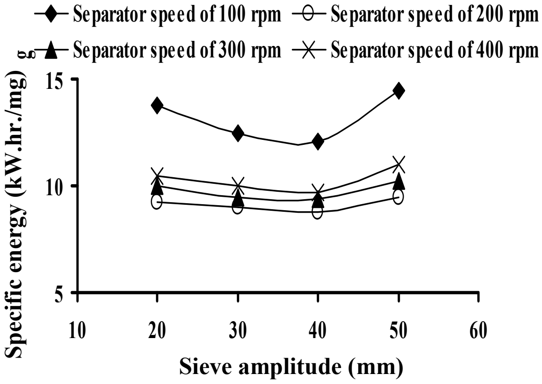


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

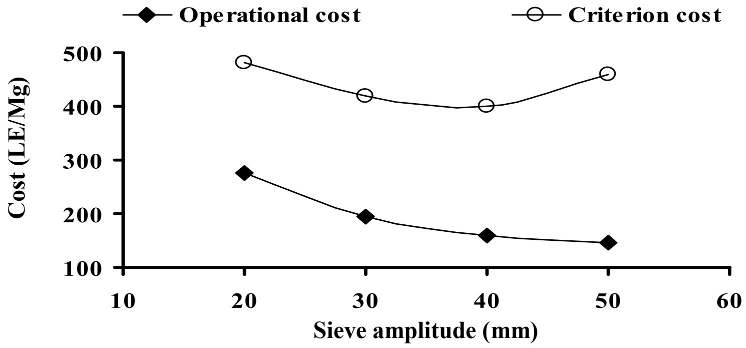


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــــع وتقييــــــــم أداء آلــــــــــــة محليــــــــــة الصنـــــع لتفــــريــط بـــذور الـرمــــــان

نجلاء صلاح أنور[1] - محمد محمد مراد حسن[1] - محب محمد أنيس الشرباصي[2]- طارق حسين على[3]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt

3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

* **Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

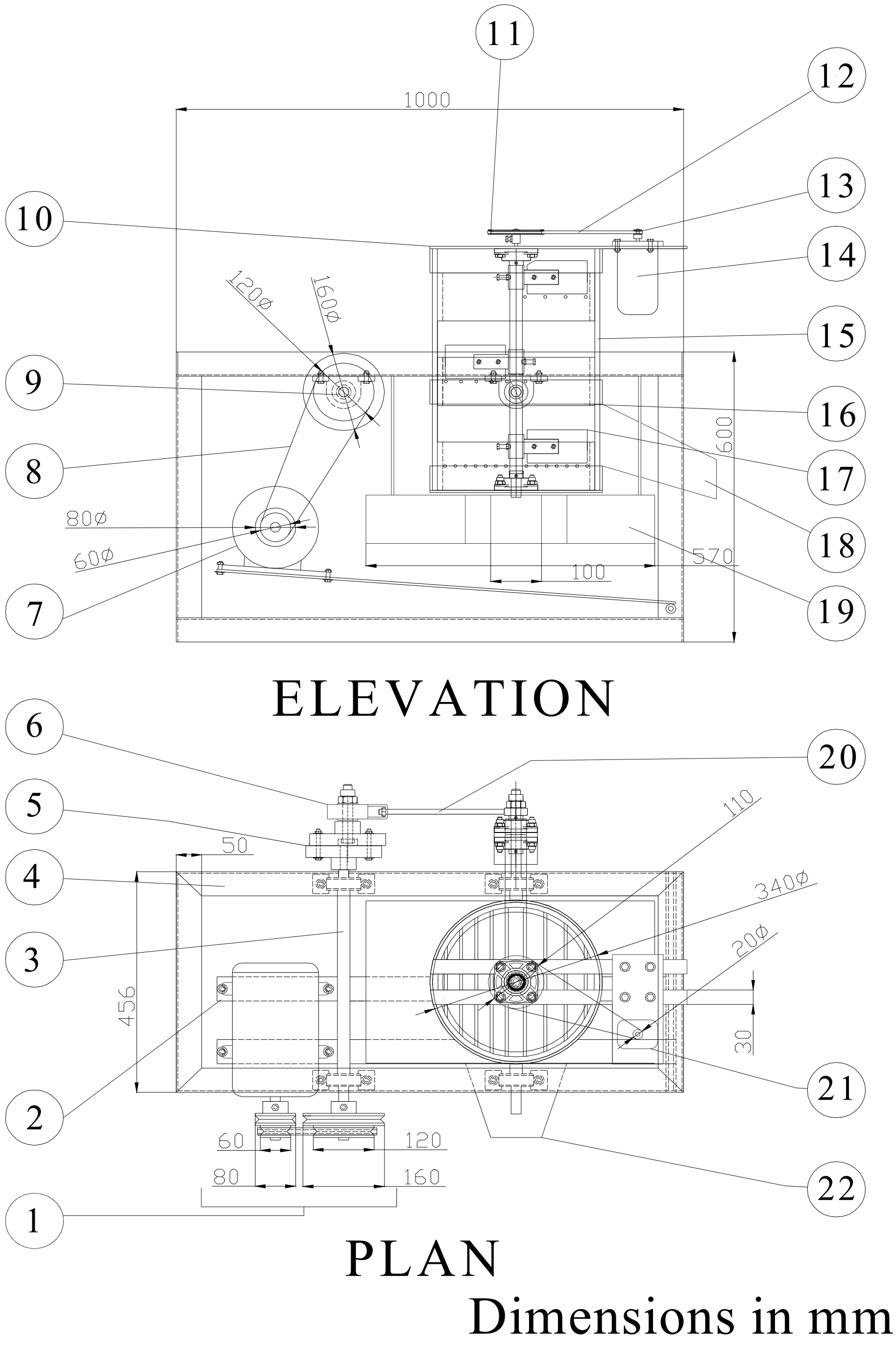
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

cos θ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

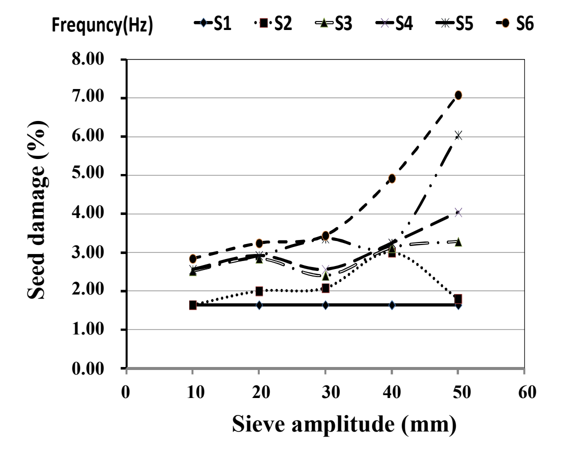
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

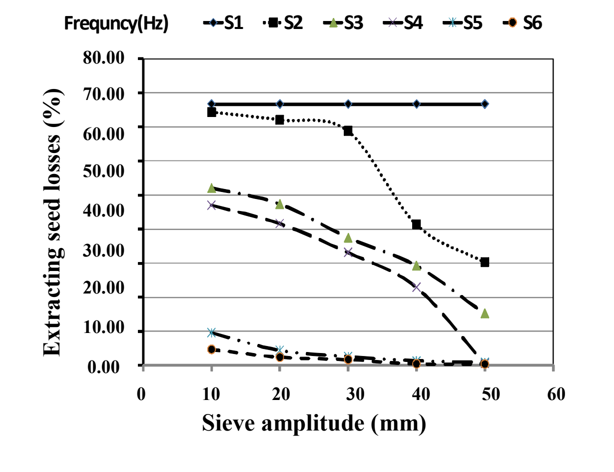
The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage



B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

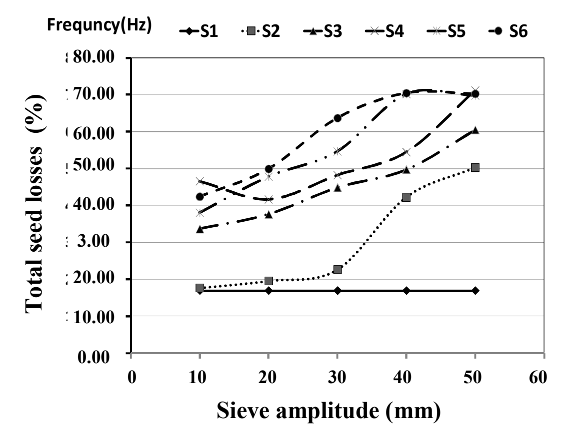
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

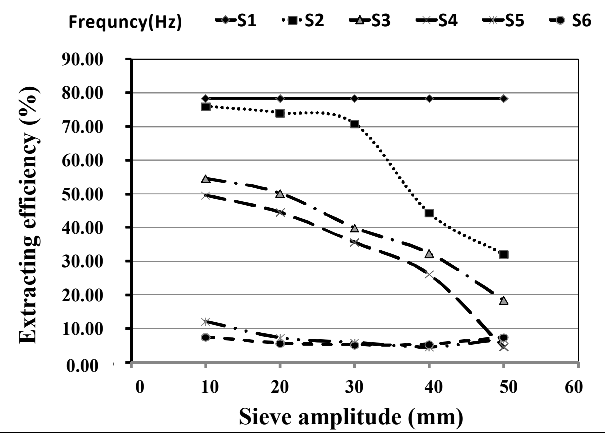
It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses



B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

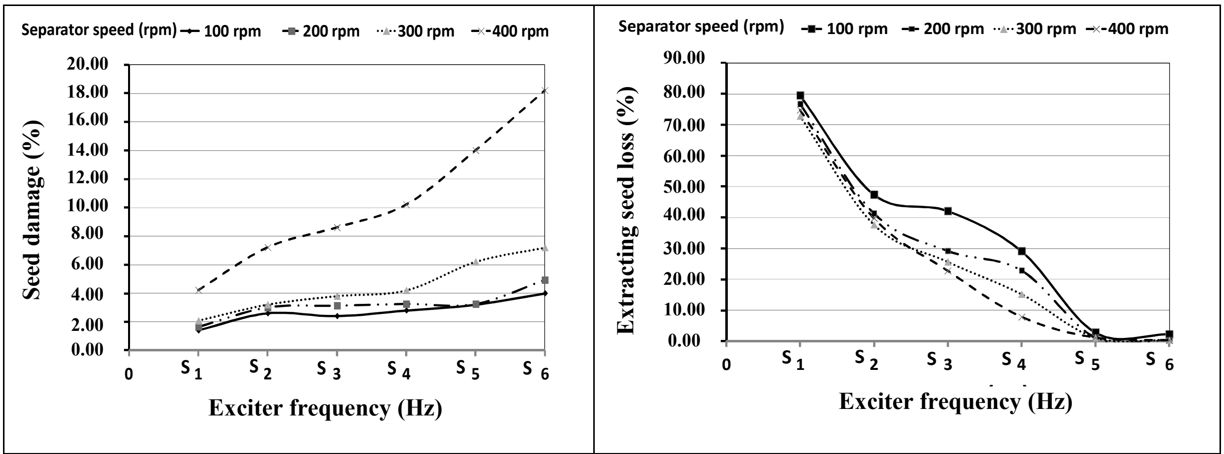
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage

B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

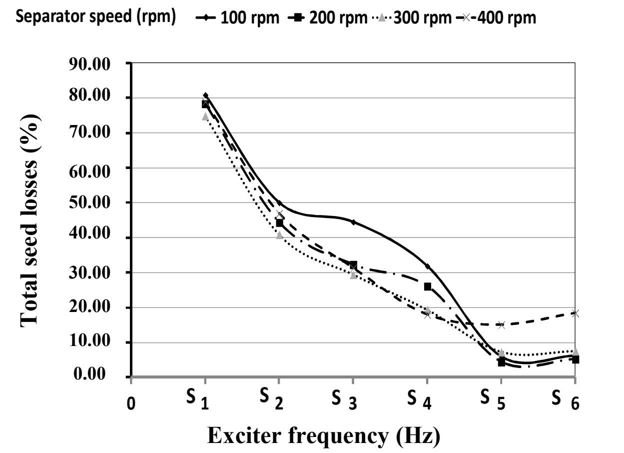
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

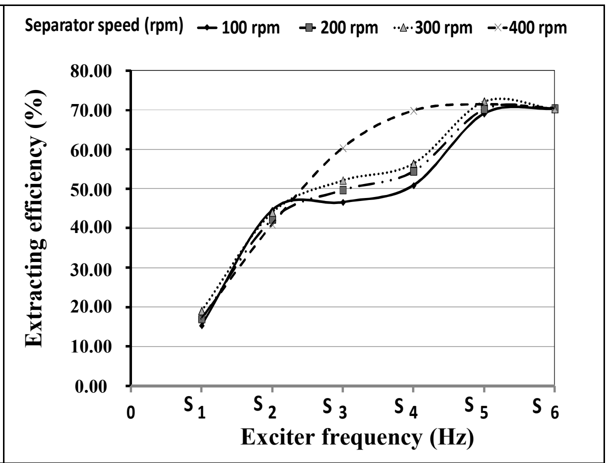
Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses



B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

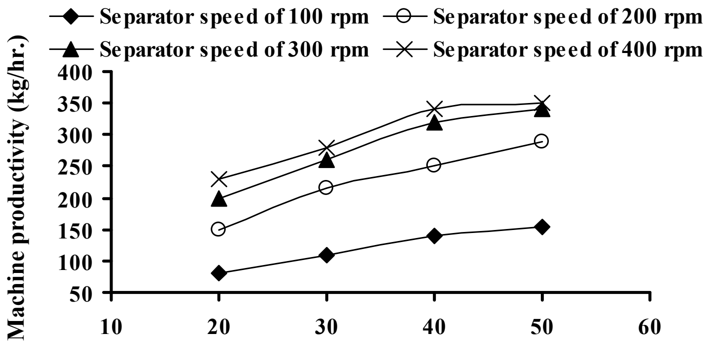


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

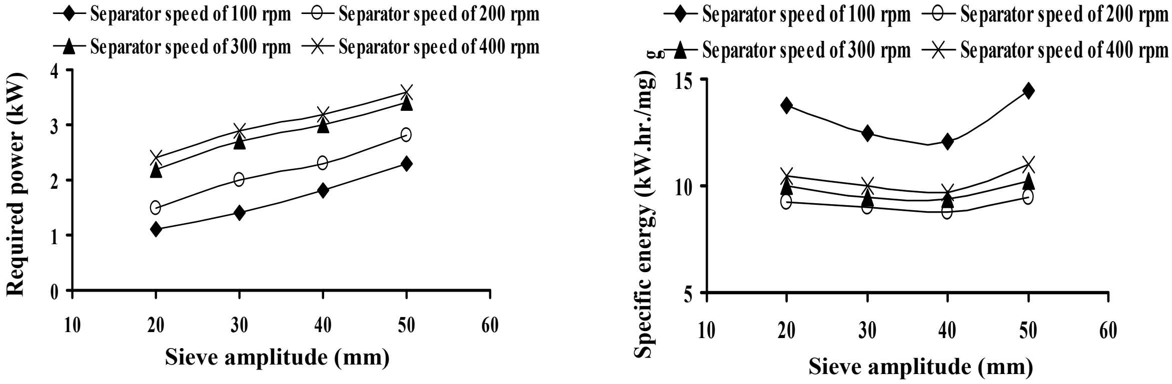


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

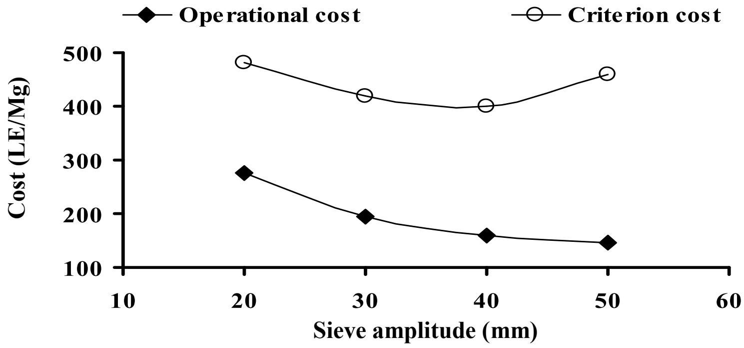


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــع وتقييـــــم أداء آلـــــــــة محليــــــــة الصنـــع لتفـــريـط بـــذور الـرمــــان

نجلاء صلاح أنور[1] ـ محمد محمد مراد حسن[1] ـ محب محمد أنيس الشرباصي[2] ـ طارق حسين على[3]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١ـ أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢ـ أ.د. محمود مصطفى علـــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt

3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

* **Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

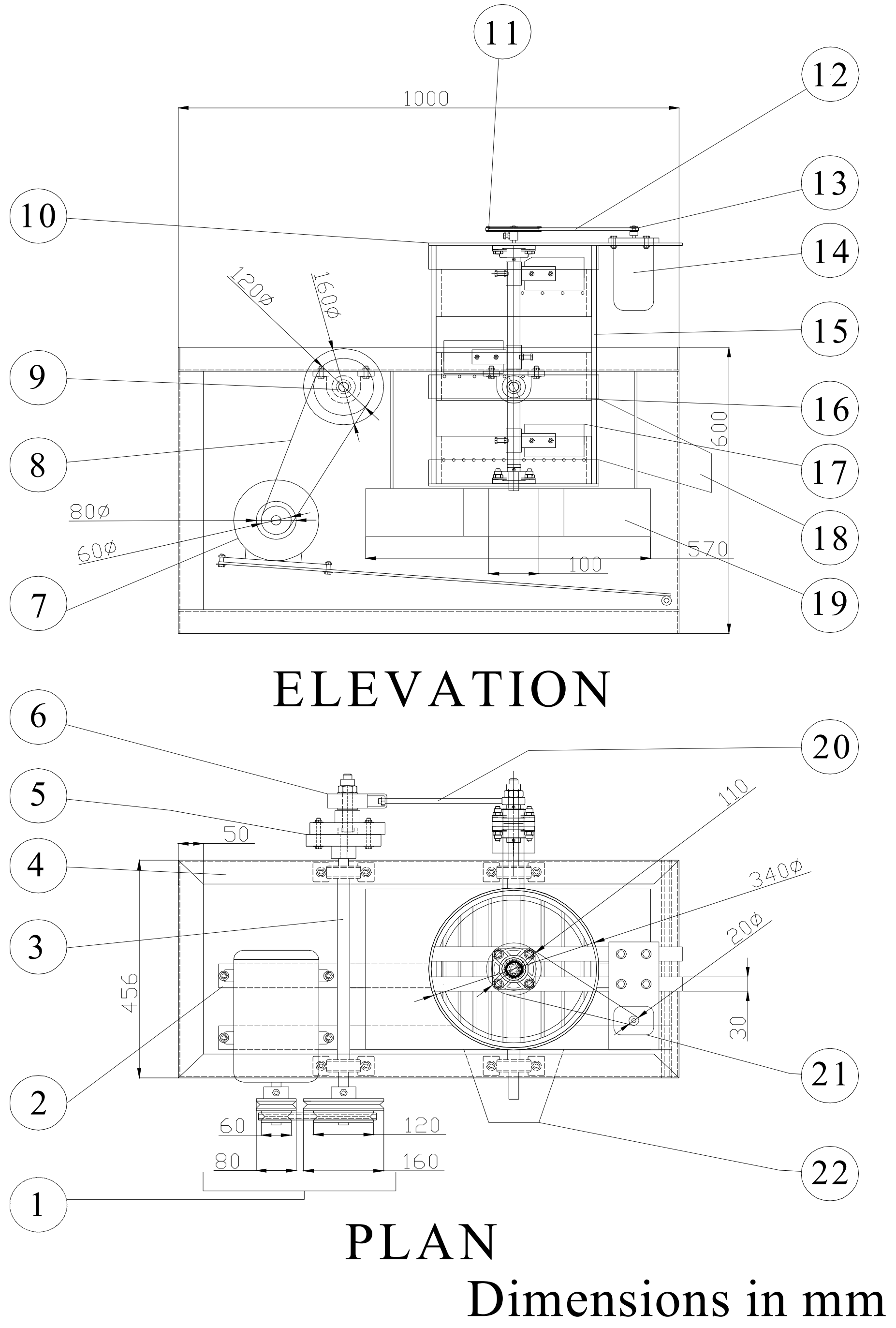
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

cos θ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

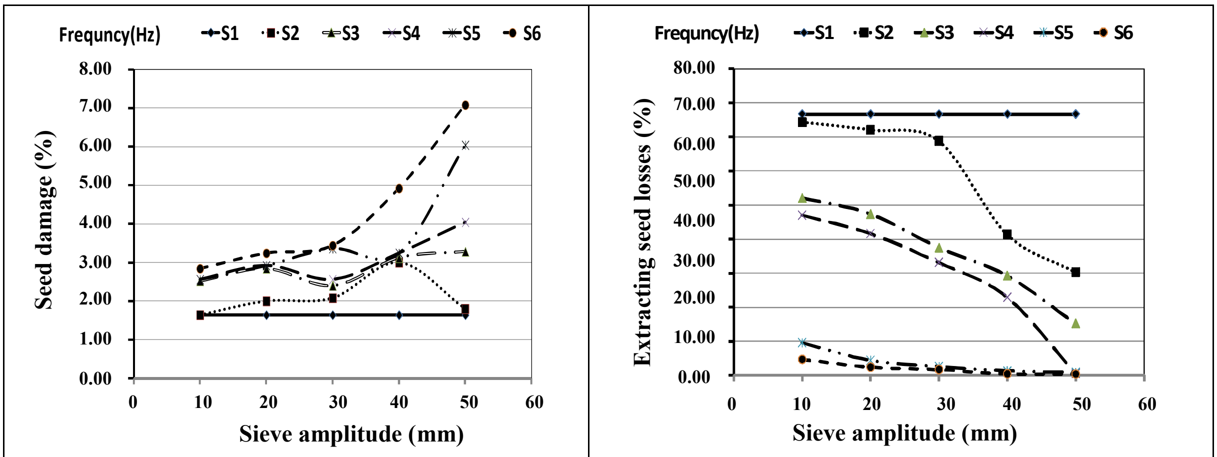
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage	**B. Effect of sieve amplitude and exciter frequency on extracting losses**

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

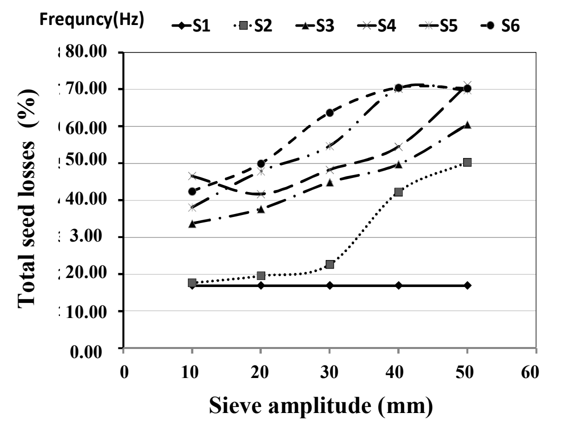
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

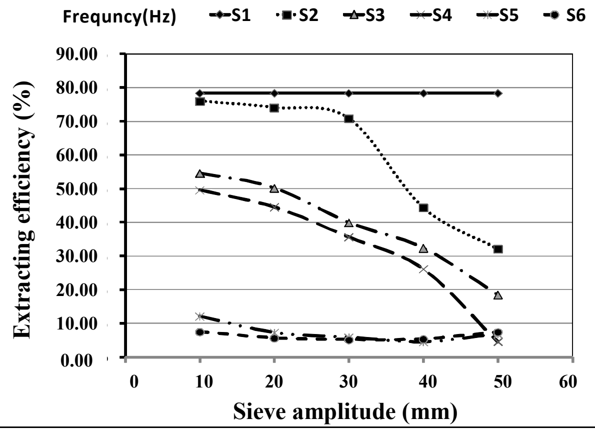
It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses



B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

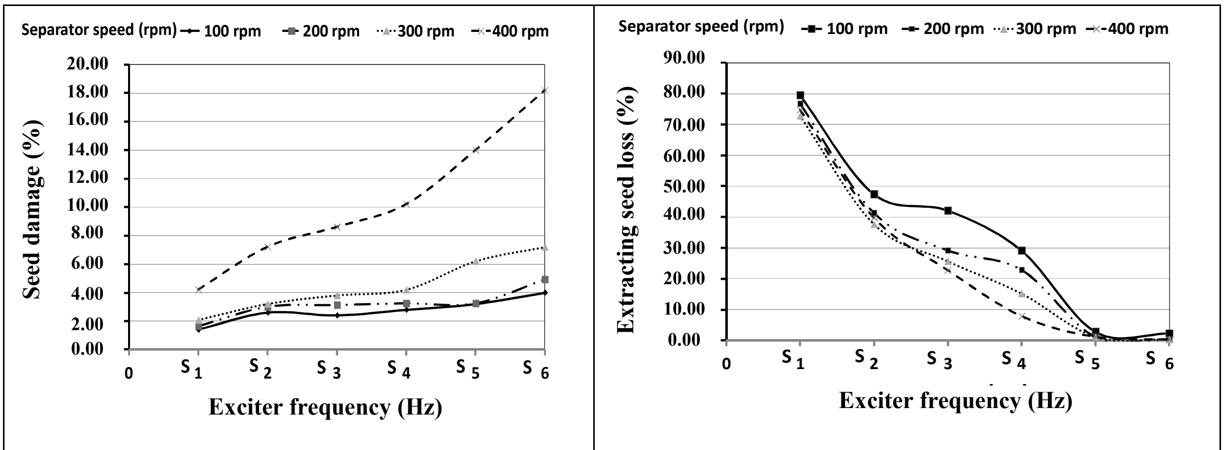
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage	B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

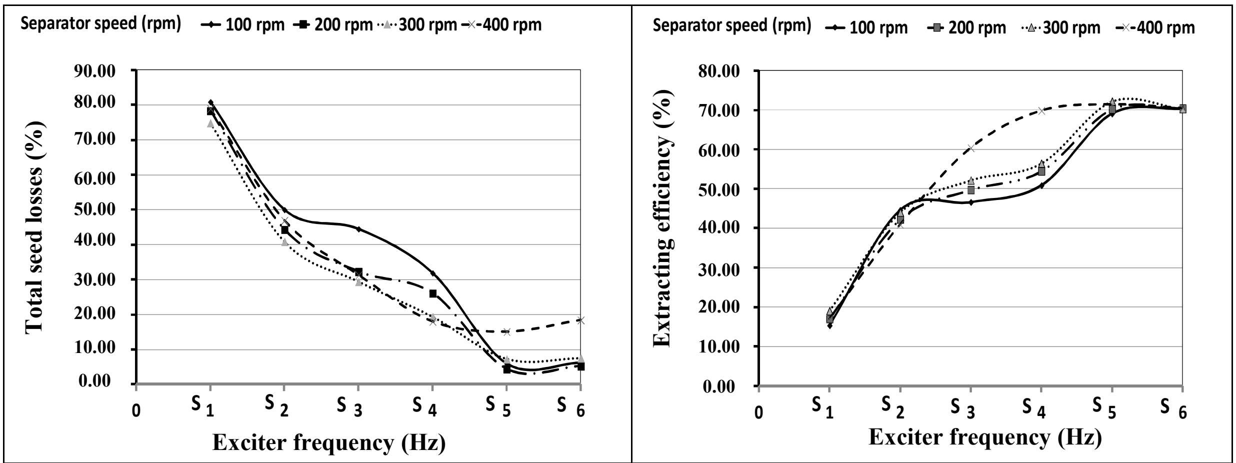
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses

B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

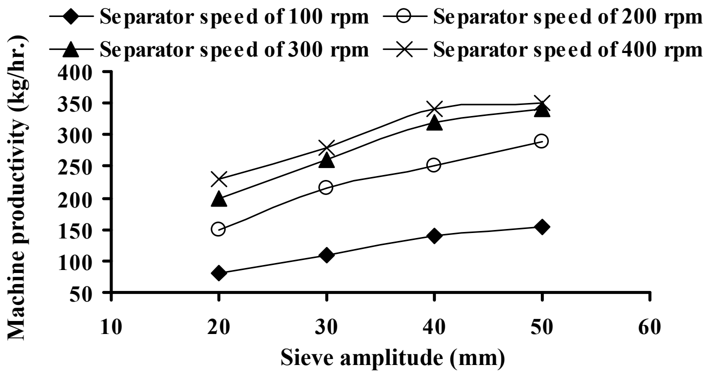


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

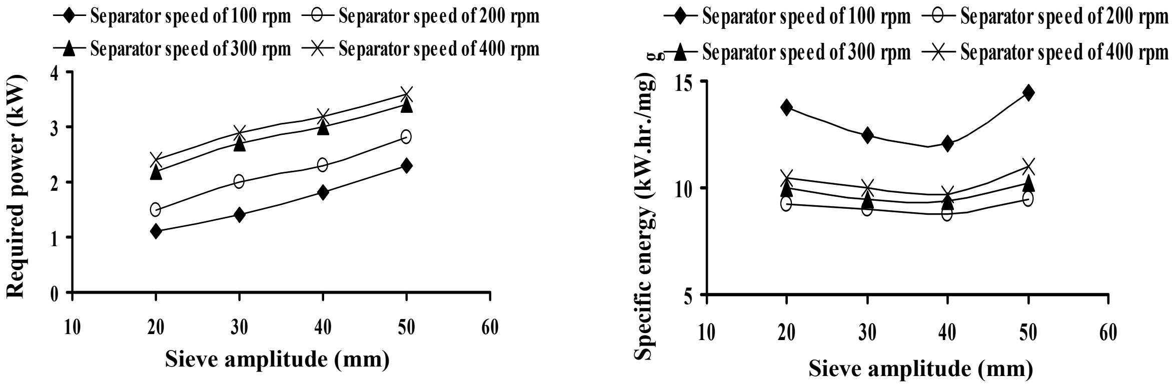


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

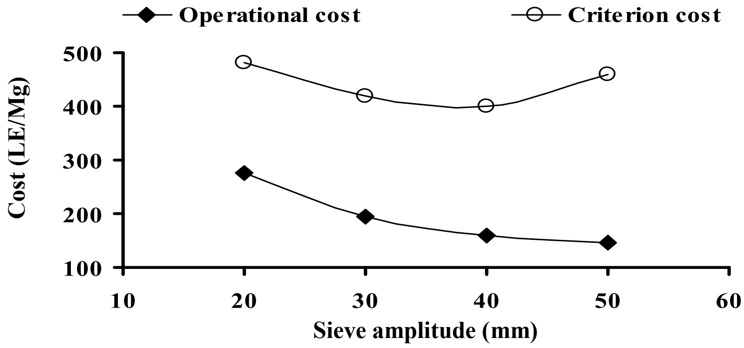


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــــع وتقييـــــــم أداء آلـــــــــة محليـــــــــة الصنــــع لتفـــريـط بـــذور الـرمـــــان

نجلاء صلاح أنور[١] - محمد محمد مراد حسن[١] - محب محمد أنيس الشرباصي[٢]- طارق حسين على[٣]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علـــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt

3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

*** Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

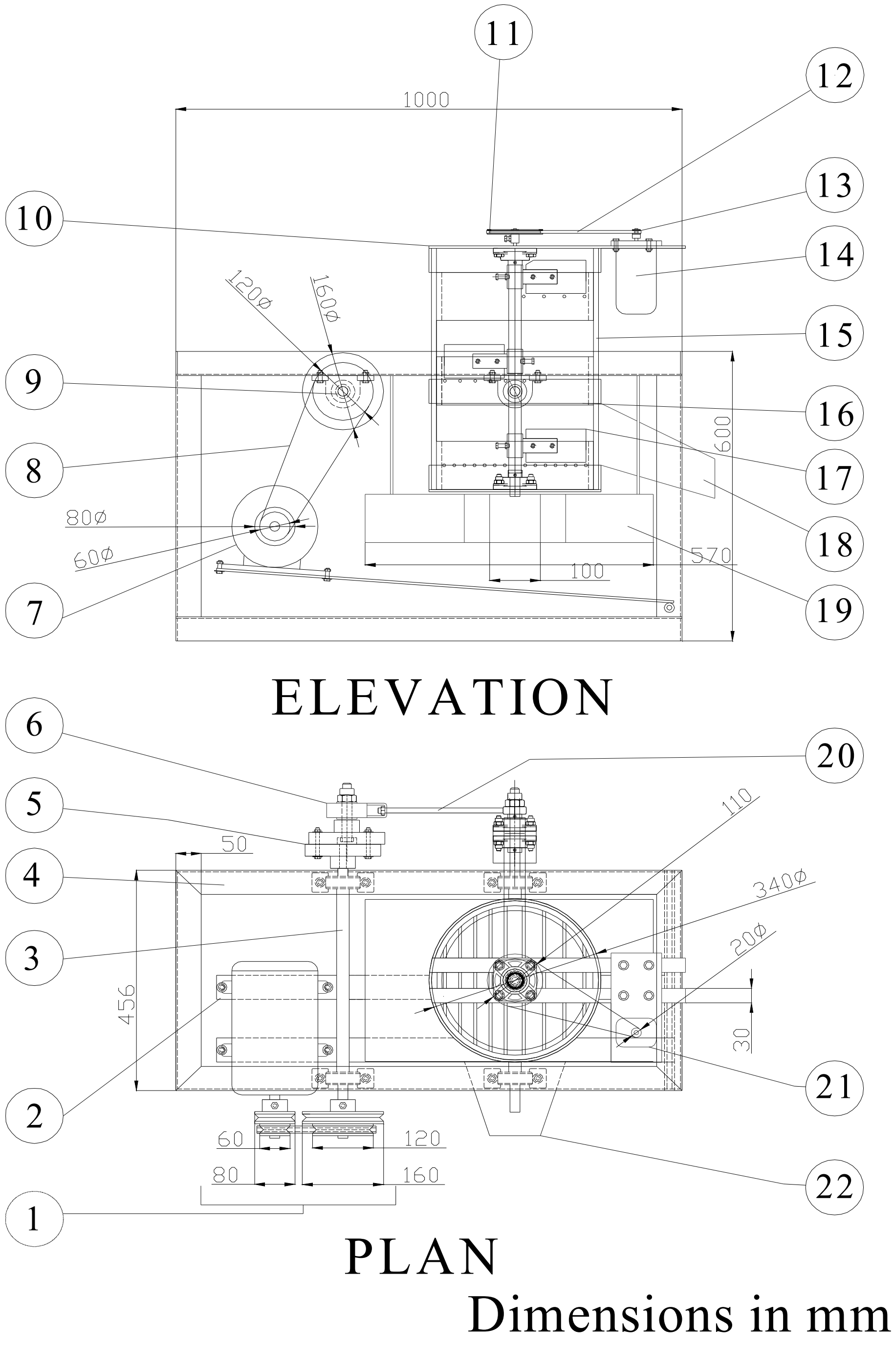
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)}=\frac{M_b}{M_t}\times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)}=\frac{60\times M_C}{T_e\times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)}=\frac{I\times V\times\cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

cos θ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

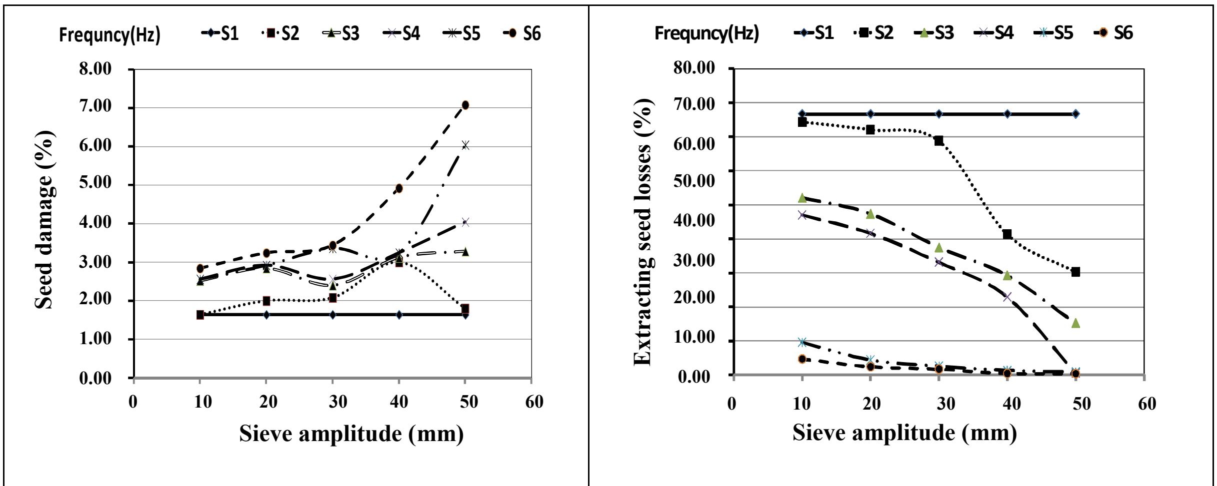
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage

B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

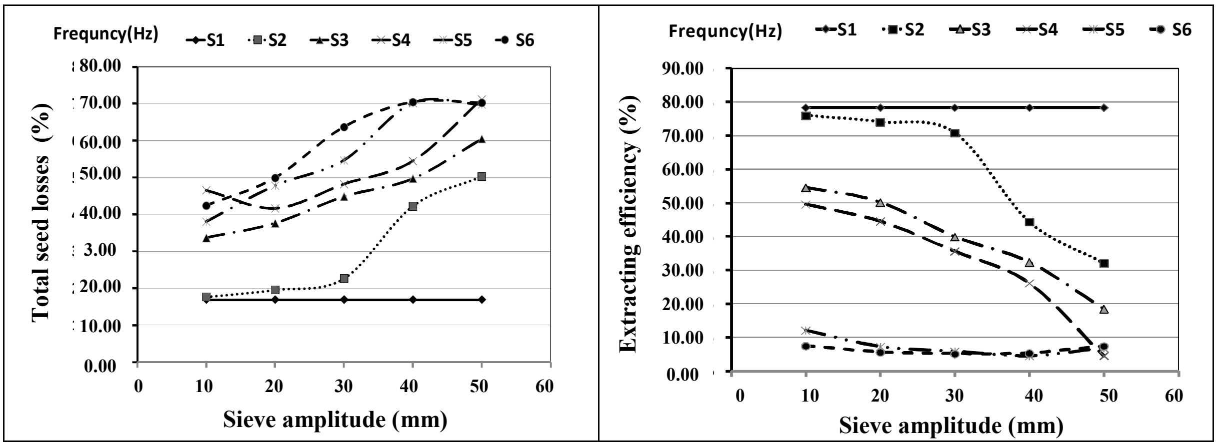
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses	B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

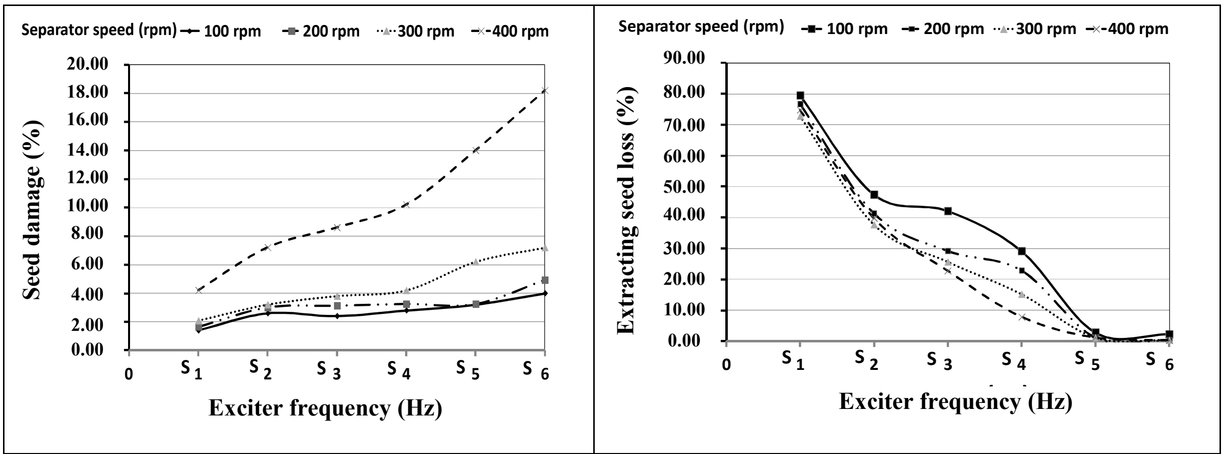
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage	B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

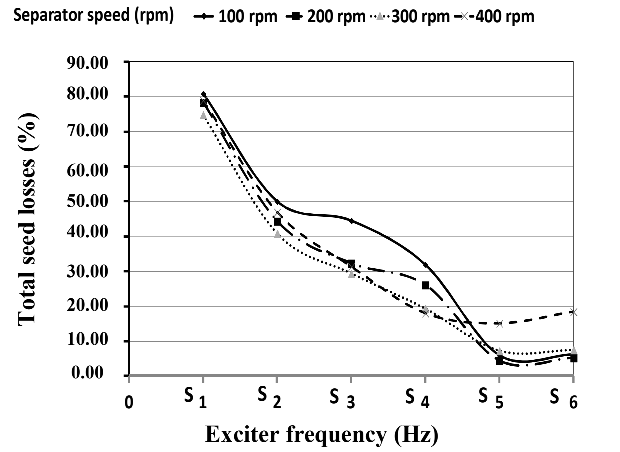
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

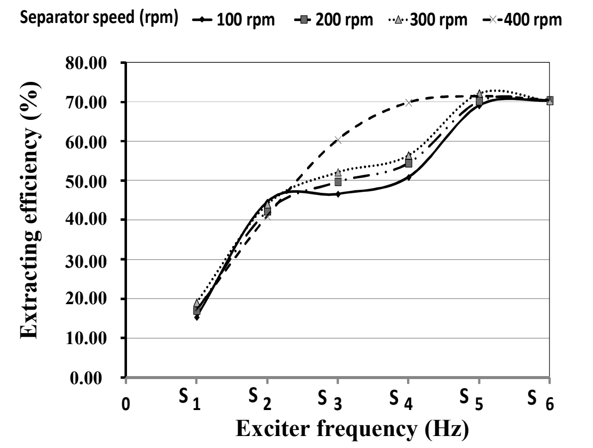
Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses



B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

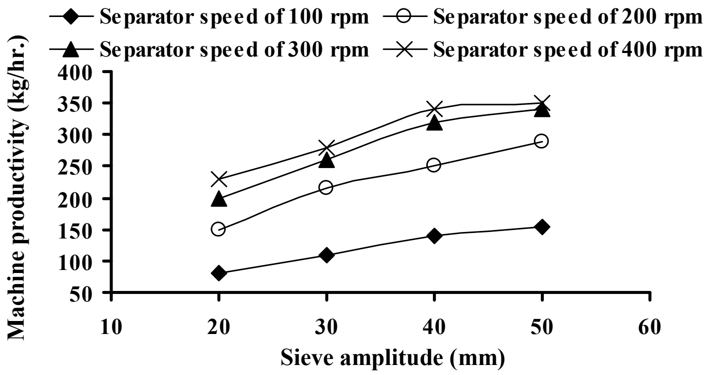


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

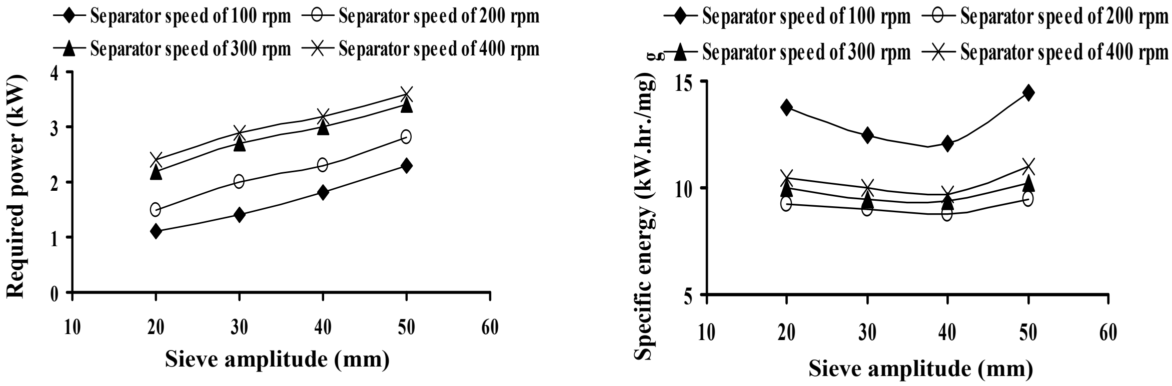


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

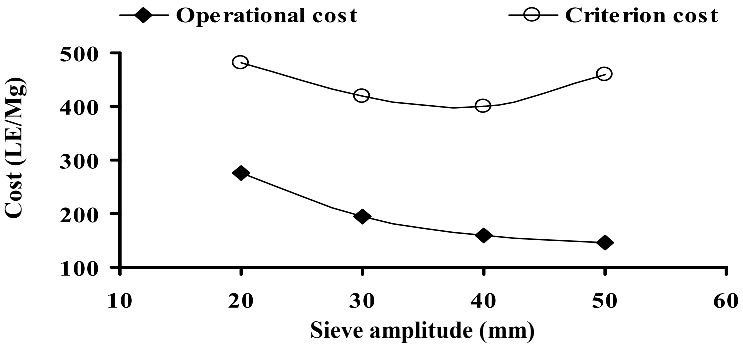


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــع وتقييـــــم أداء آلـــــــة محليـــــــة الصنــــع لتفـــريـط بـــذور الـرمــــان

نجلاء صلاح أنور[1] - محمد محمد مراد حسن[1] - محب محمد أنيس الشرباصي[2]- طارق حسين على[3]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt
2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt
3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

* **Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

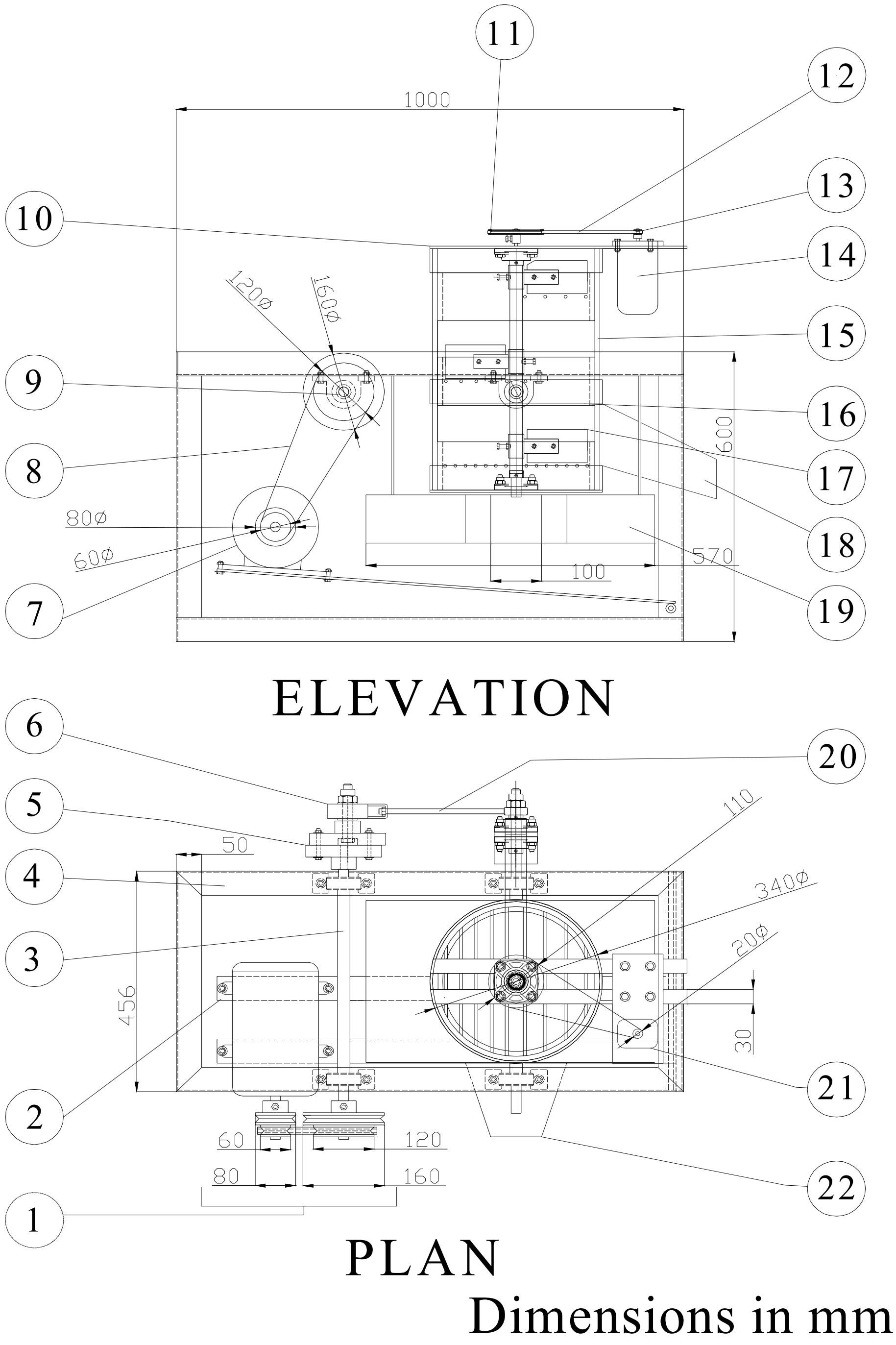
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

$\cos\theta$ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

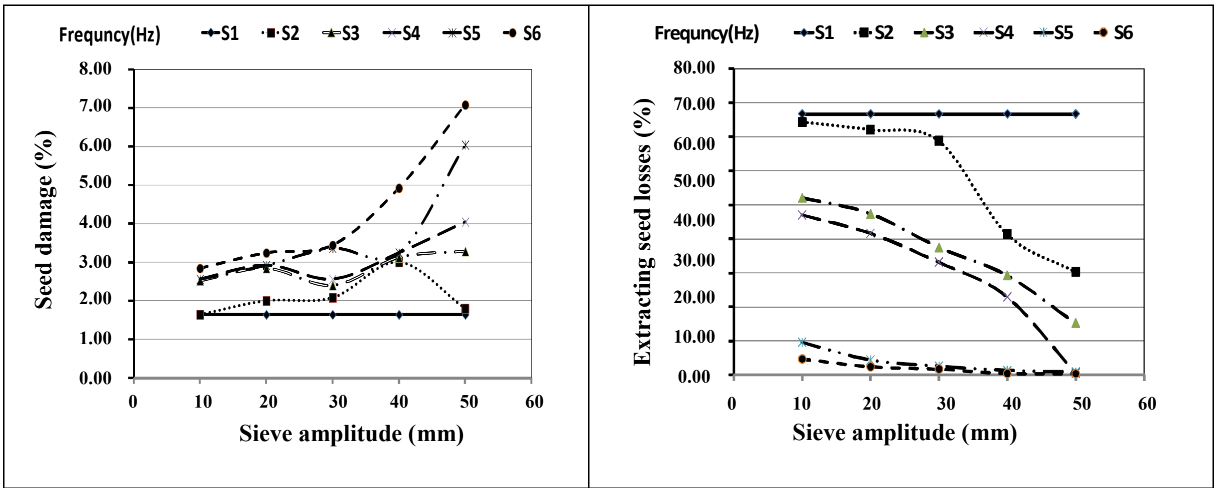
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage	B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

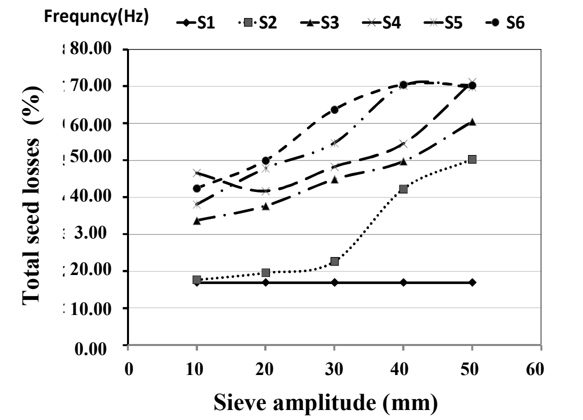
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

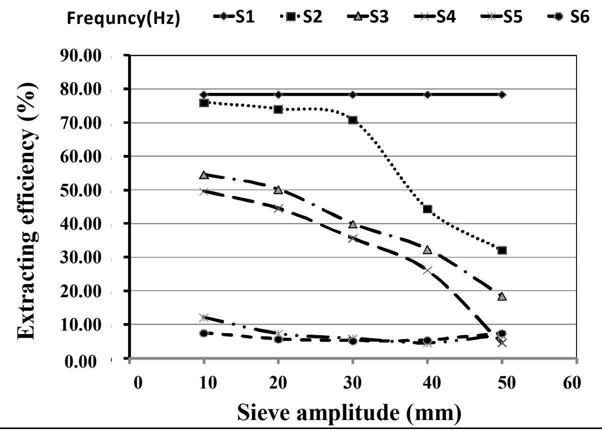
It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses



B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

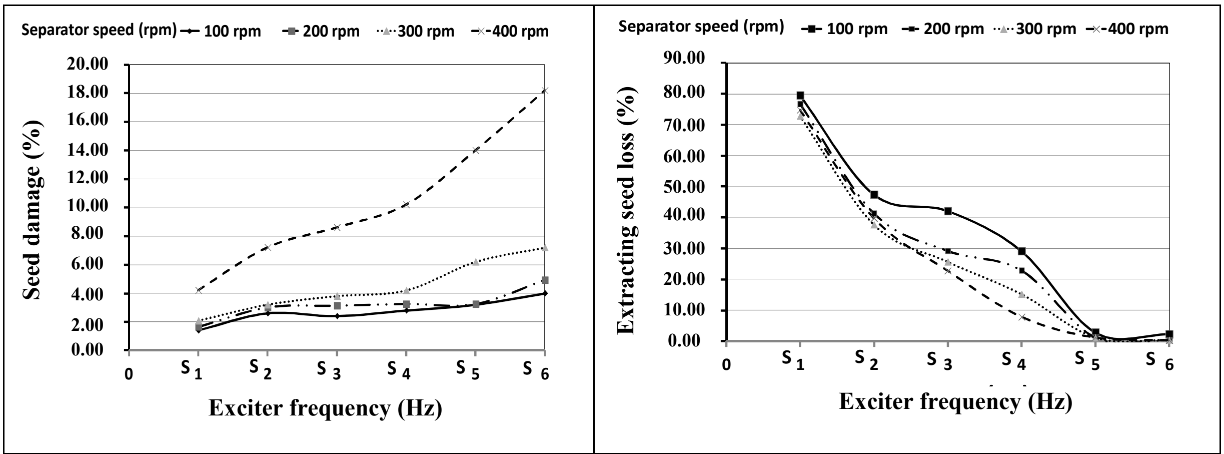
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage	**B. Effect of separator speed and exciter frequency on extracting seed loss**

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

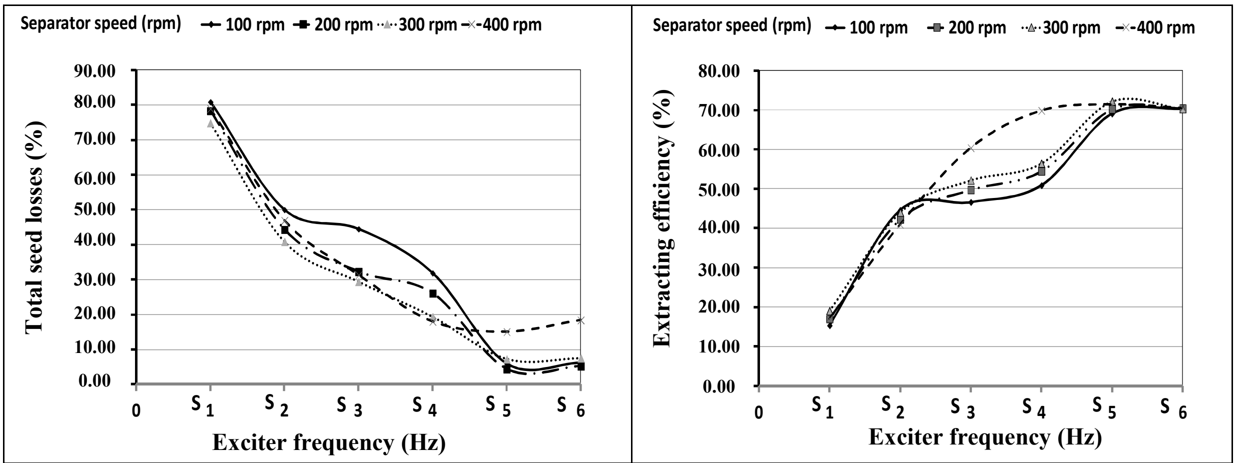
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses

B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

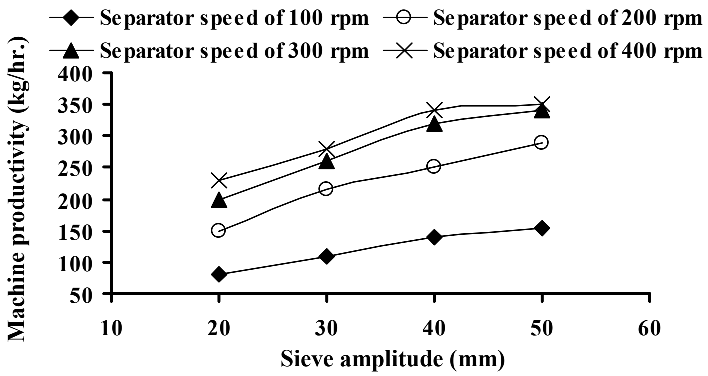


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

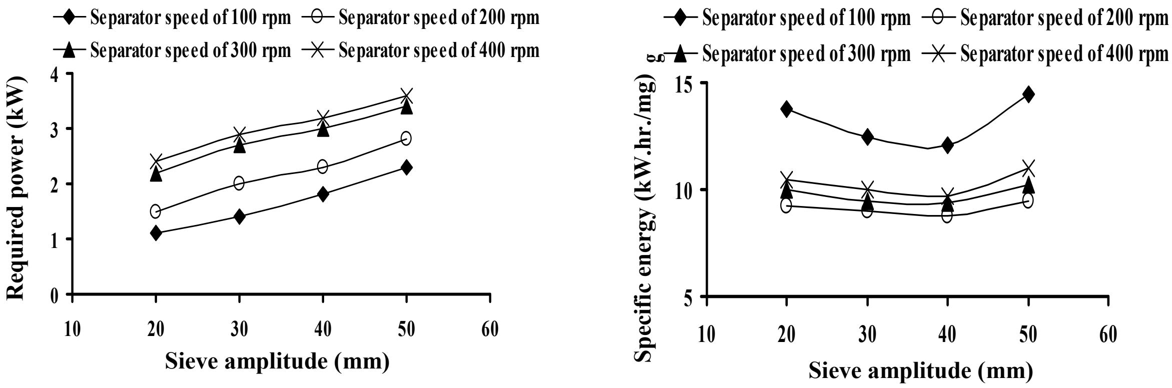


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

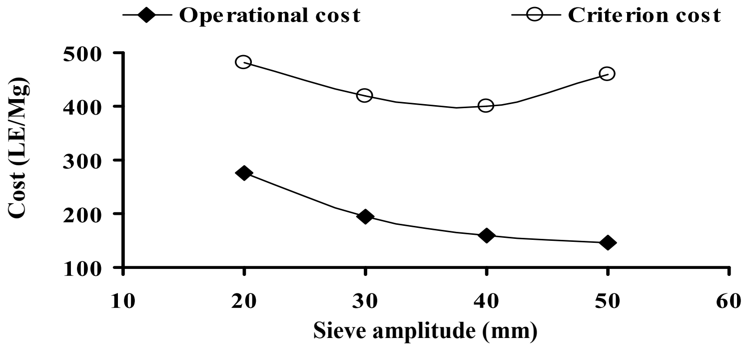


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــــع وتقييـــــــم أداء آلـــــــــــة محليـــــــــــة الصنـــــع لتفـــــريـط بـــذور الرمـــــان

نجلاء صلاح أنور[1] - محمد محمد مراد حسن[1] - محب محمد أنيس الشرباصي[2] - طارق حسين على[3]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علـــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt

3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

* **Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

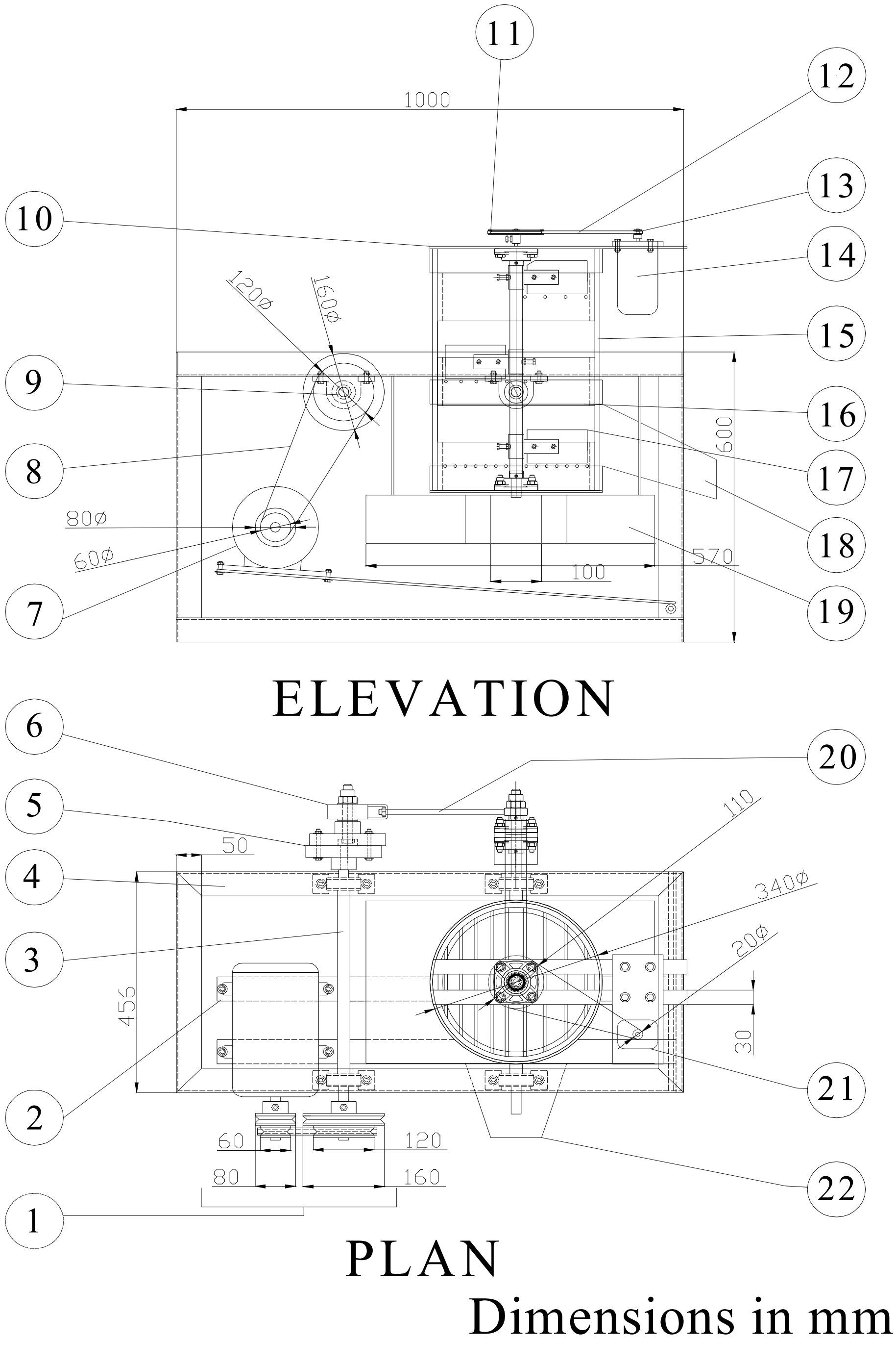
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

cos θ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

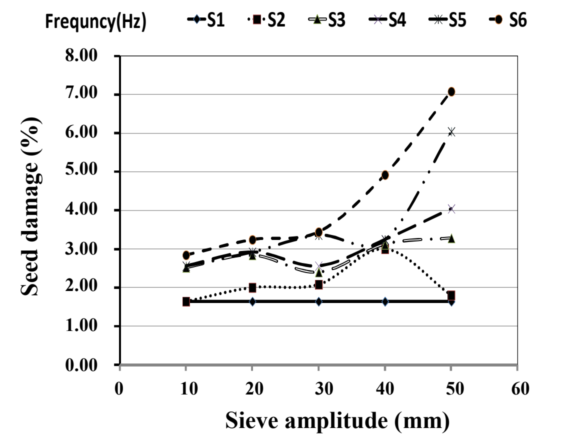
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

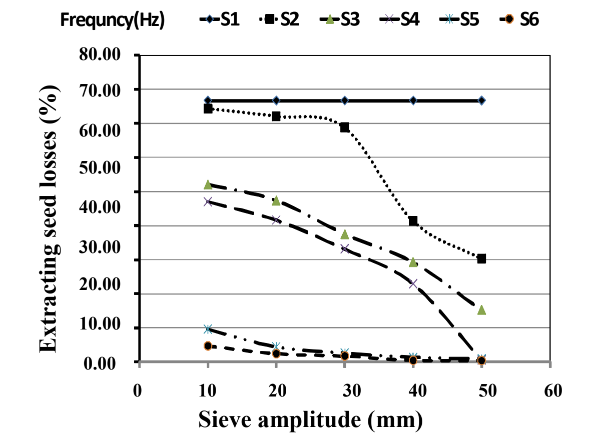
The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage



B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

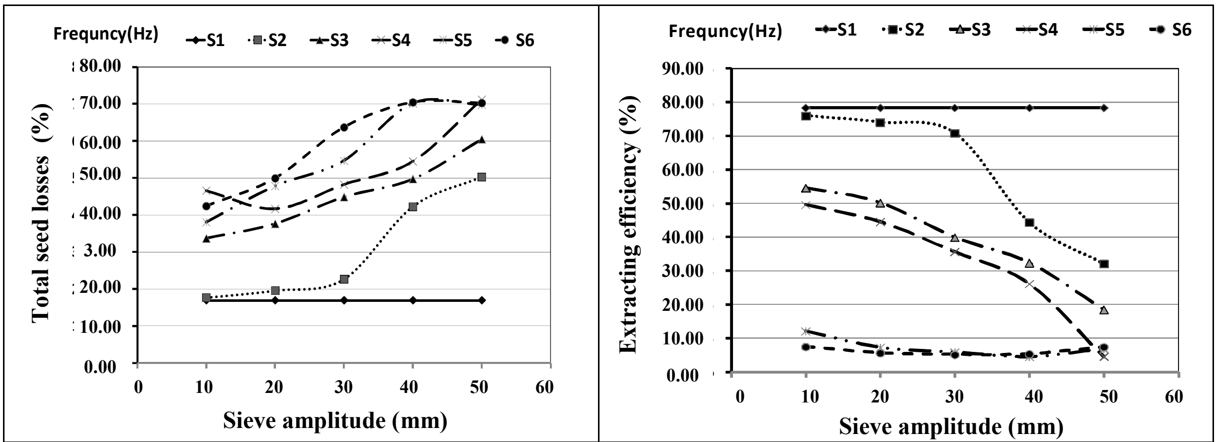
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses

B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

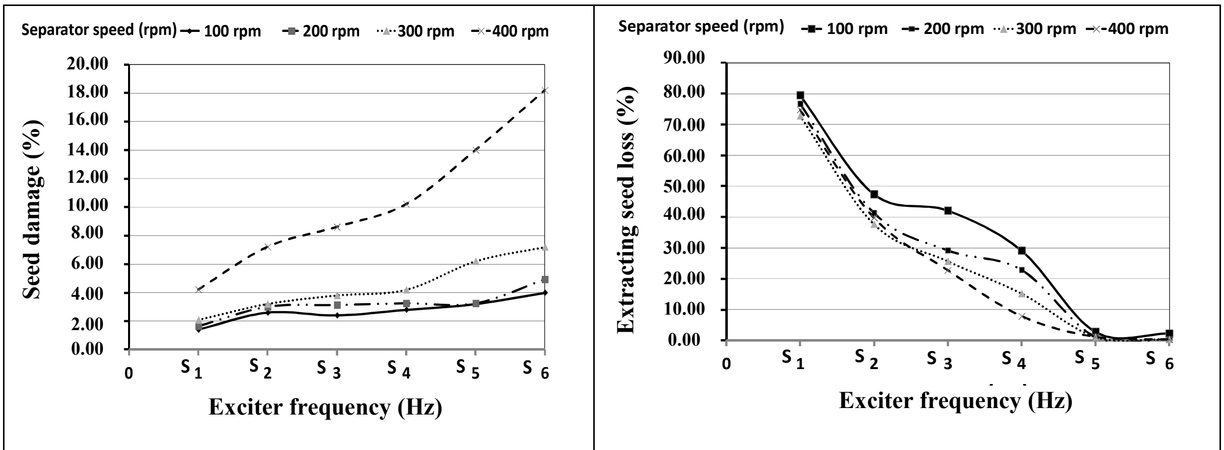
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage	B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

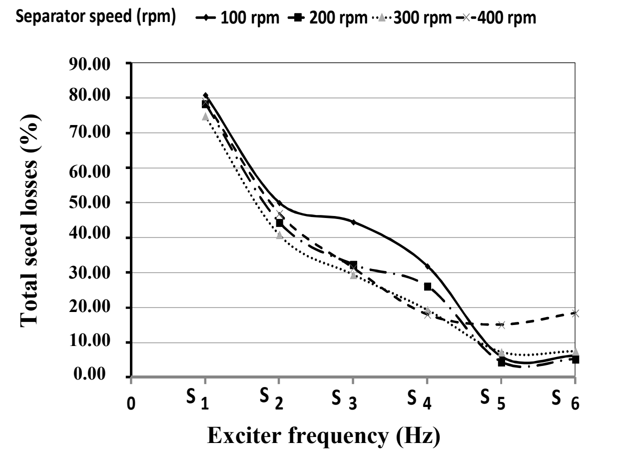
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

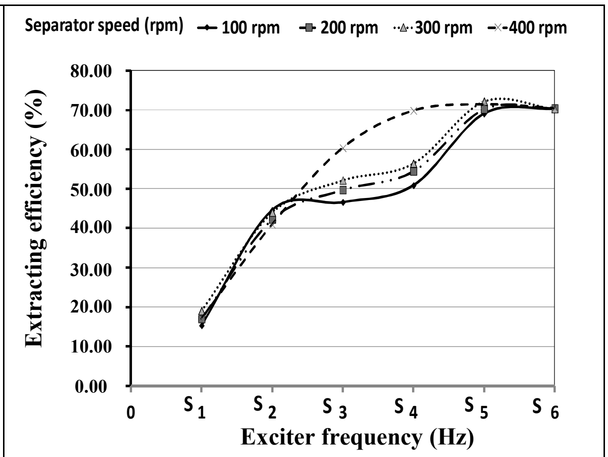
Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses



B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

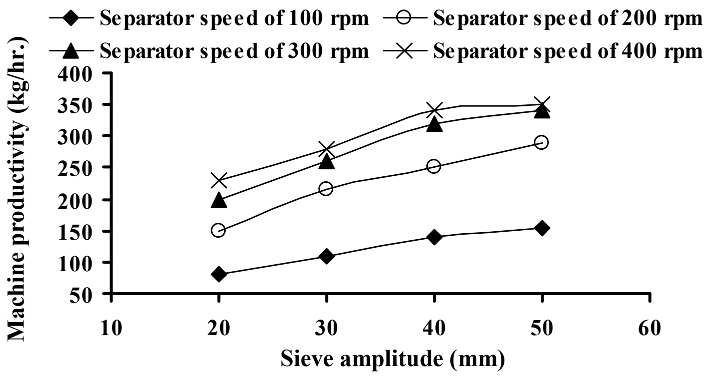


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

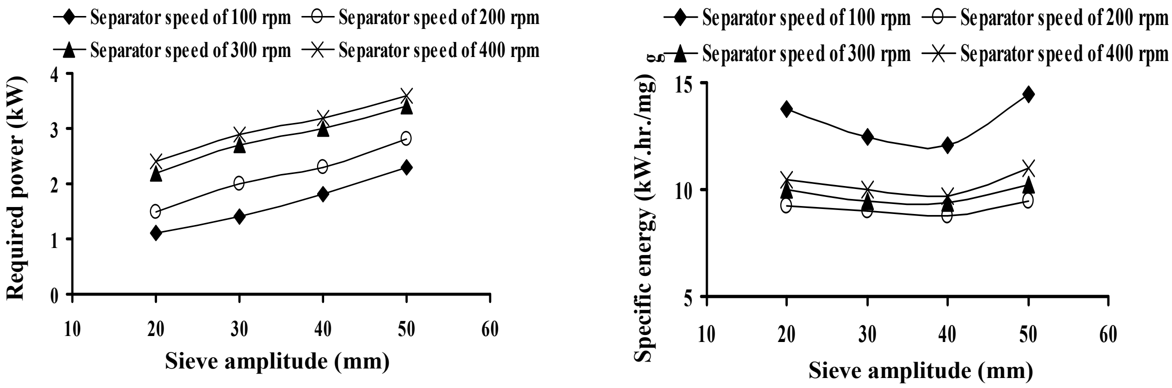


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

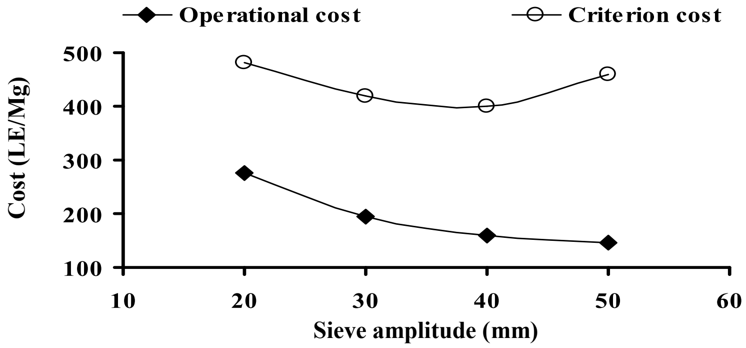


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــع وتقييـــــم أداء آلـــــــــة محليـــــــــة الصنـــع لتفـــريـط بـــذور الـرمــــان

نجلاء صلاح أنور[1] - محمد محمد مراد حسن[1] - محب محمد أنيس الشرباصي[2] - طارق حسين على[3]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علـــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt

3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

* **Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

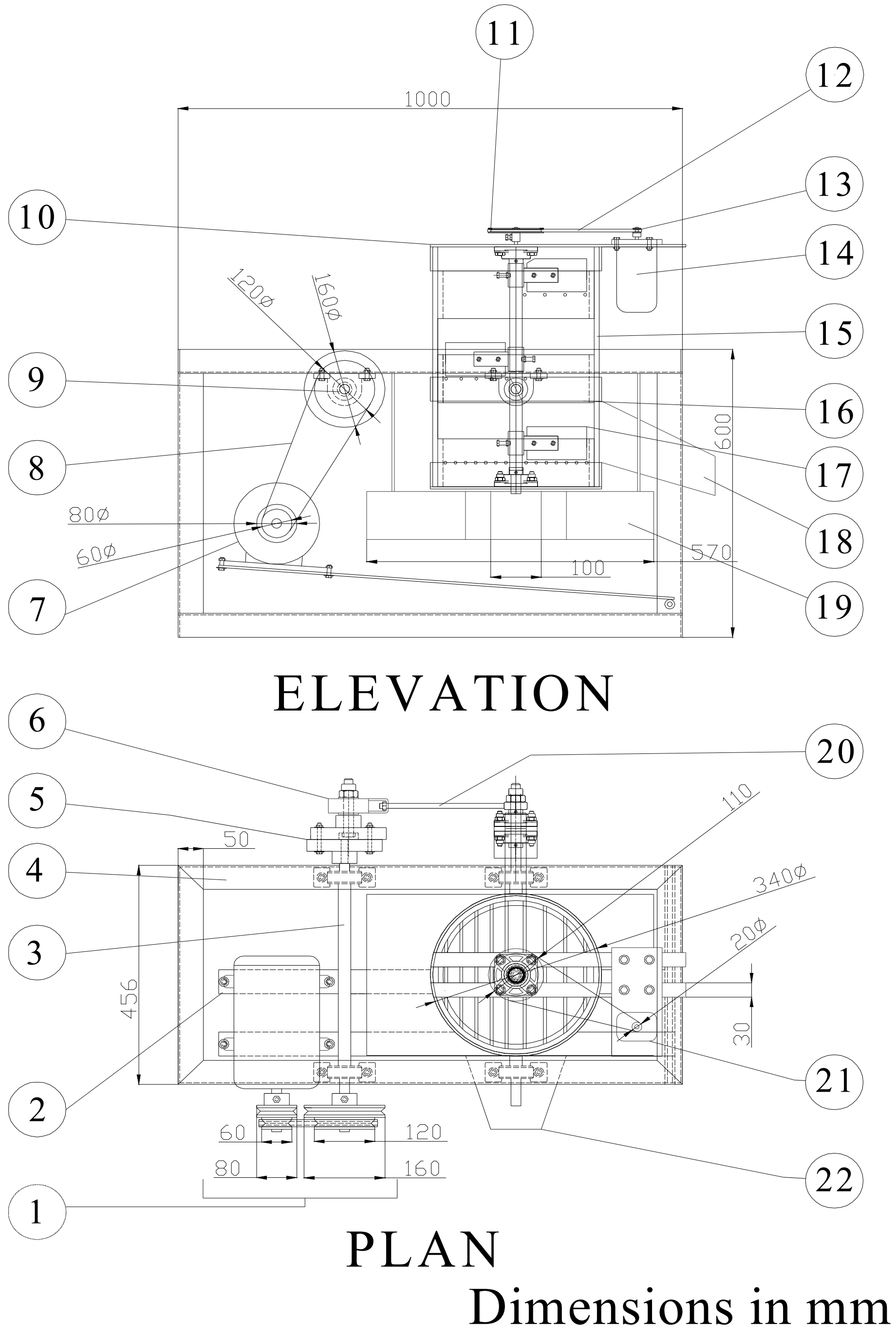
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

$\cos\theta$ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

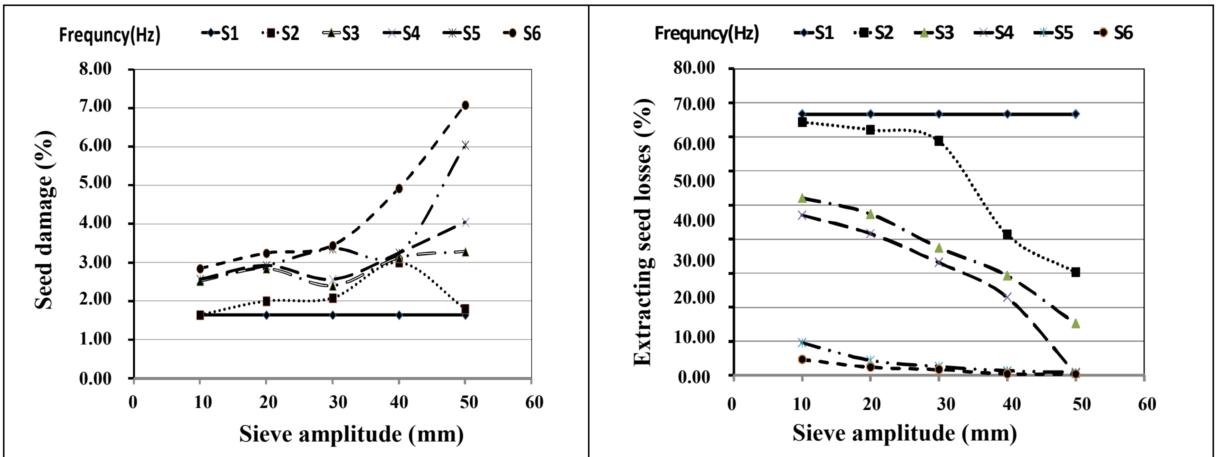
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage	**B. Effect of sieve amplitude and exciter frequency on extracting losses**

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

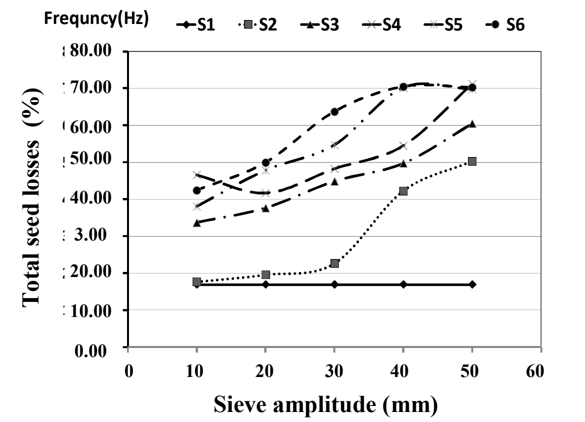
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

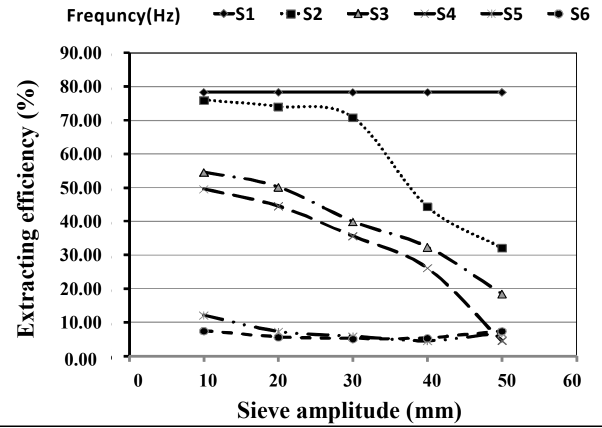
It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses



B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

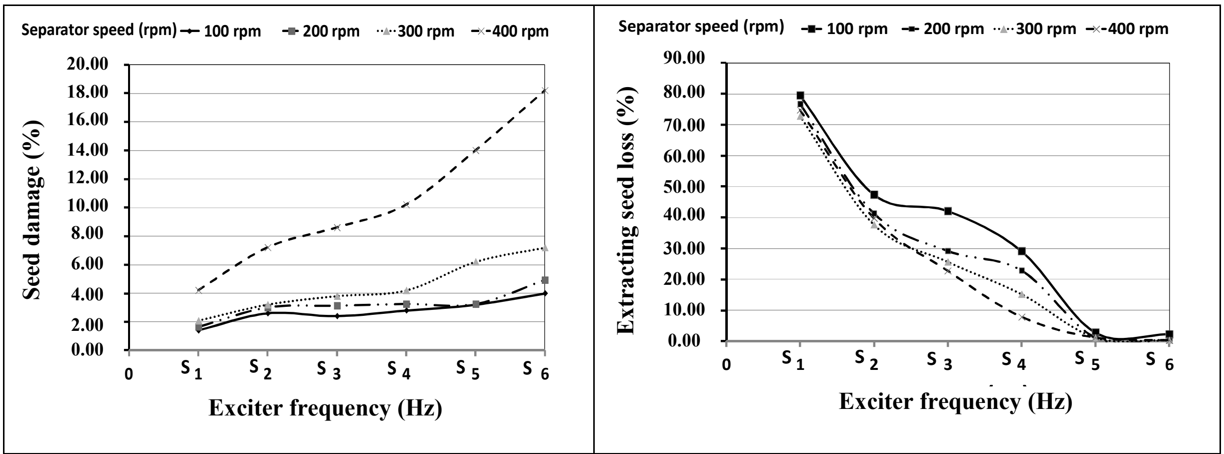
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage	B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

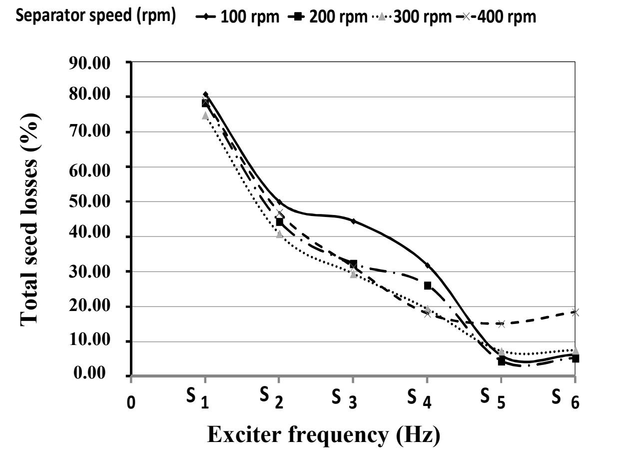
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

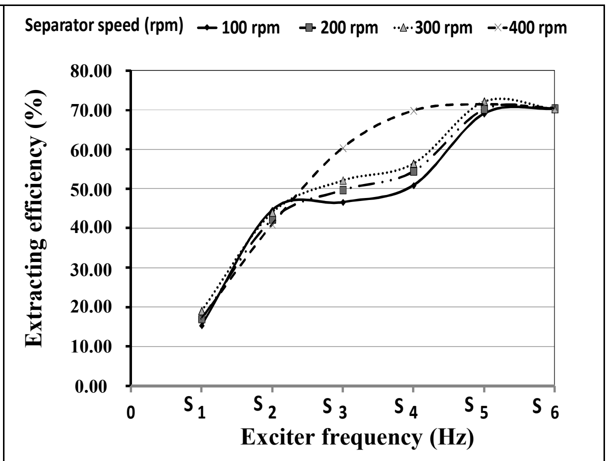
Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses



B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

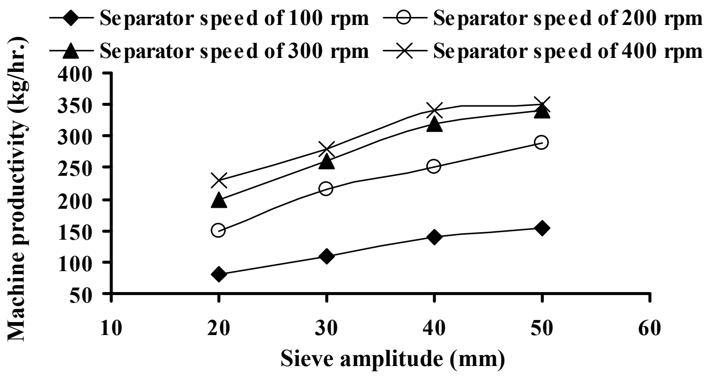
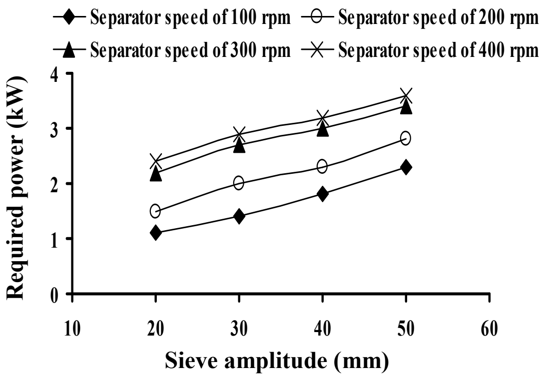


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz



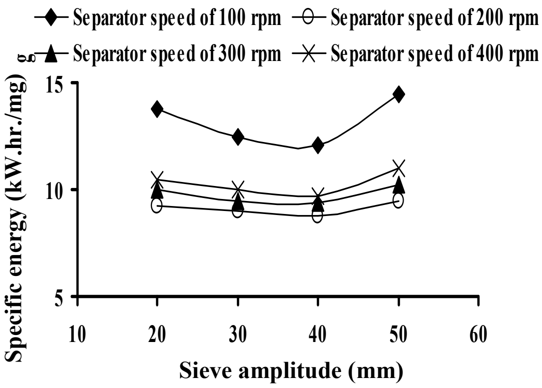


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

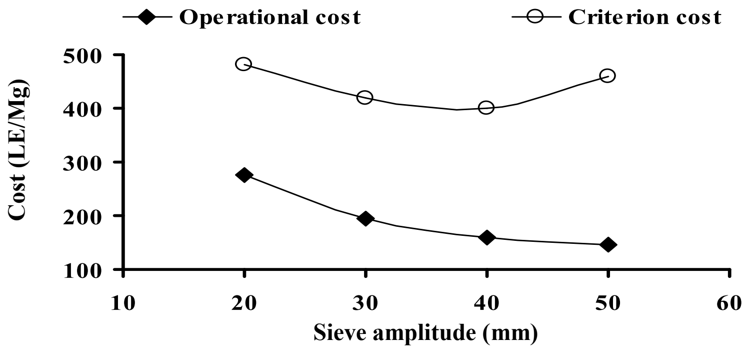


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــــع وتقييـــــــم أداء آلـــــــــــة محليـــــــــة الصنـــــع لتفـــريـط بـــذور الـرمـــــان

نجلاء صلاح أنور[1] - محمد محمد مراد حسن[1] - محب محمد أنيس الشرباصي[2] - طارق حسين على[3]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt

3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

*** Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

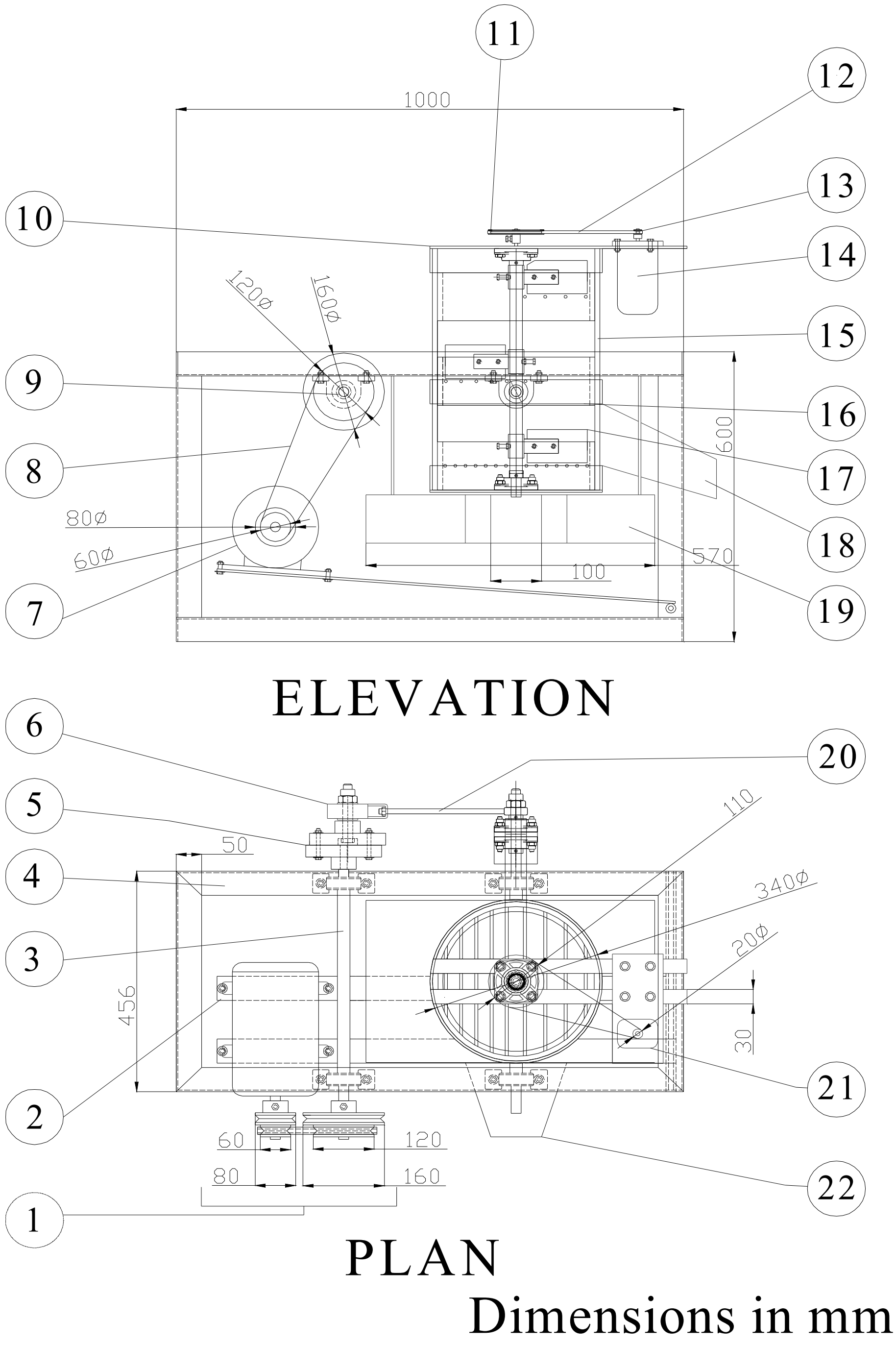
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

$\cos\theta$ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

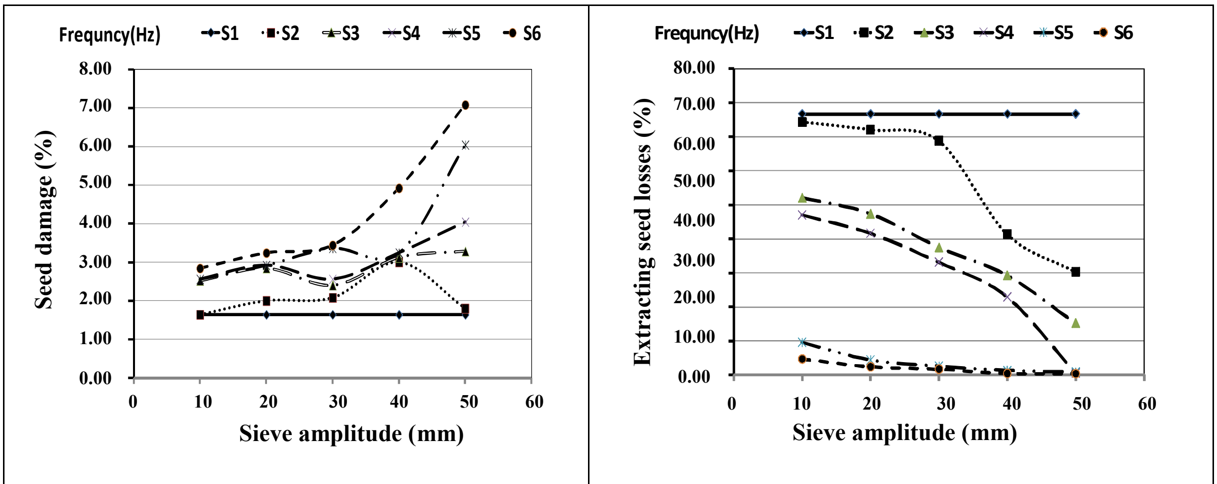
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage	B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

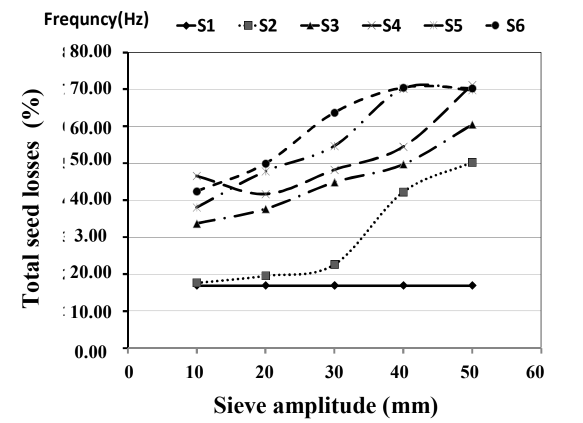
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

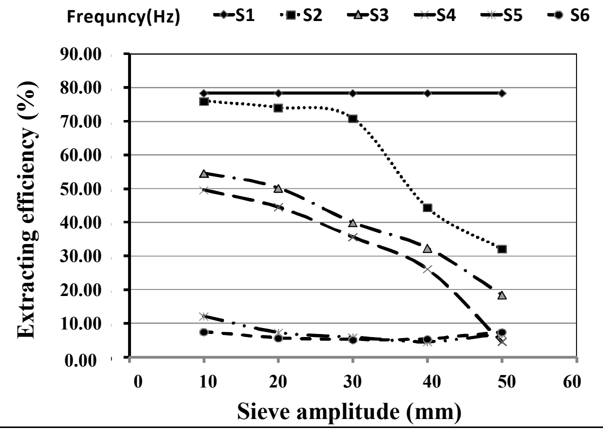
It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses



B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

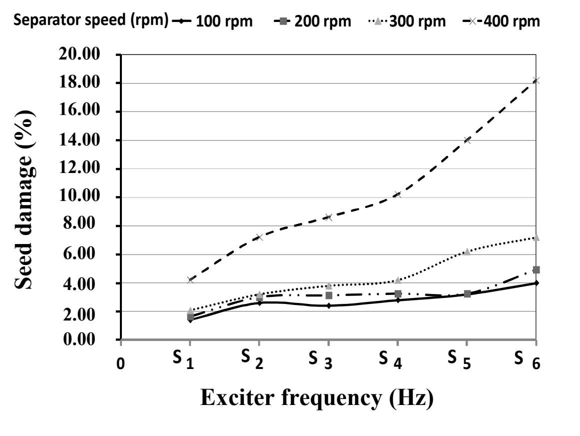
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

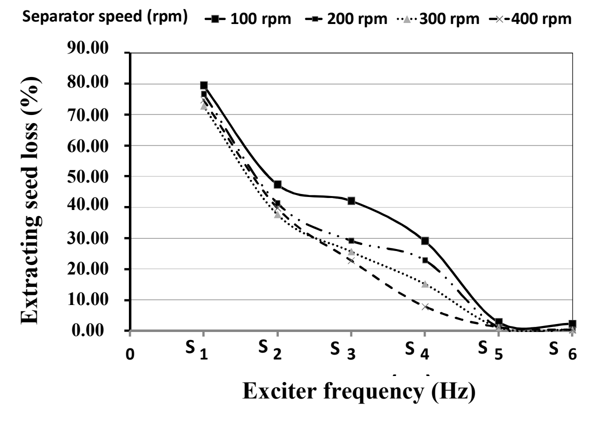
At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage



B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

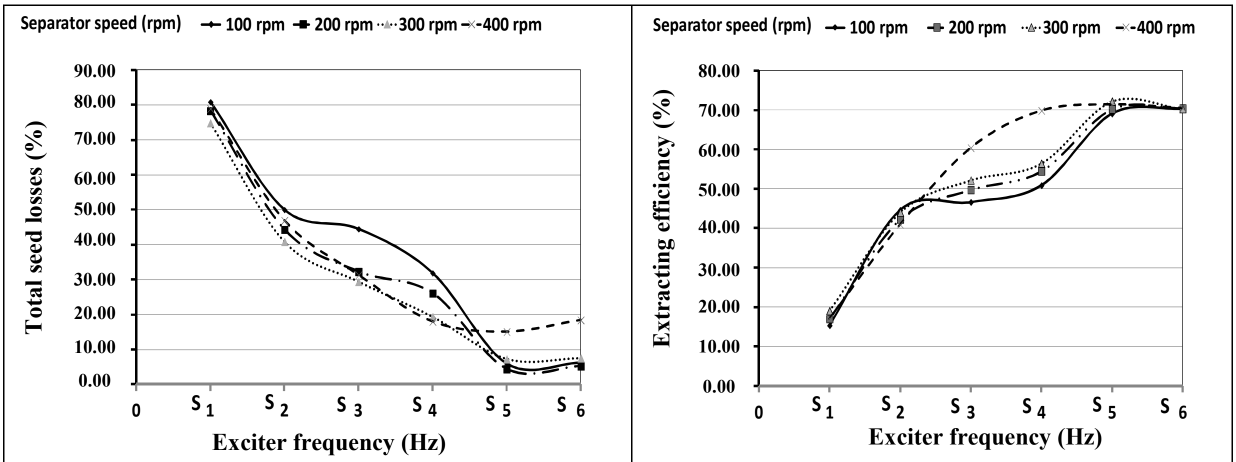
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses

B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

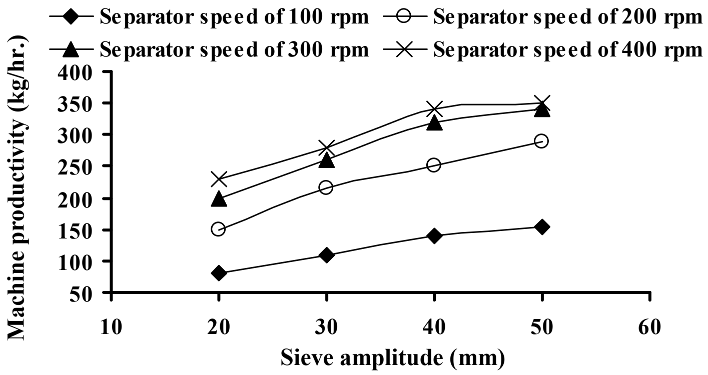
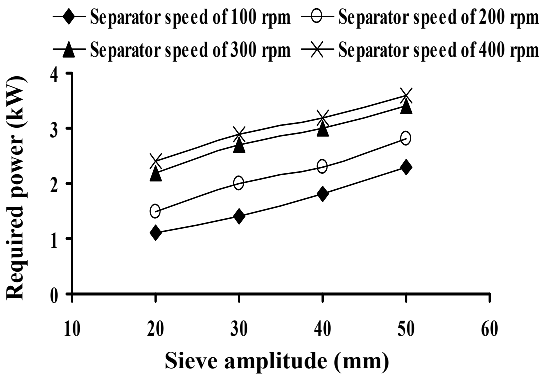


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz



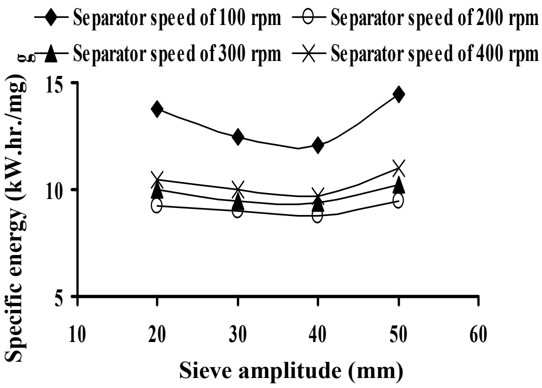


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

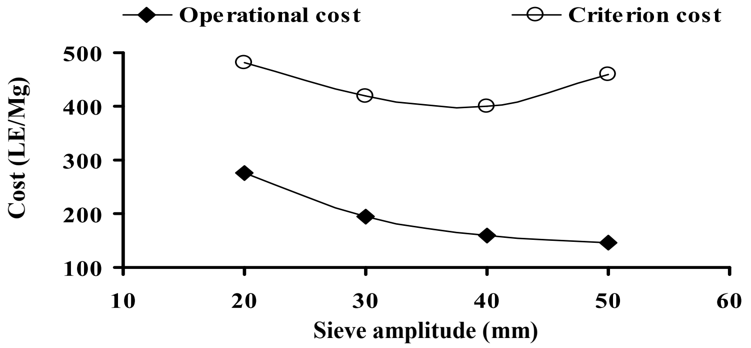


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــــع وتقييـــــــم أداء آلـــــــــــة محليـــــــــة الصنـــــع لتفـــريـط بـــذور الـرمـــــان

نجلاء صلاح أنور[1] - محمد محمد مراد حسن[1] - محب محمد أنيس الشرباصي[2]- طارق حسين على[3]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علـــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt

3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

* **Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

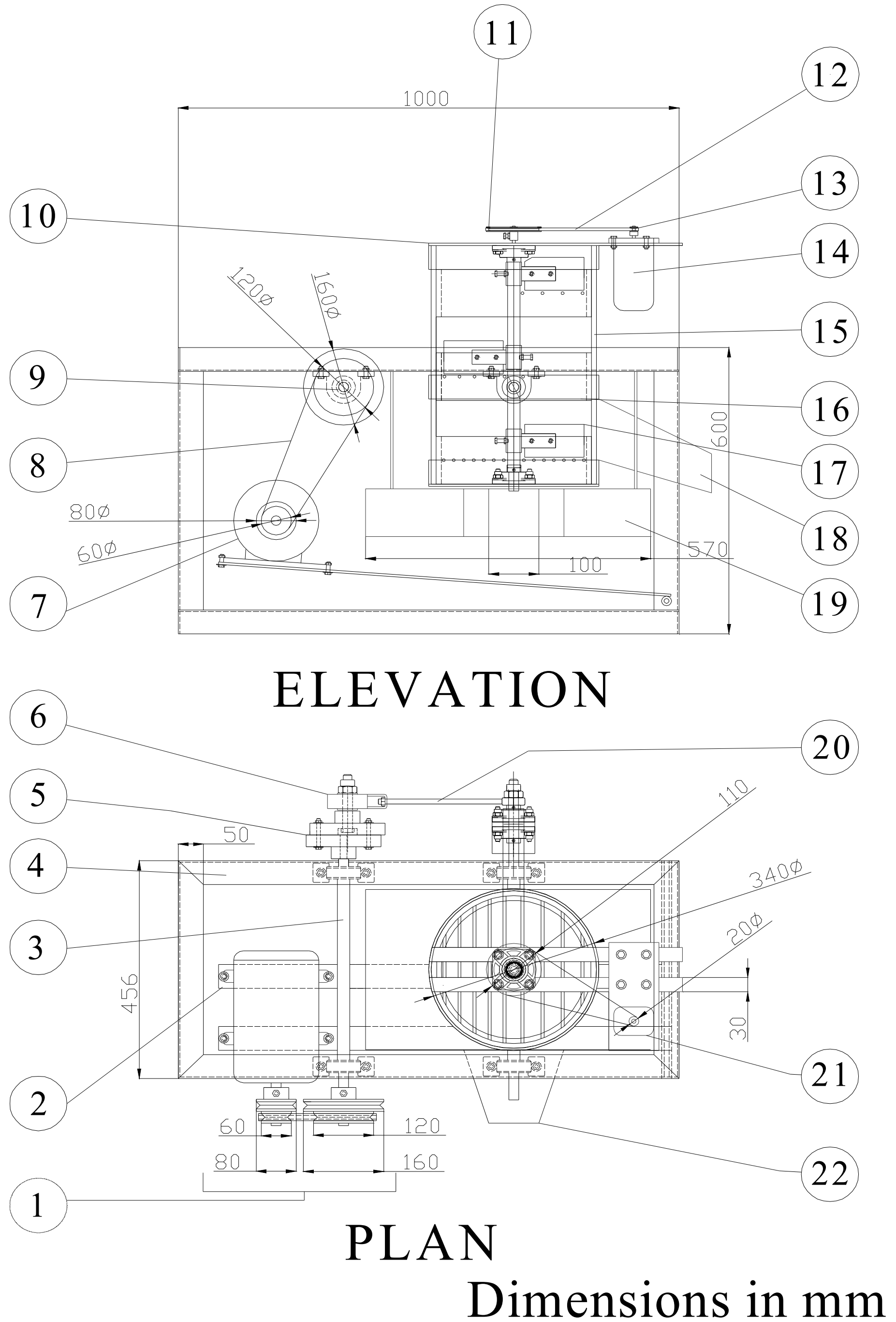
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

$\cos\theta$ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

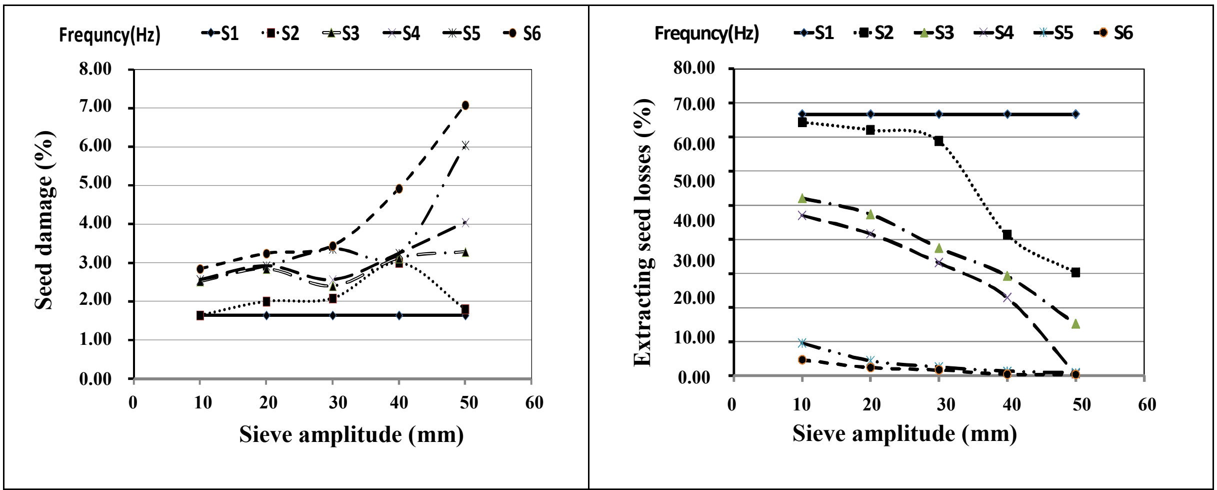
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage

B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

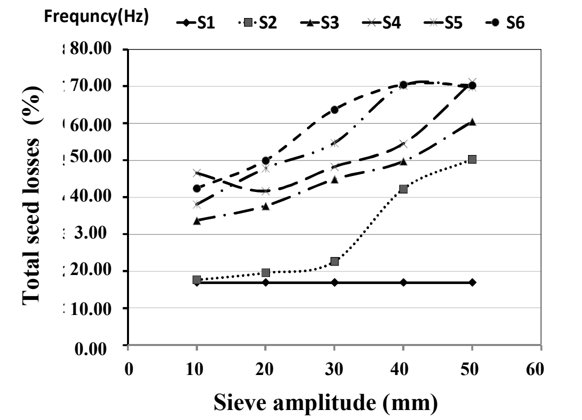
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

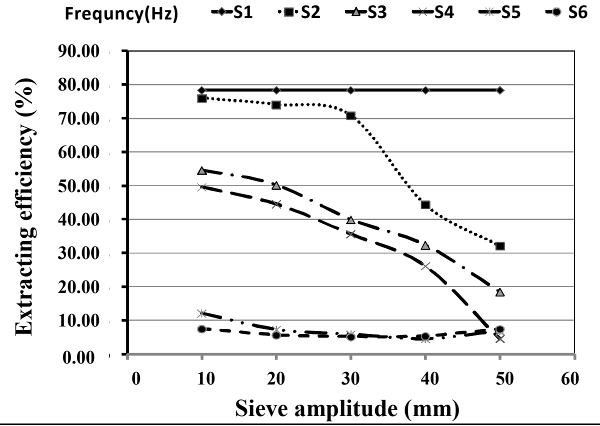
It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses



B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

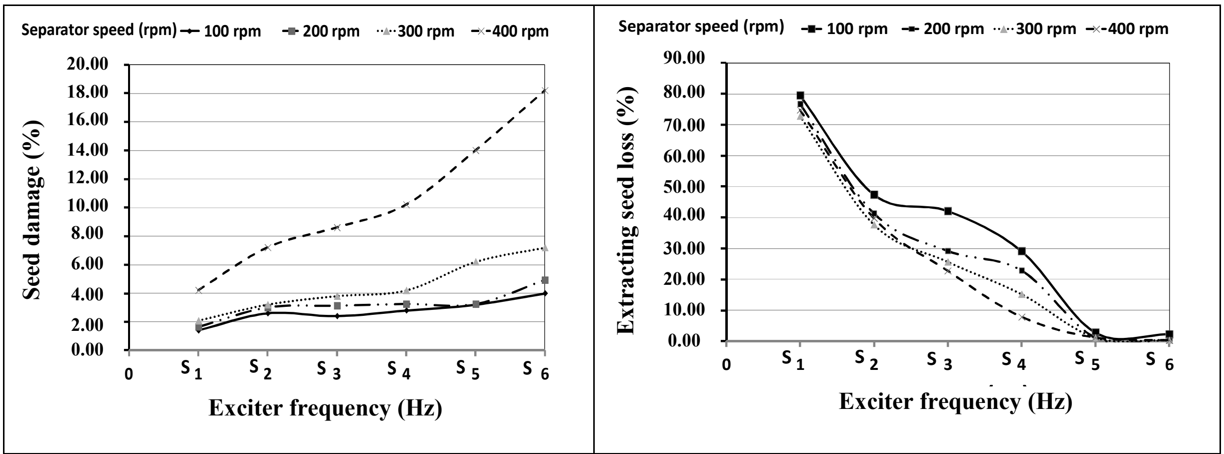
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage

B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

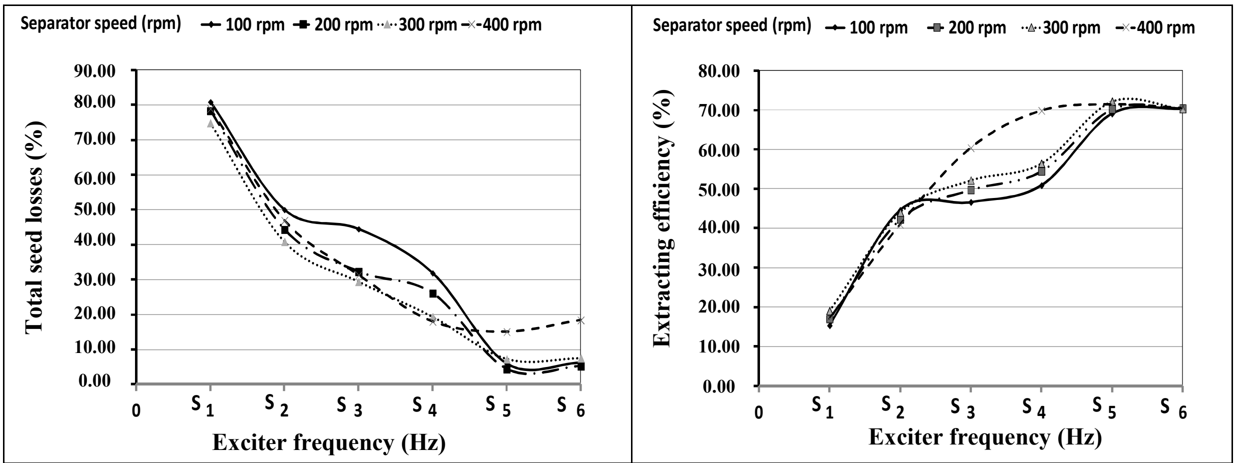
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses

B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

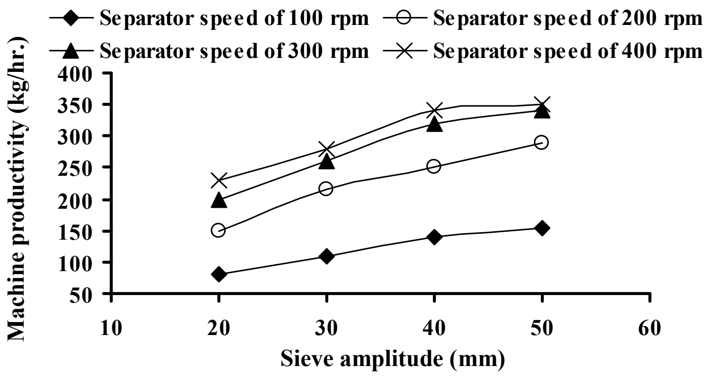
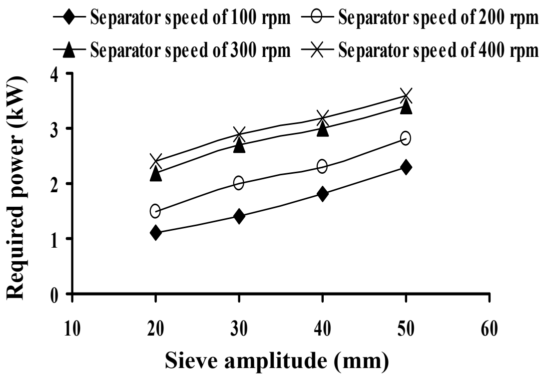


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz



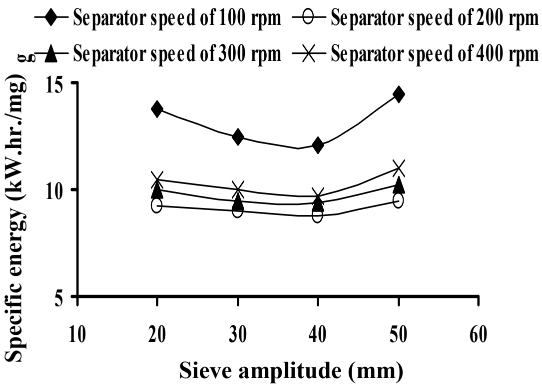


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

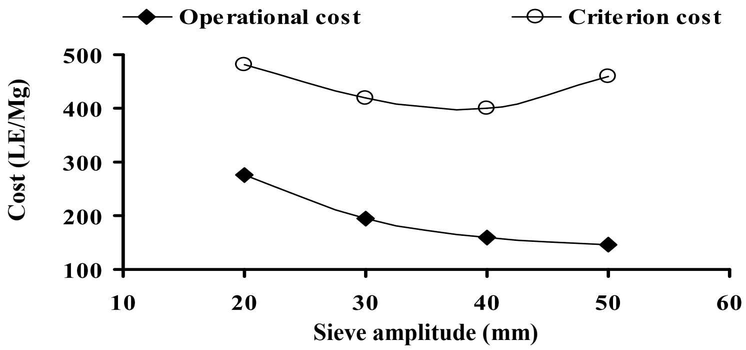


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيــــع وتقييـــــــم أداء آلـــــــــــة محليـــــــــة الصنـــــع لتفـــريـط بـــذور الرمـــــان

نجلاء صلاح أنور[١] - محمد محمد مراد حسن[١] - محب محمد أنيس الشرباصي[٢]- طارق حسين على[٣]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر	أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.
٢- أ.د. محمود مصطفى علـــي	أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt

3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

*** Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

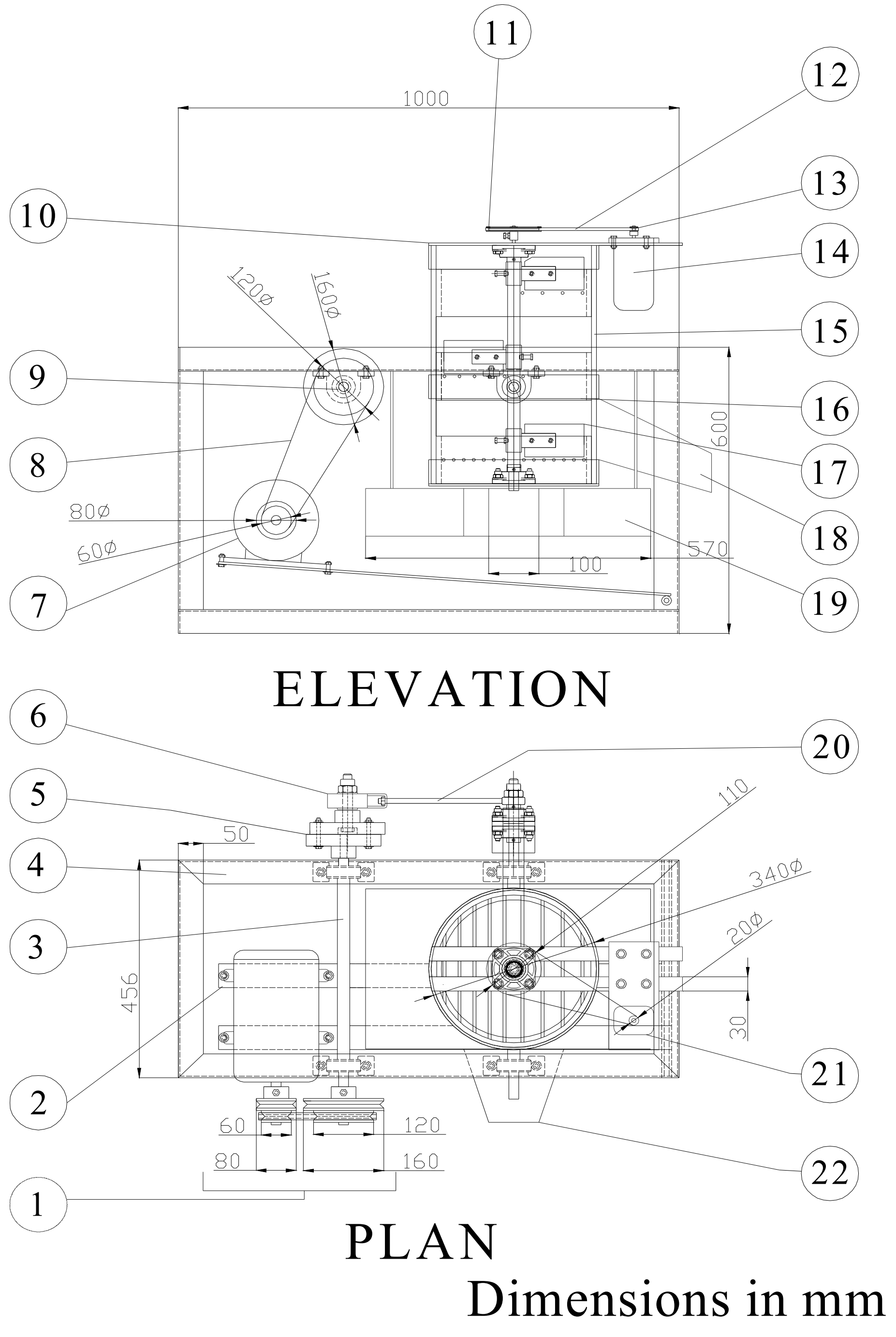
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

$\cos\theta$ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

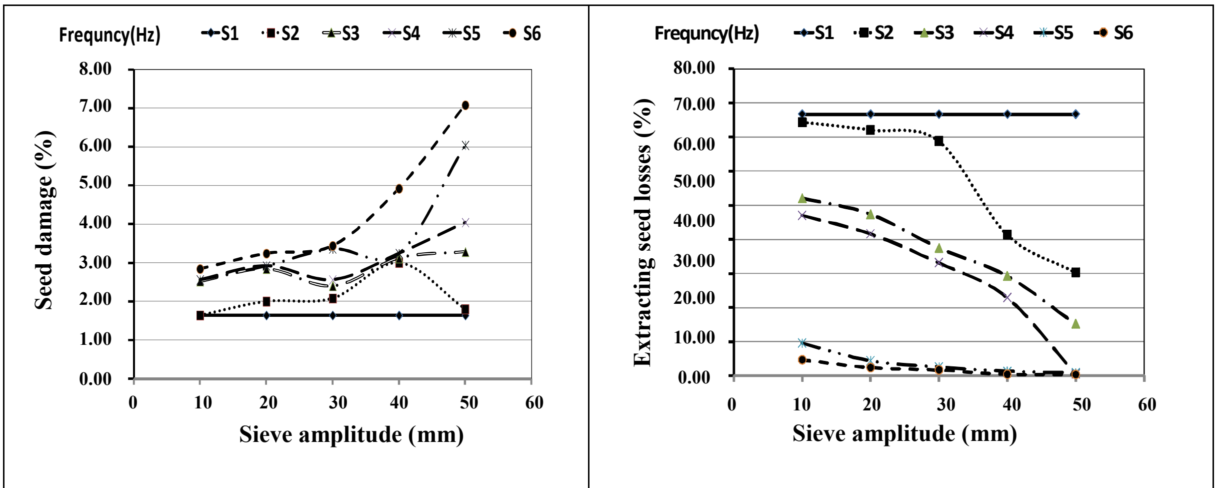
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage

B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

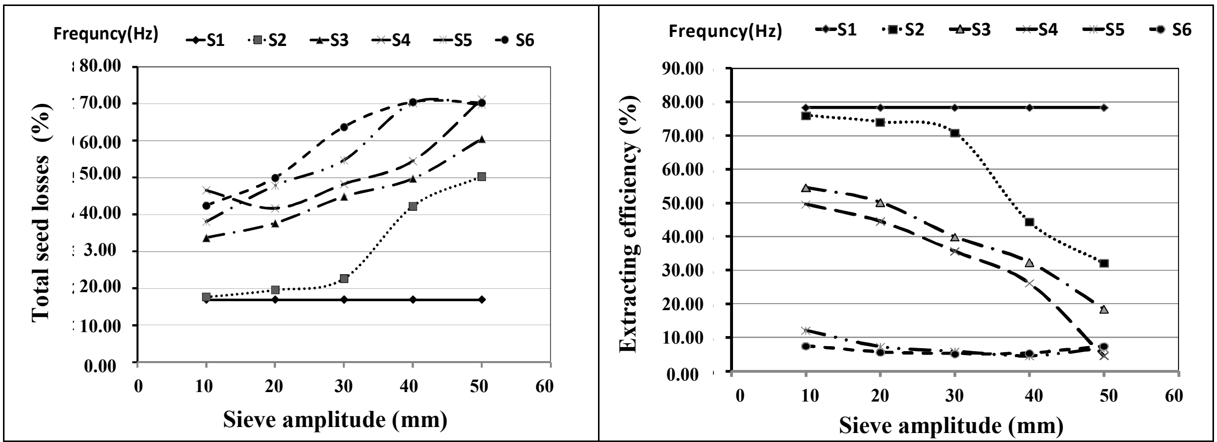
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses	B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

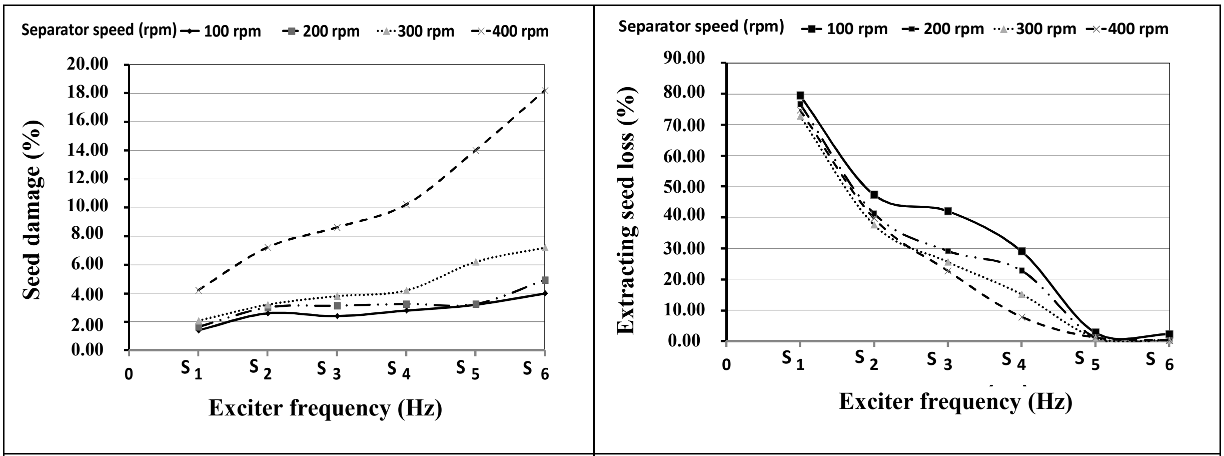
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage	B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

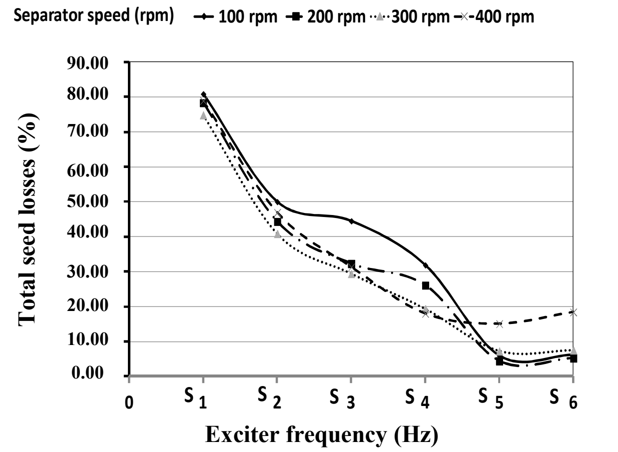
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

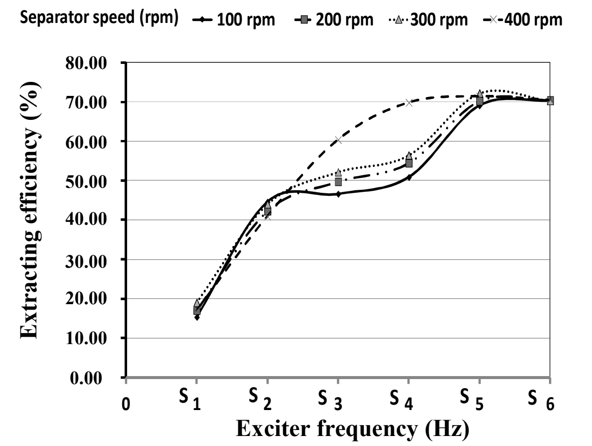
Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses



B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

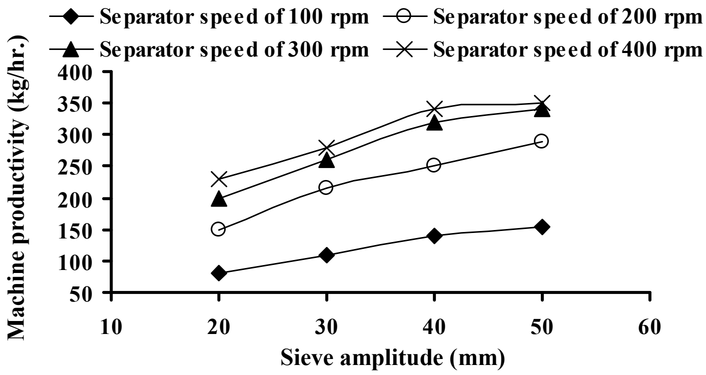


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

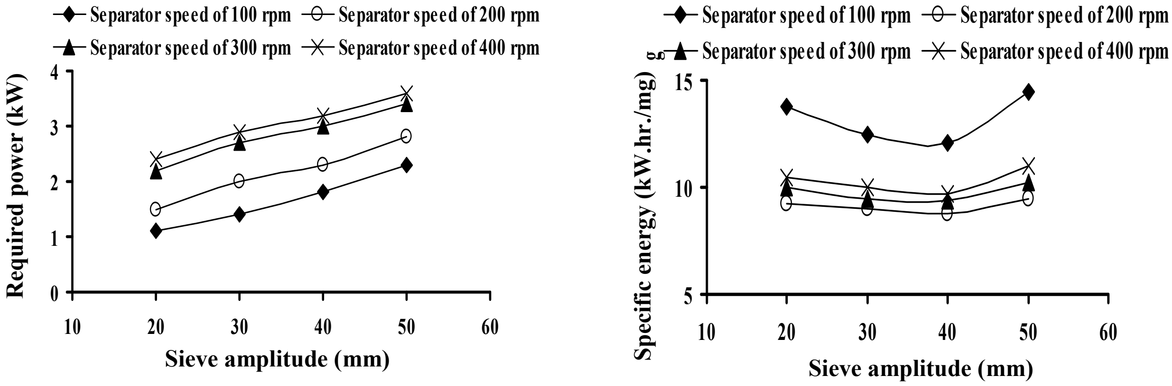


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

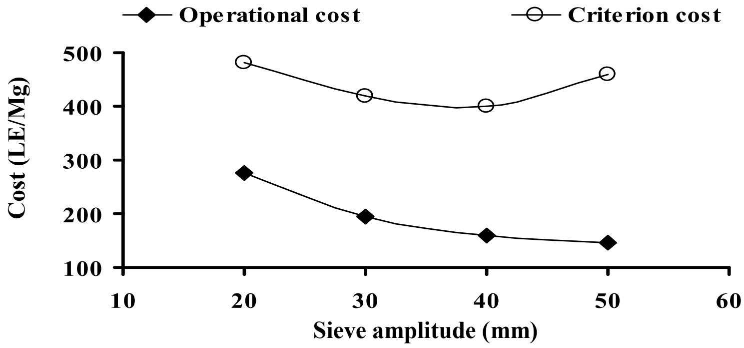


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــــع وتقييـــــــم أداء آلــــــــــة محليـــــــة الصنـــــع لتفــــريـط بـــذور الـرمـــــان

نجلاء صلاح أنور[1] - محمد محمد مراد حسن[1] - محب محمد أنيس الشرباصي[2] - طارق حسين على[3]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علـــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt

3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

*** Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

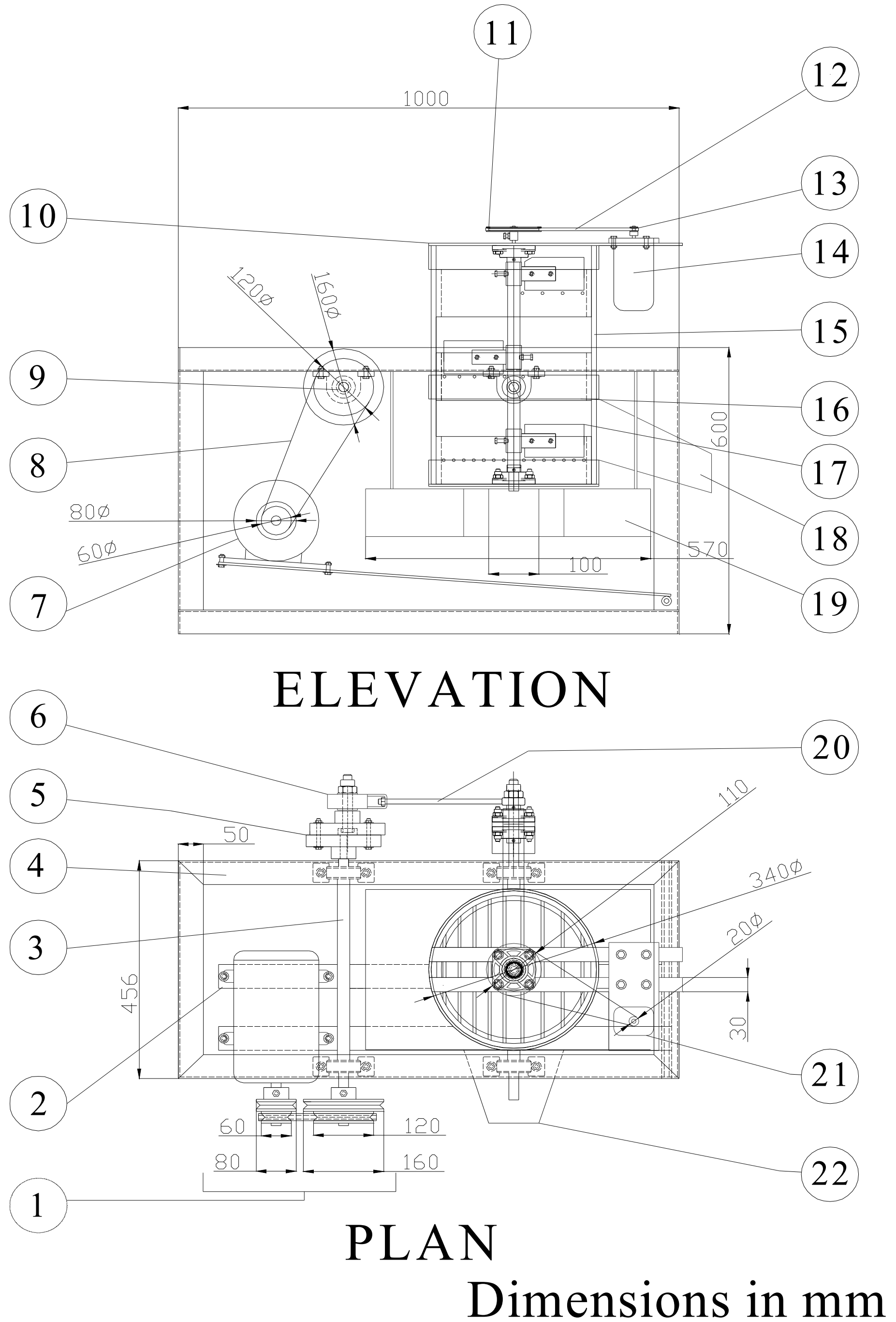
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

$\cos\theta$ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

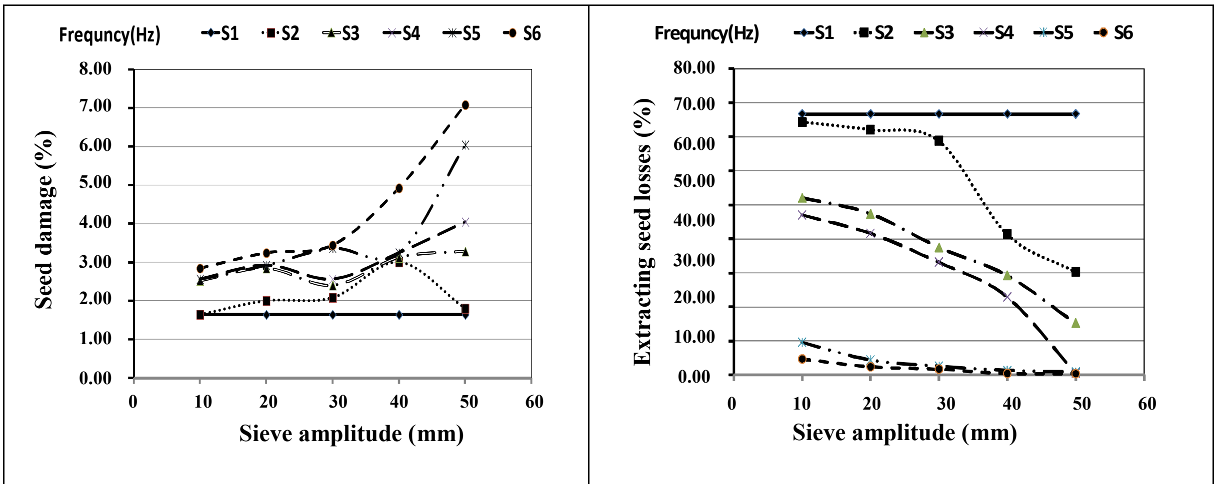
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage

B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

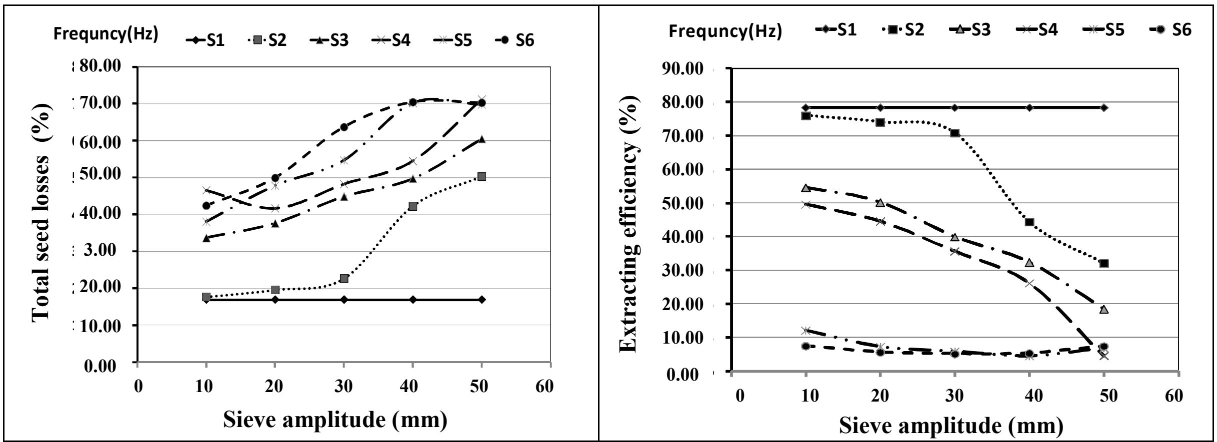
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses

B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

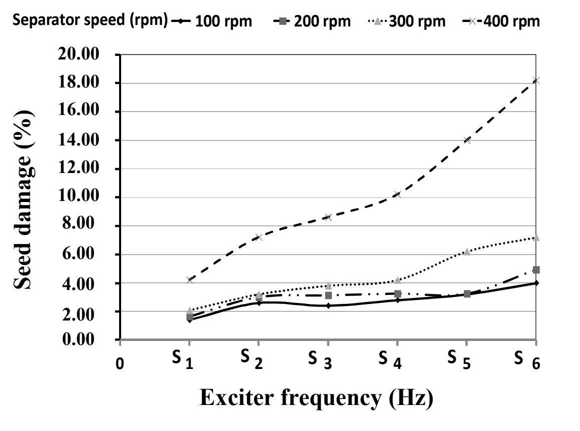
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

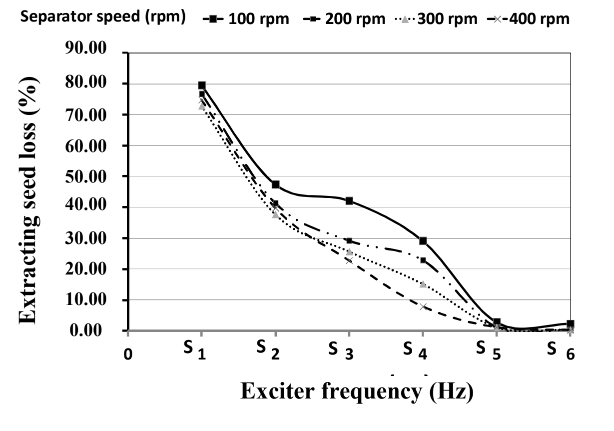
The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.





A. Effect of separator speed and exciter frequency on seed damage	B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

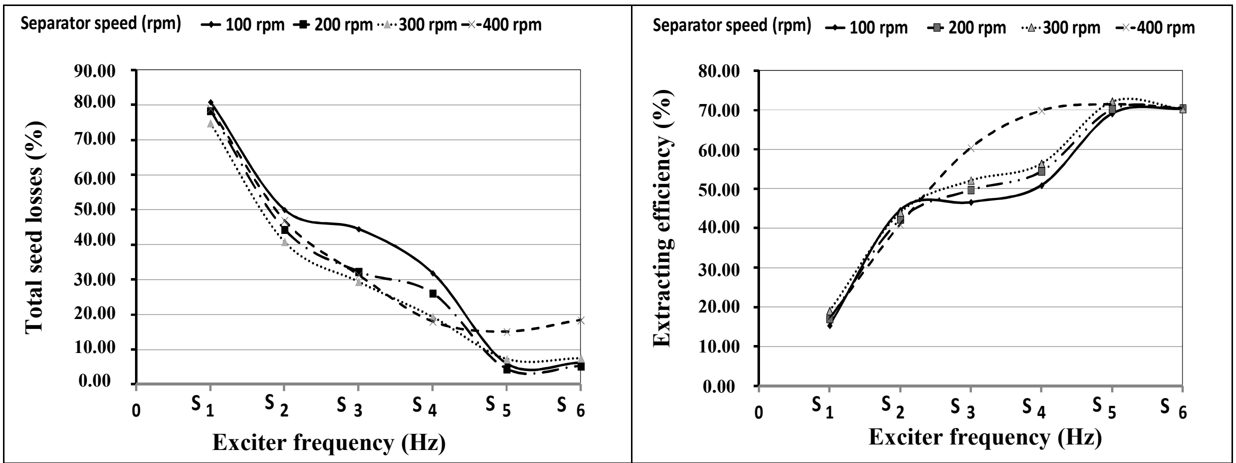
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses	B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

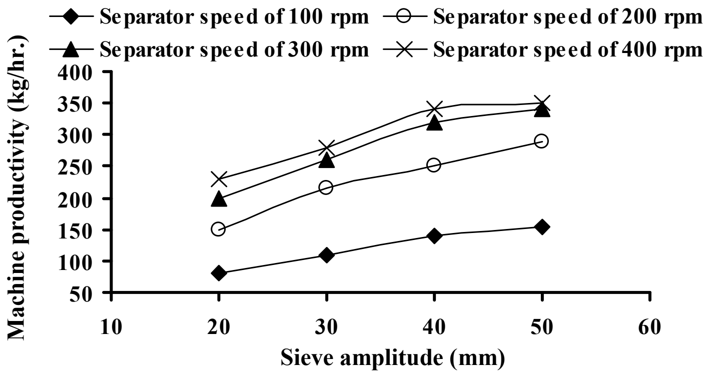


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

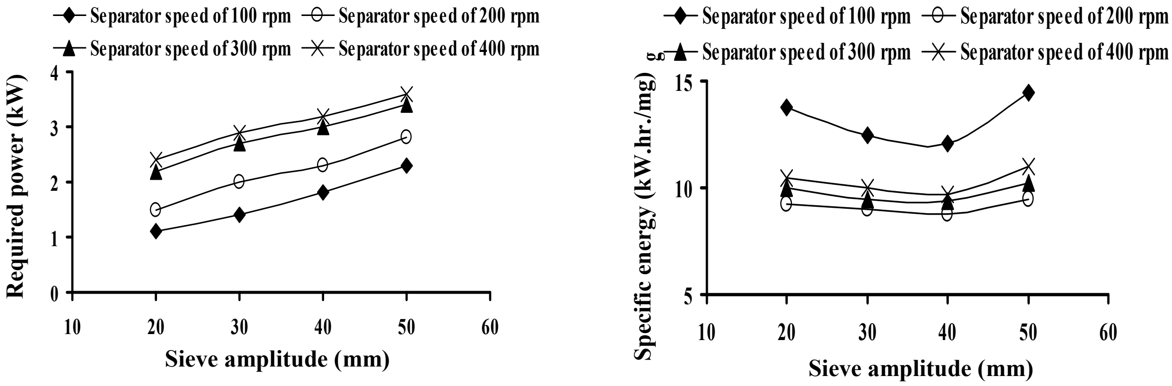


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

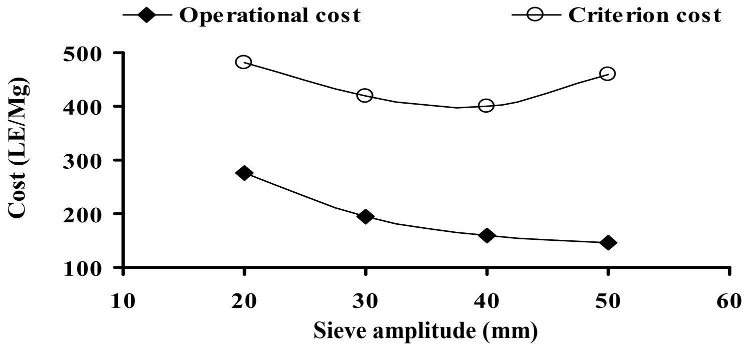


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــــع وتقييـــــــم أداء آلـــــــــــة محليـــــــــة الصنـــــع لتفـــريـط بـــذور الـرمـــــان

نجلاء صلاح أنور[1] - محمد محمد مراد حسن[1] - محب محمد أنيس الشرباصي[2]- طارق حسين على[3]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علـــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt

3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

*** Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

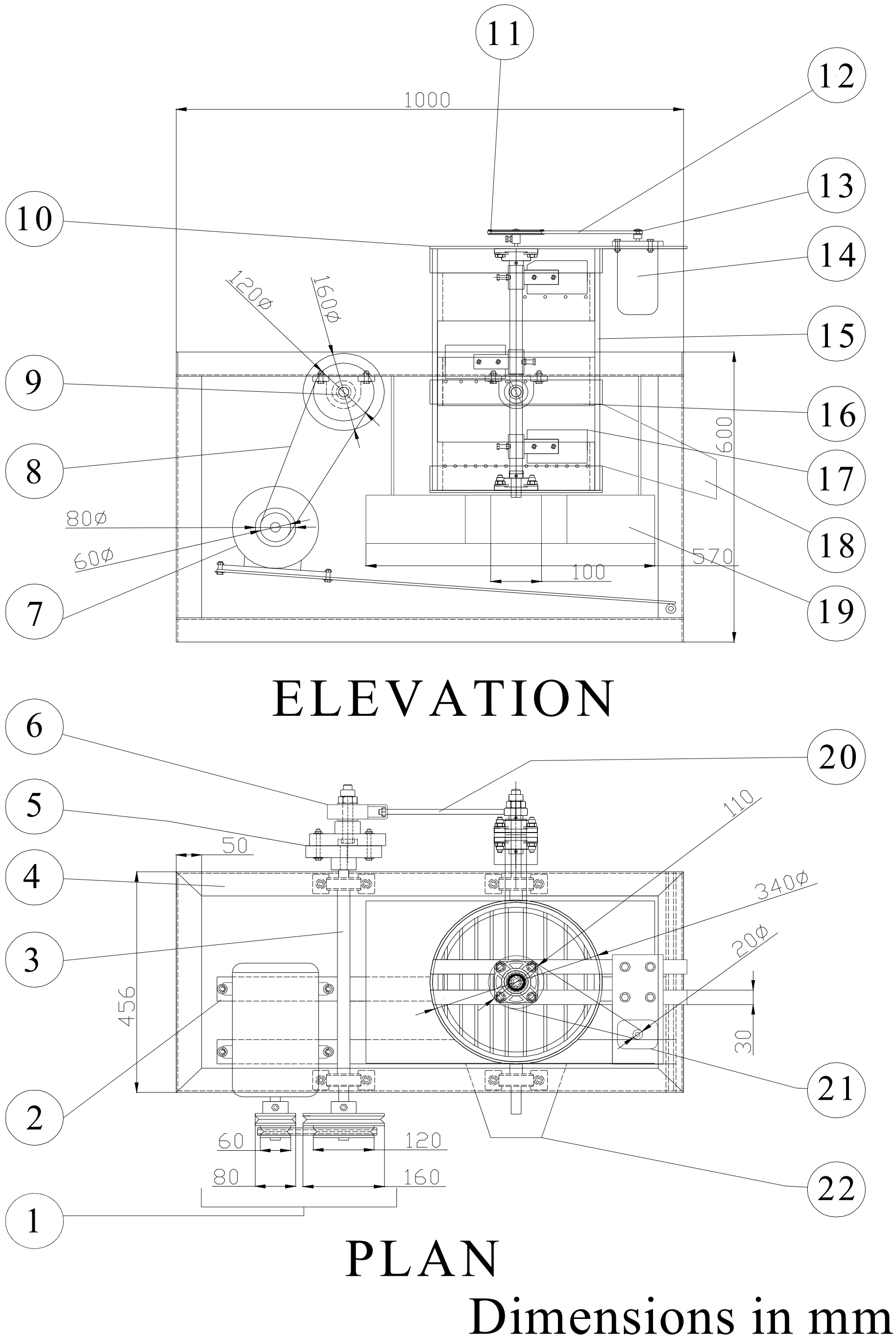
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)}=\frac{M_b}{M_t}\times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)}=\frac{60\times M_C}{T_e\times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)}=\frac{I\times V\times\cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

$\cos\theta$ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

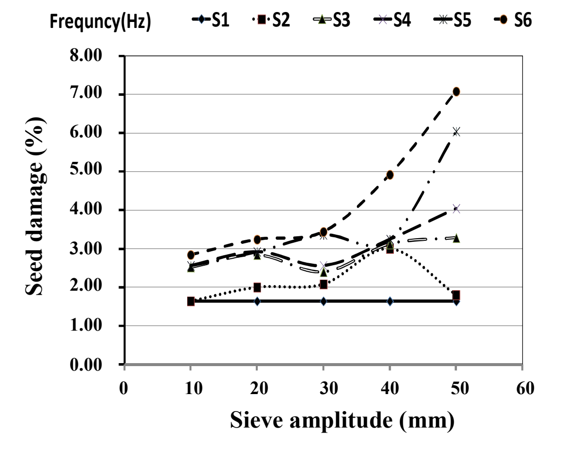
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

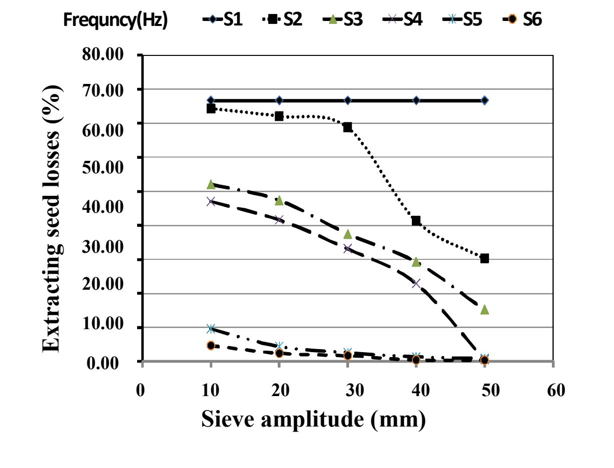
The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage



B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

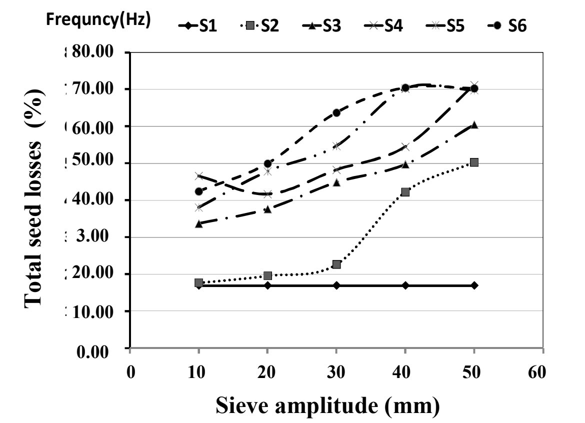
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

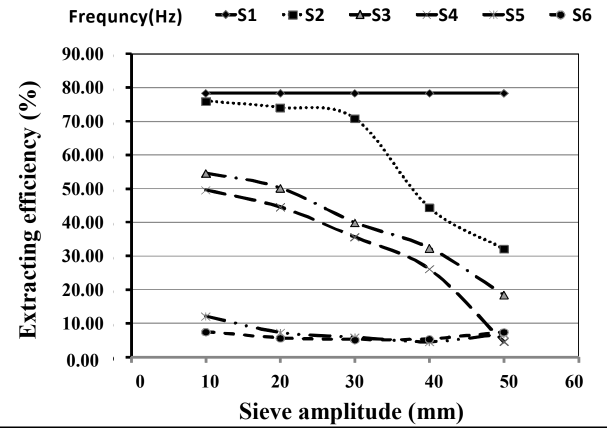
It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses



B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

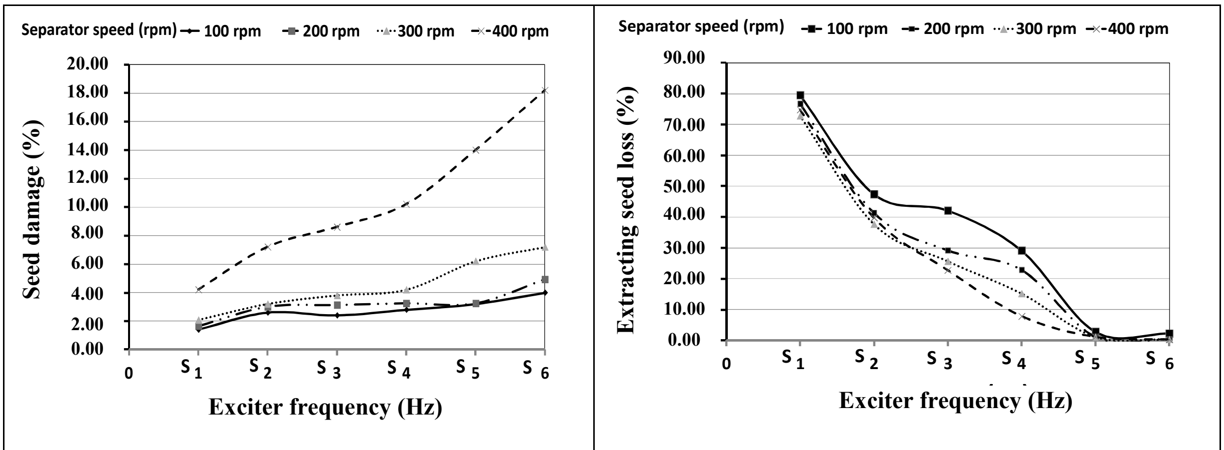
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage	**B. Effect of separator speed and exciter frequency on extracting seed loss**

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

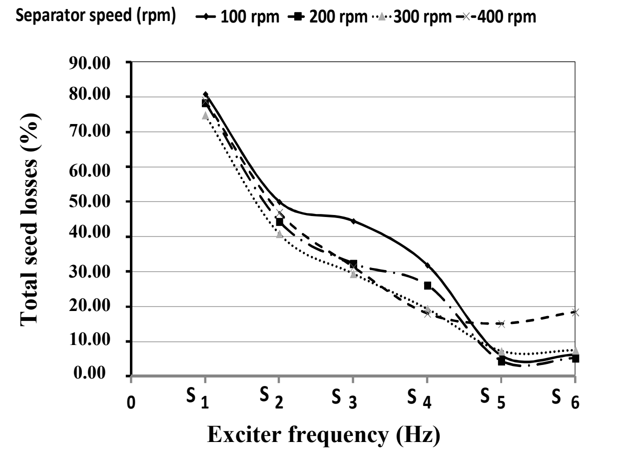
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

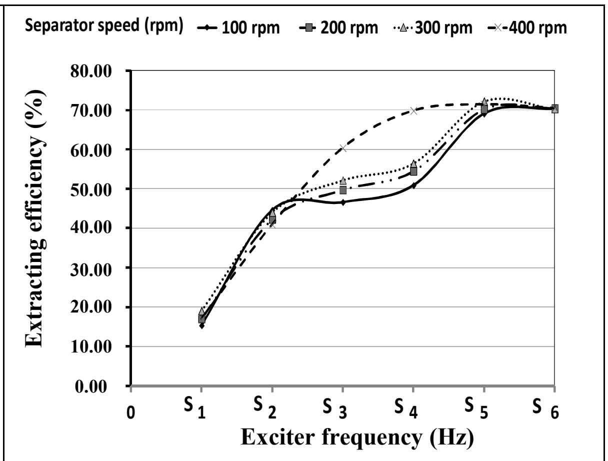
Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses



B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

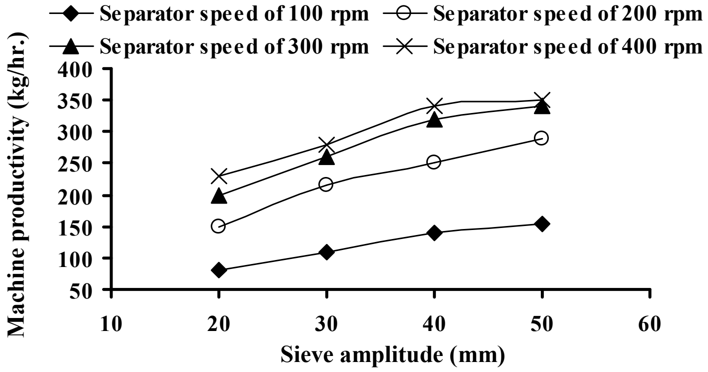


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

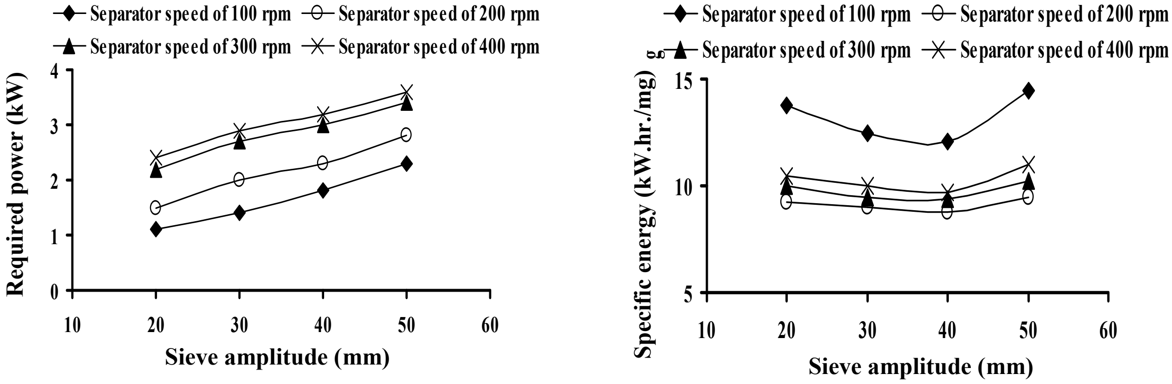


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

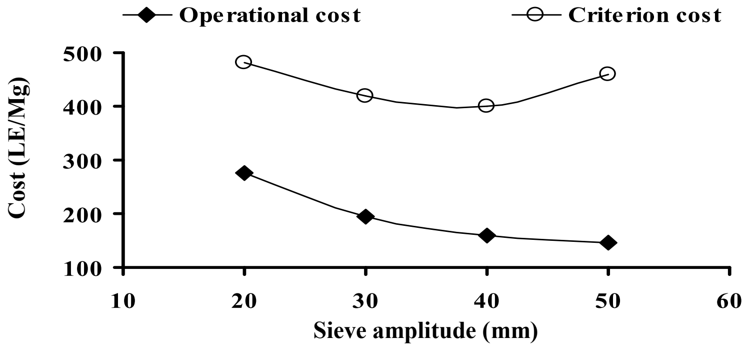


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــــع وتقييـــــــم أداء آلــــــــــة محليــــــــــة الصنــــــع لتفــــريـط بـــذور الرمـــــان

نجلاء صلاح أنور[1] - محمد محمد مراد حسن[1] - محب محمد أنيس الشرباصي[2] - طارق حسين على[3]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt

3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

* **Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

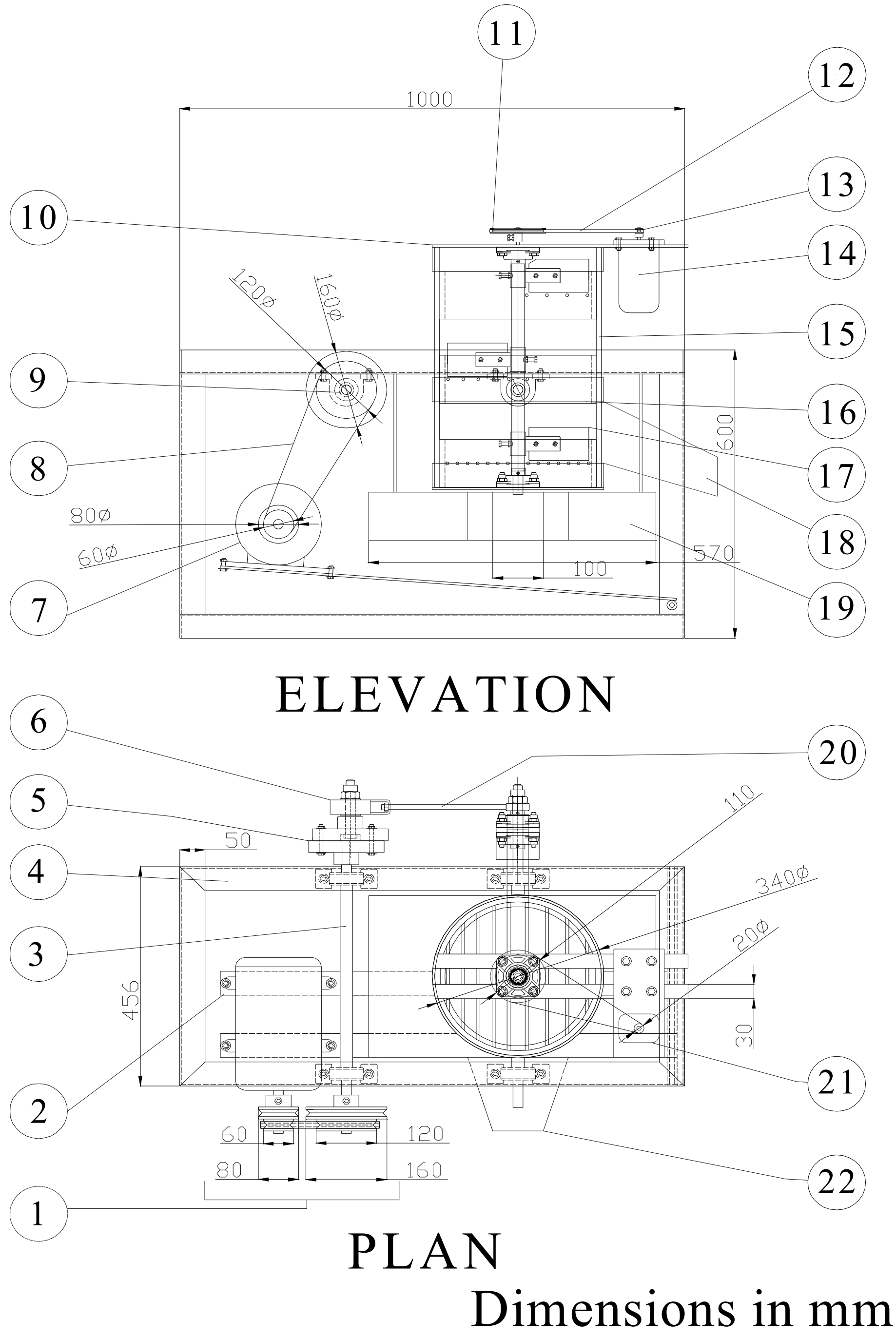
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

cos θ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

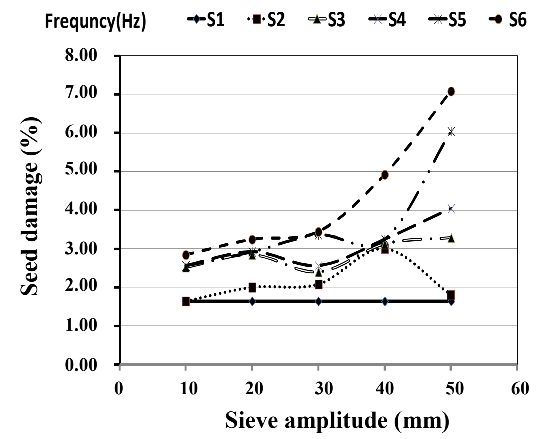
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

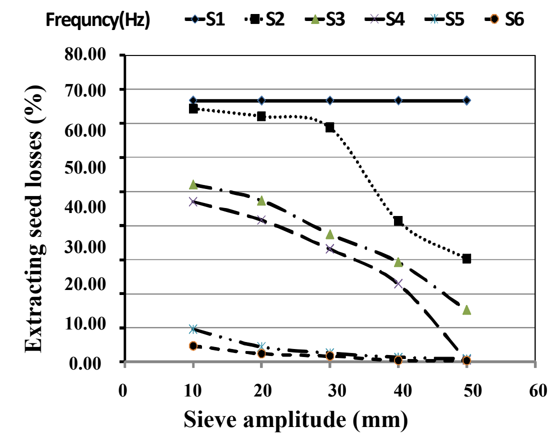
The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage



B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

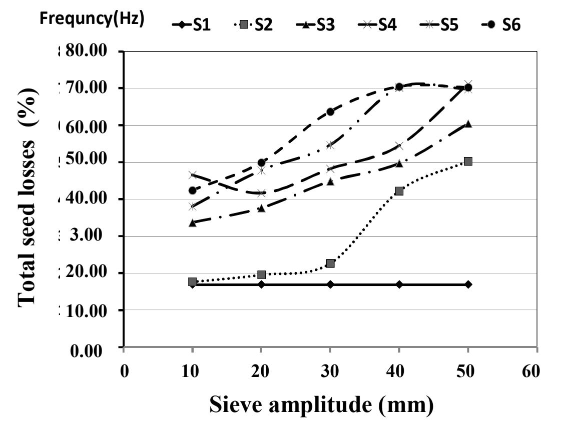
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

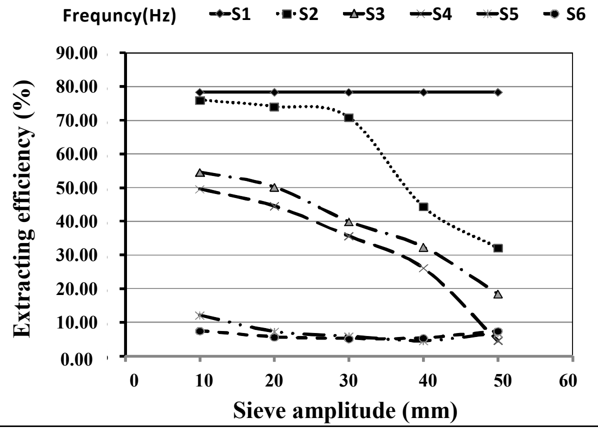
It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses



B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

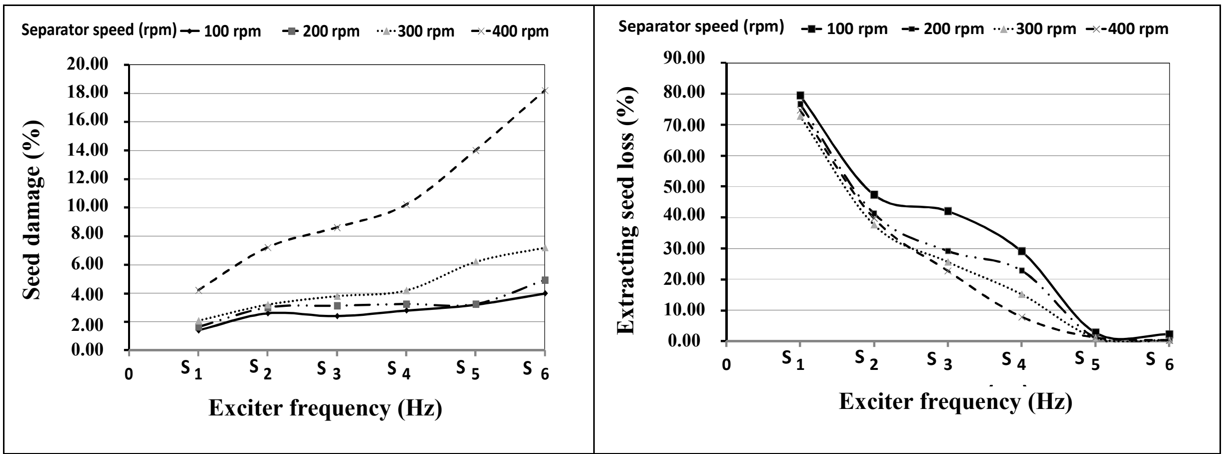
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage	B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

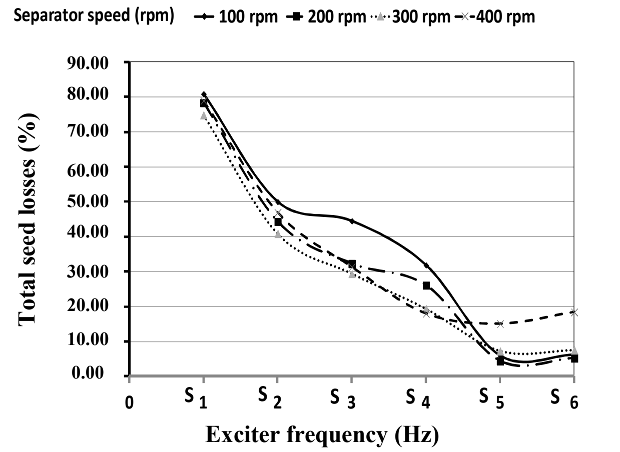
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

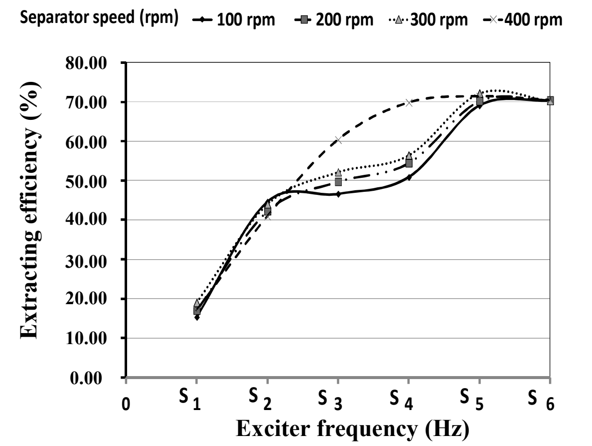
Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses



B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

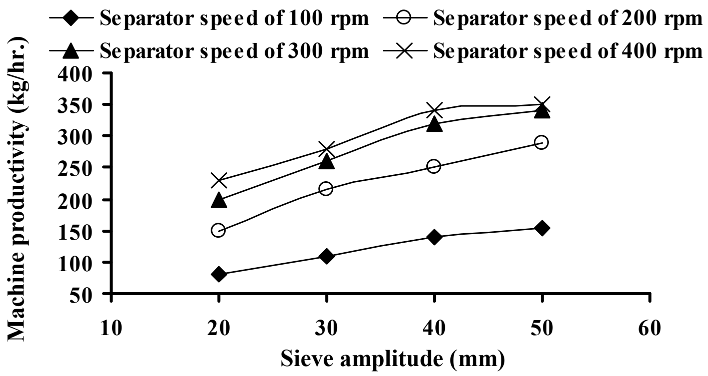


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

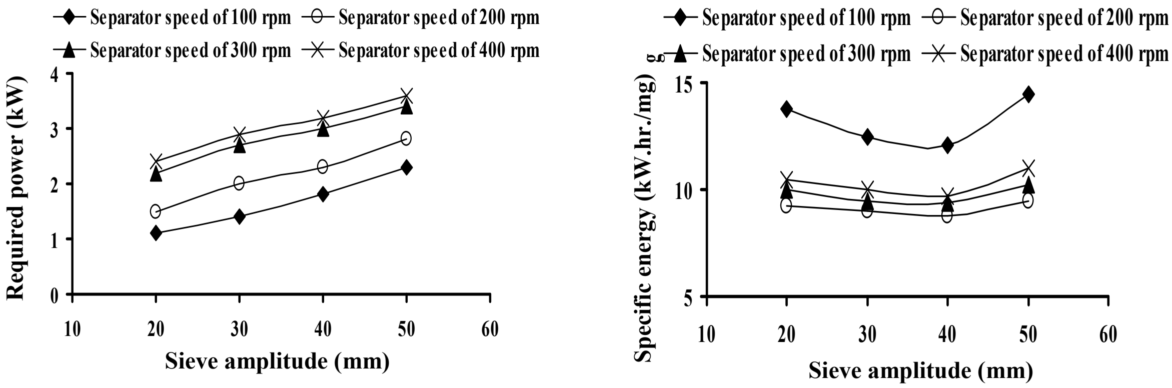


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

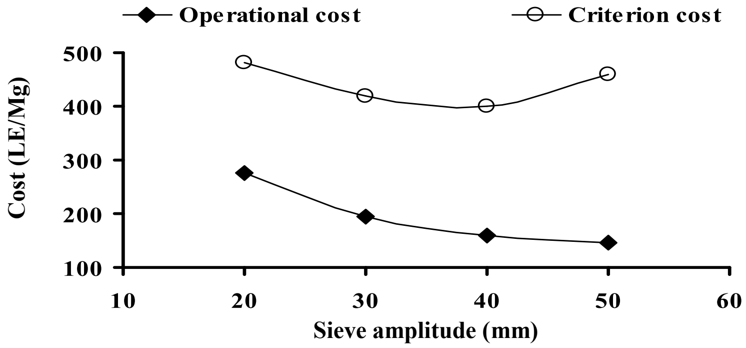


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــــع وتقييـــــــم أداء آلـــــــــــة محليـــــــــة الصنـــــع لتفـــــريـط بـــذور الـرمـــــان

نجلاء صلاح أنور[1] - محمد محمد مراد حسن[1] - محب محمد أنيس الشرباصي[2]- طارق حسين على[3]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علـــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt

3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

*** Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

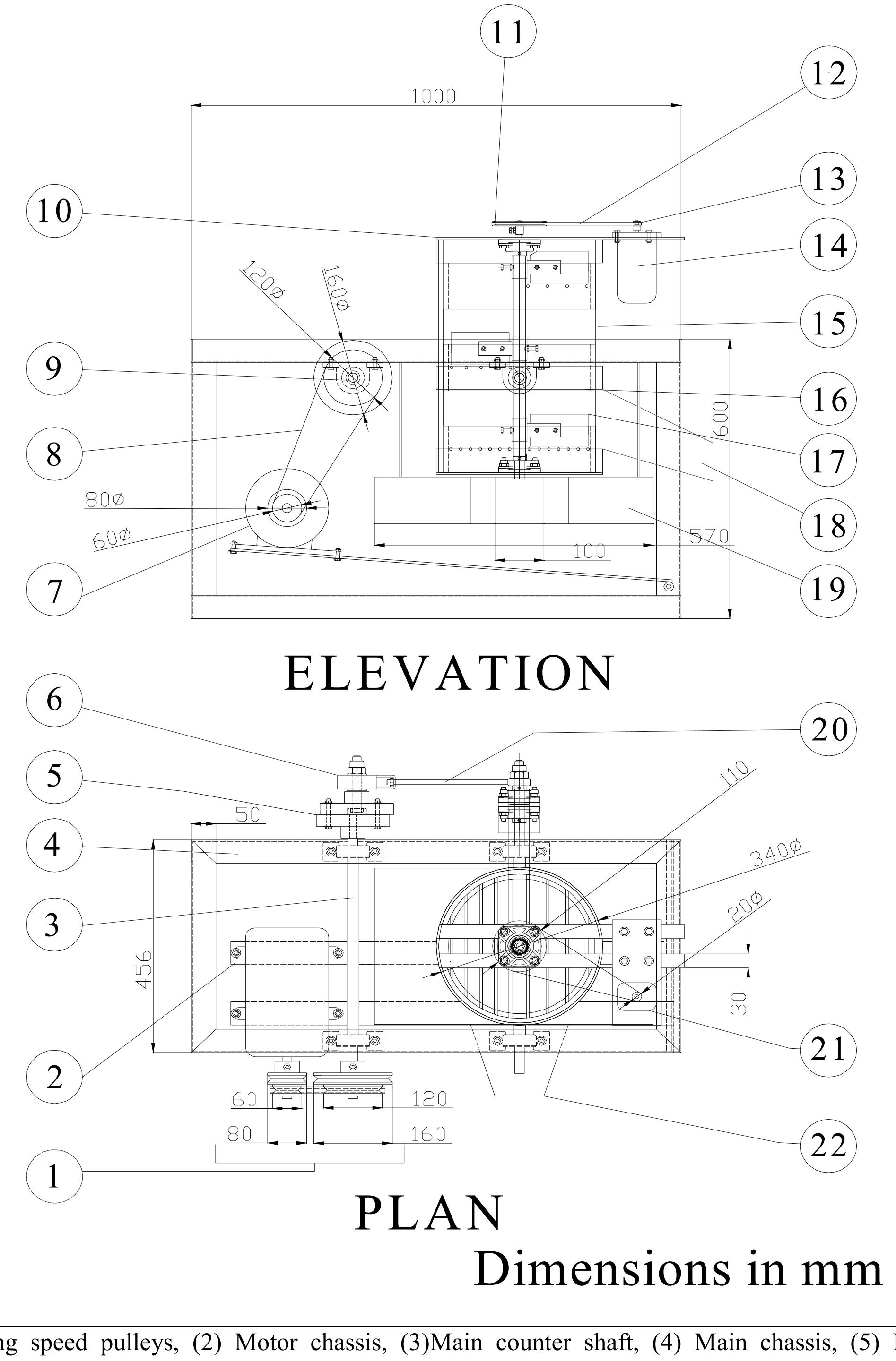
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

cos θ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

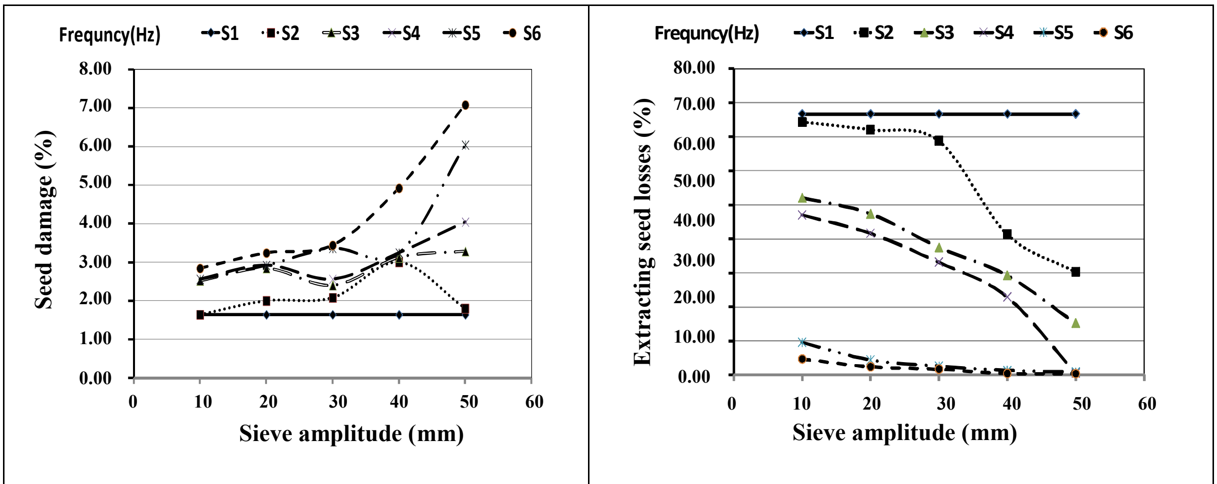
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage

B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

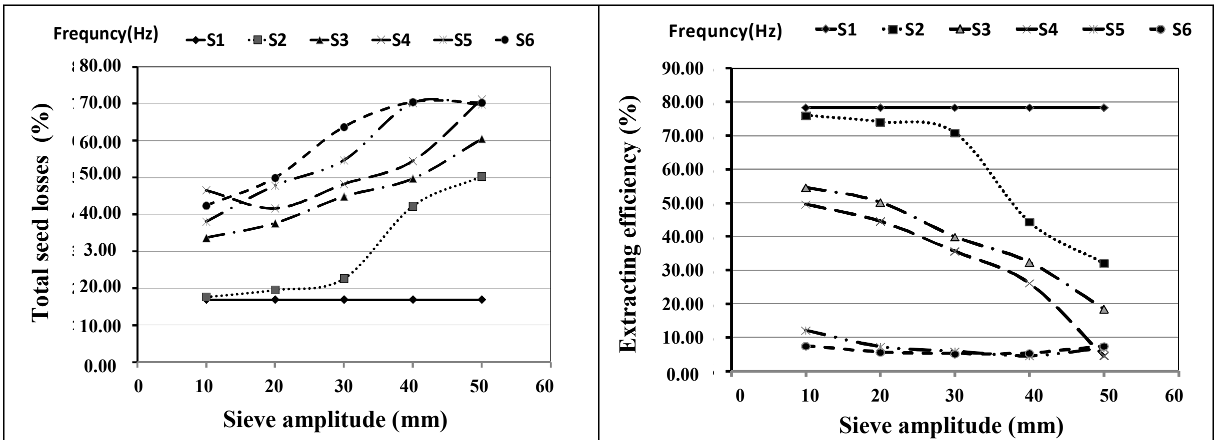
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses

B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

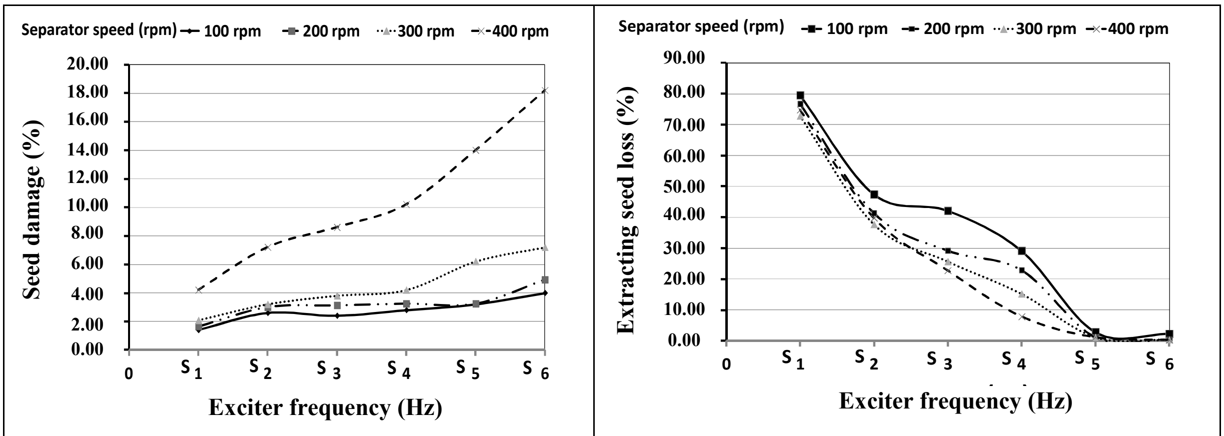
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage

B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

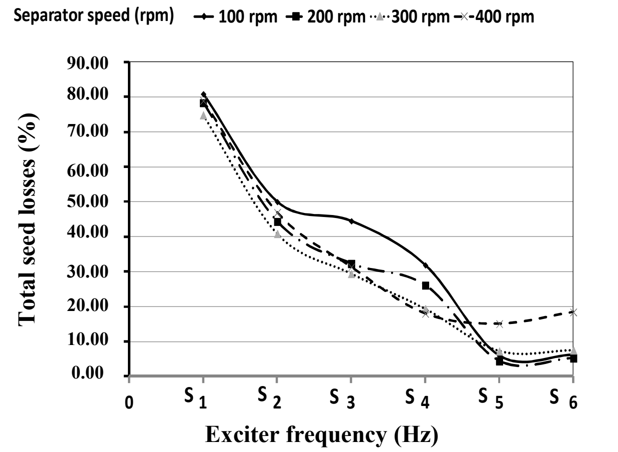
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

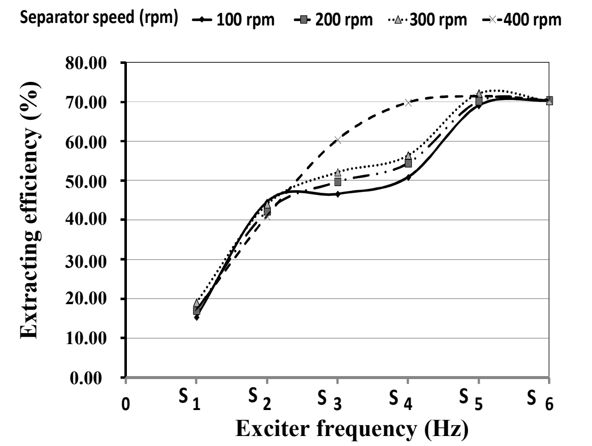
Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses



B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

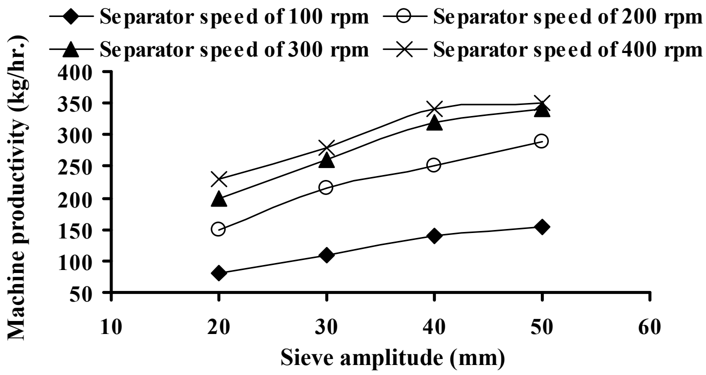


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

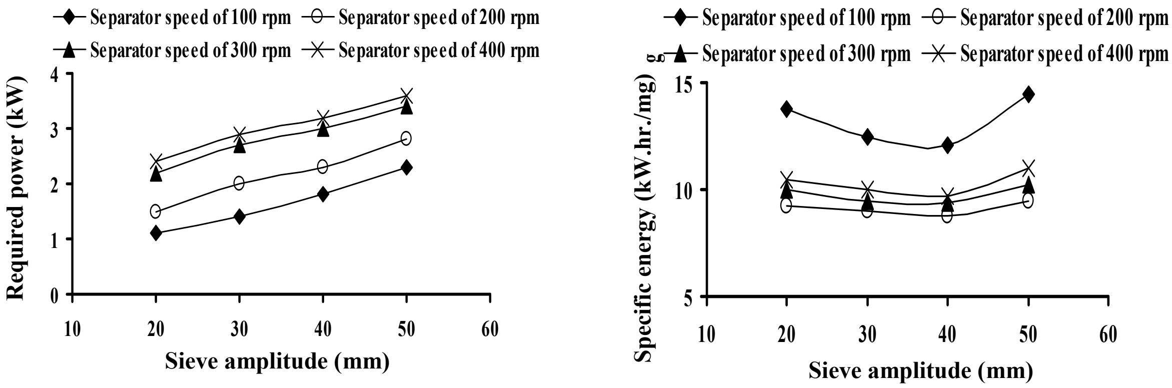


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

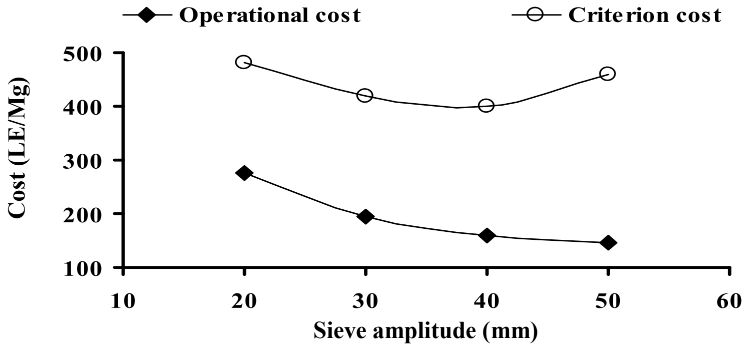


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــع وتقييــــم أداء آلـــــــة محليـــــــة الصنــــع لتفـــريـط بـــذور الـرمـــــان

نجلاء صلاح أنور[١] - محمد محمد مراد حسن[١] - محب محمد أنيس الشرباصي[٢]- طارق حسين على[٣]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علـــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt

3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

* **Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

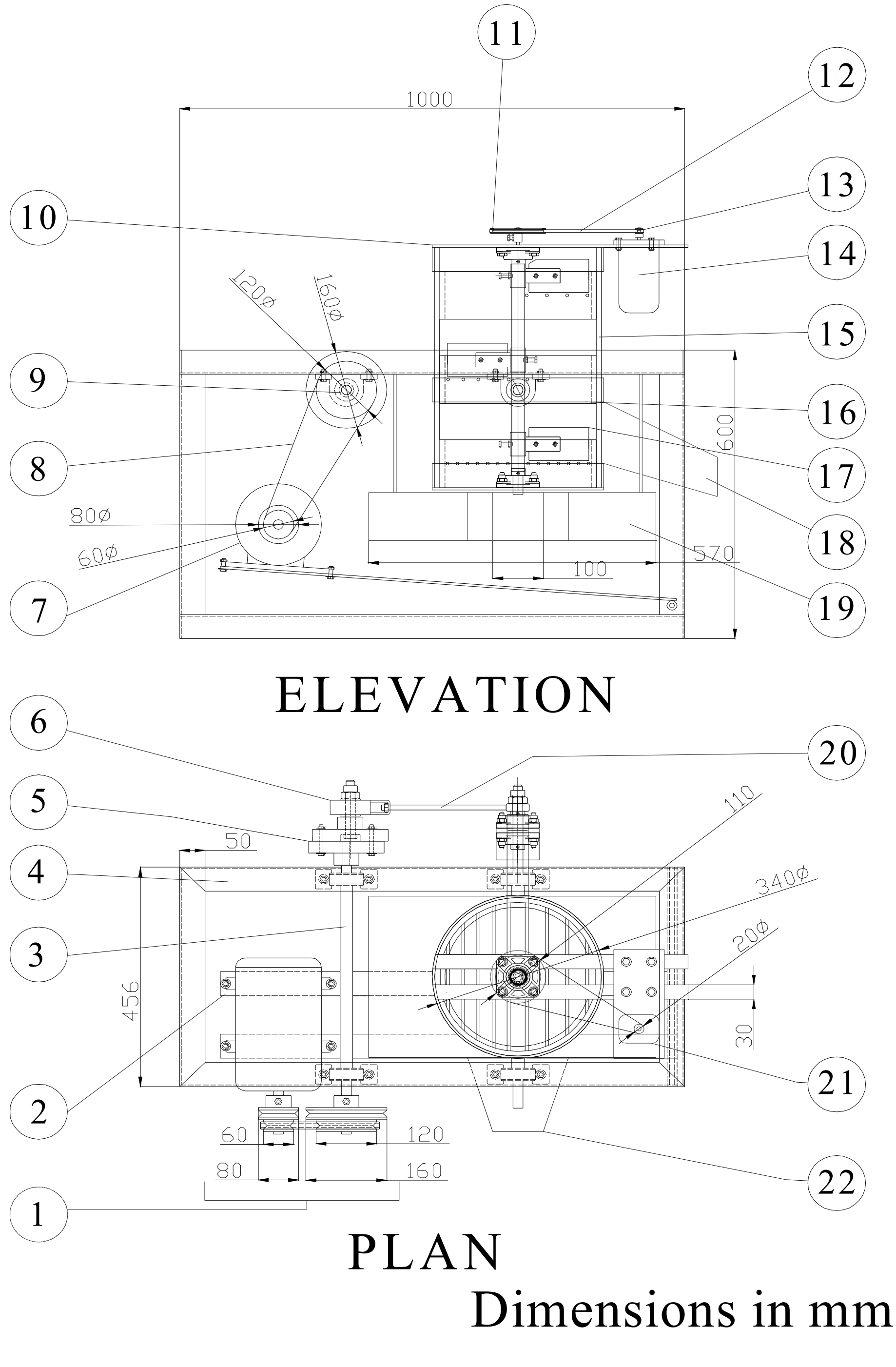
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

cos θ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

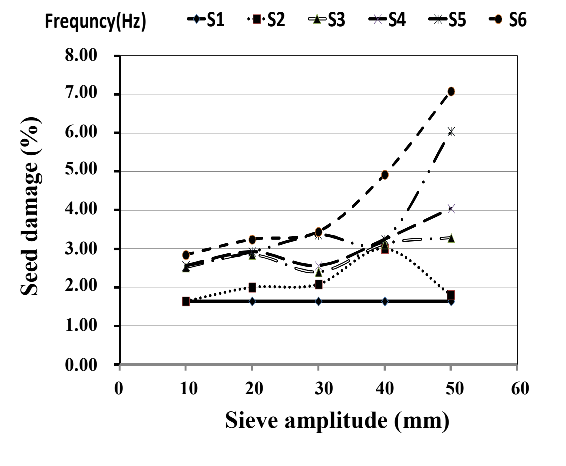
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

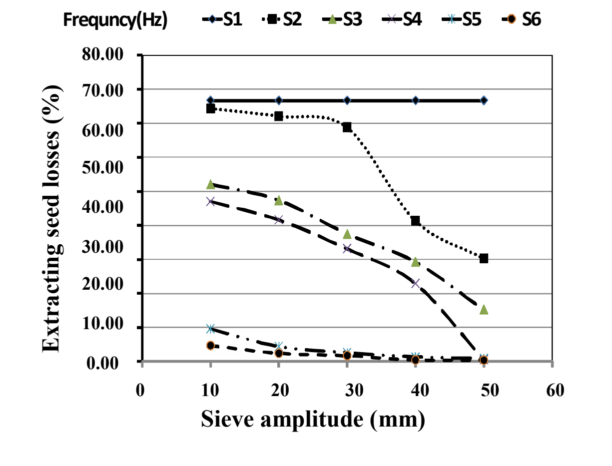
The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage



B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

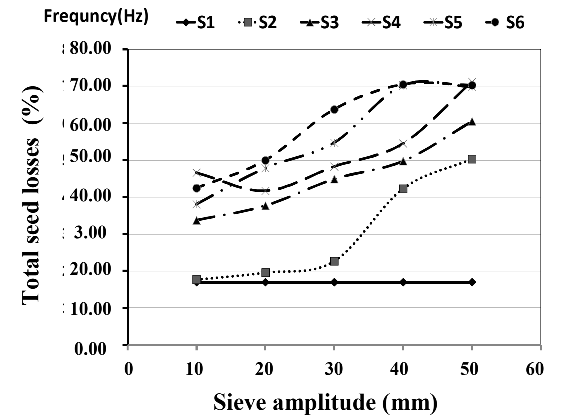
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

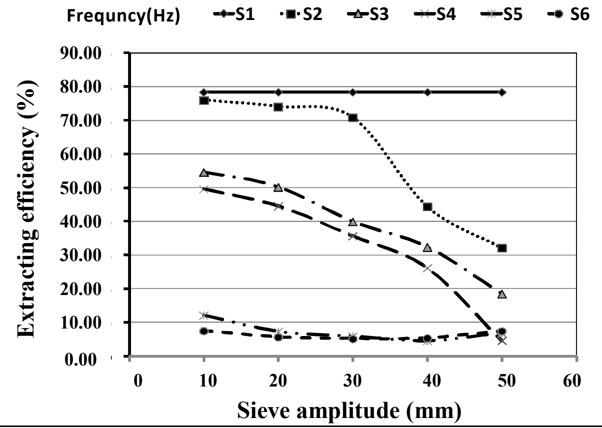
It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses



B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

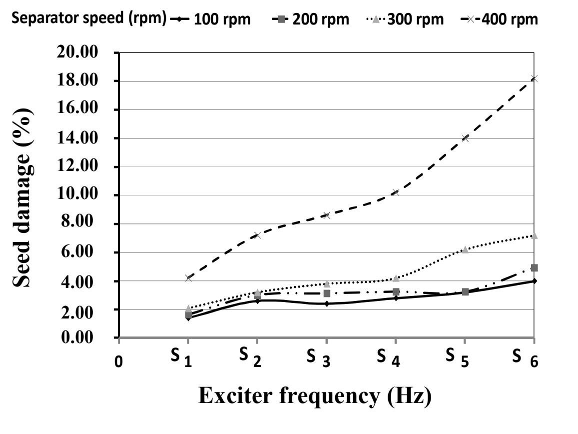
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

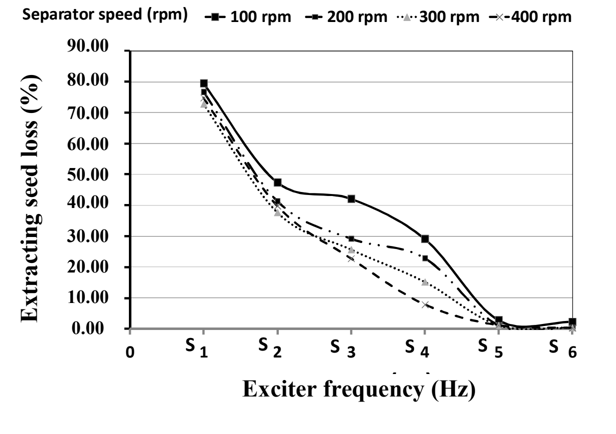
The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.





A. Effect of separator speed and exciter frequency on seed damage	B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

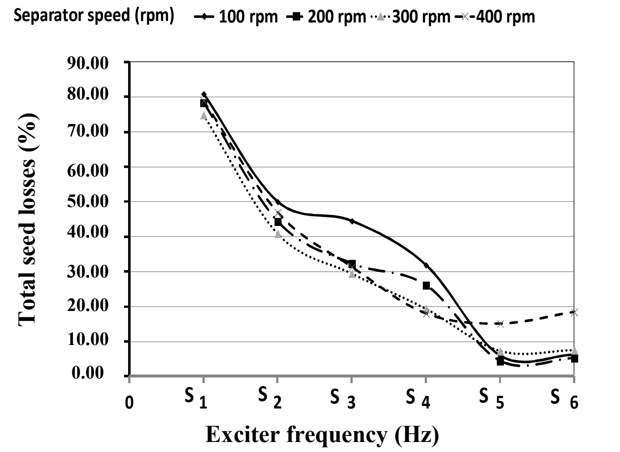
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

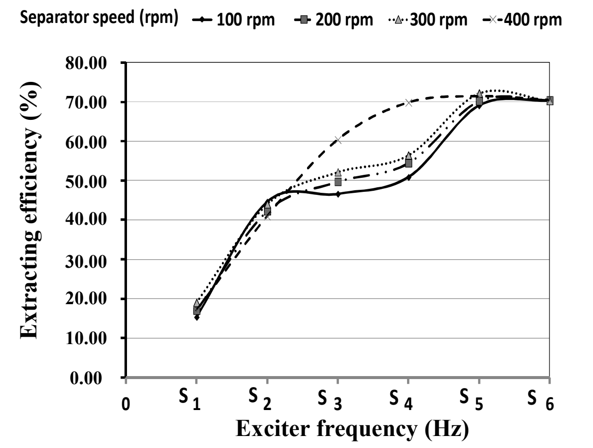
Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses



B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

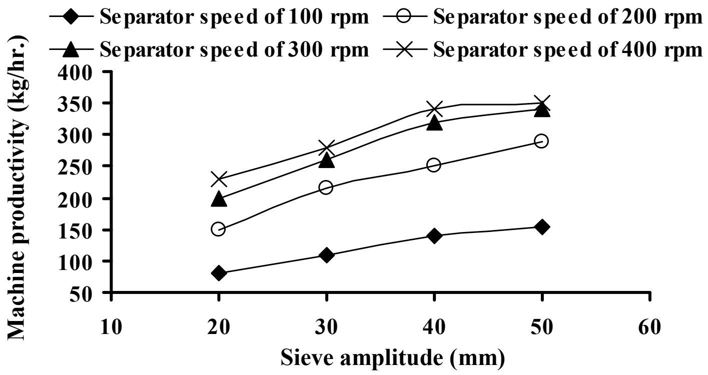


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

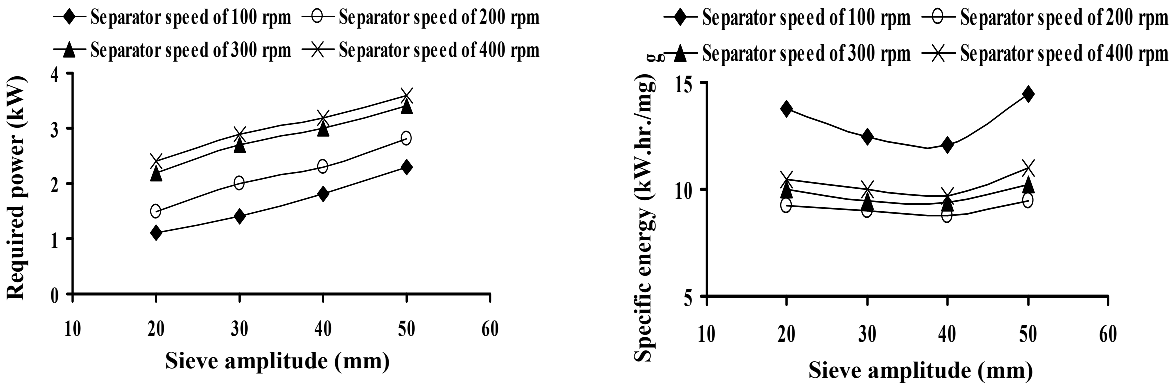


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

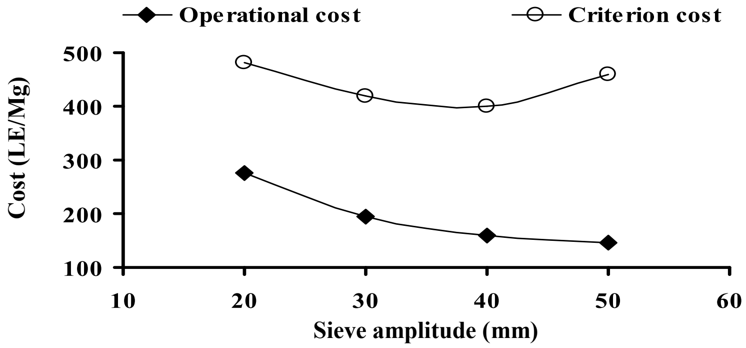


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيــــع وتقييـــــــم أداء آلـــــــــــة محليـــــــــــة الصنـــــع لتفـــريـط بـــذور الـرمــــــان

نجلاء صلاح أنور[1] - محمد محمد مراد حسن[1] - محب محمد أنيس الشرباصي[2] - طارق حسين على[3]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt
2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt
3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

* **Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

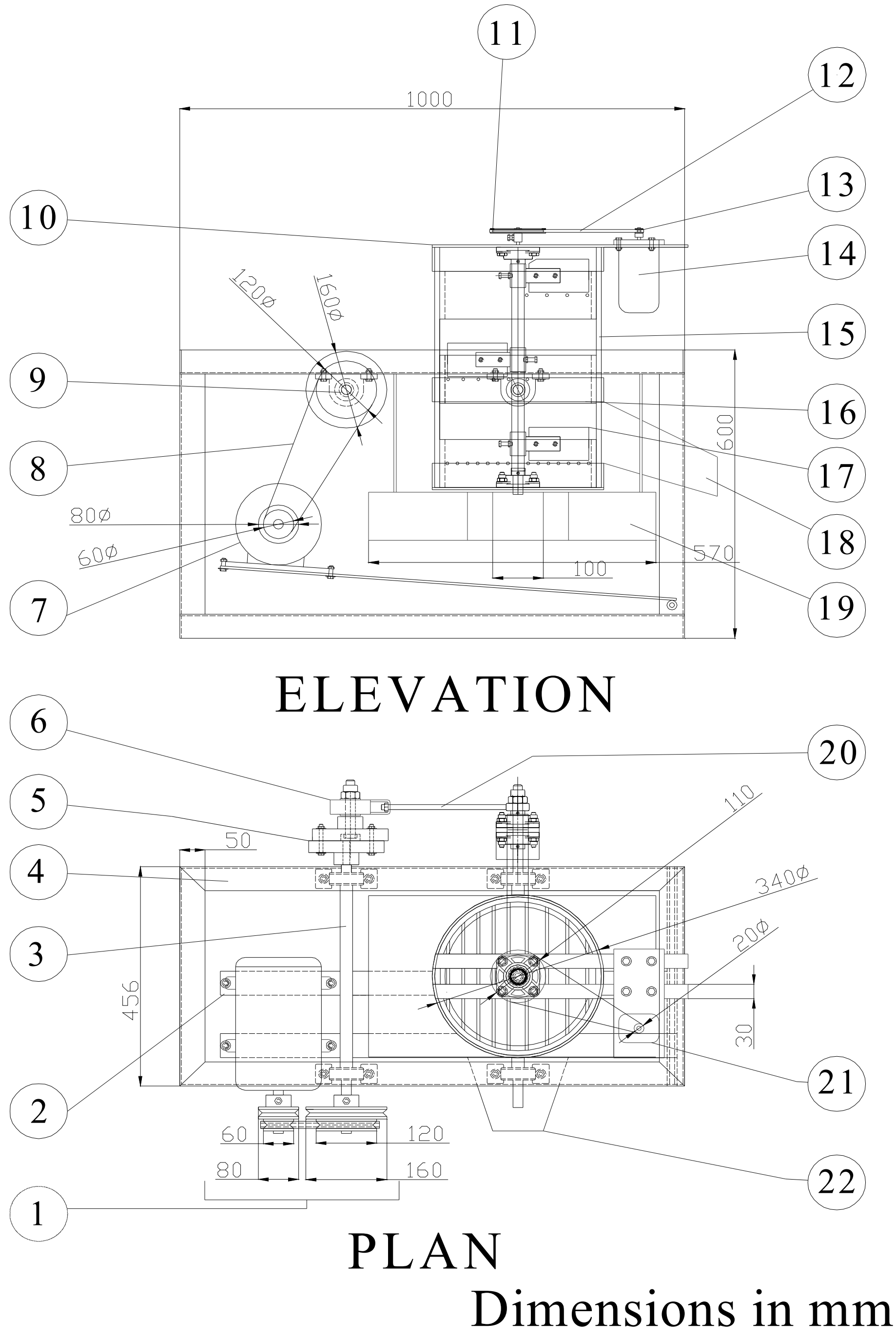
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

$\cos\theta$ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

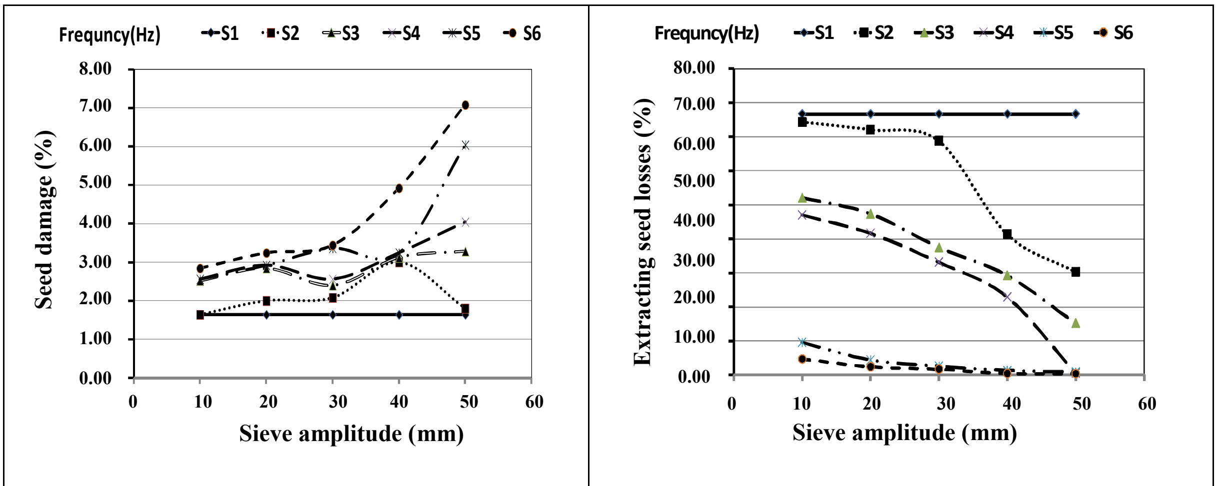
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage

B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

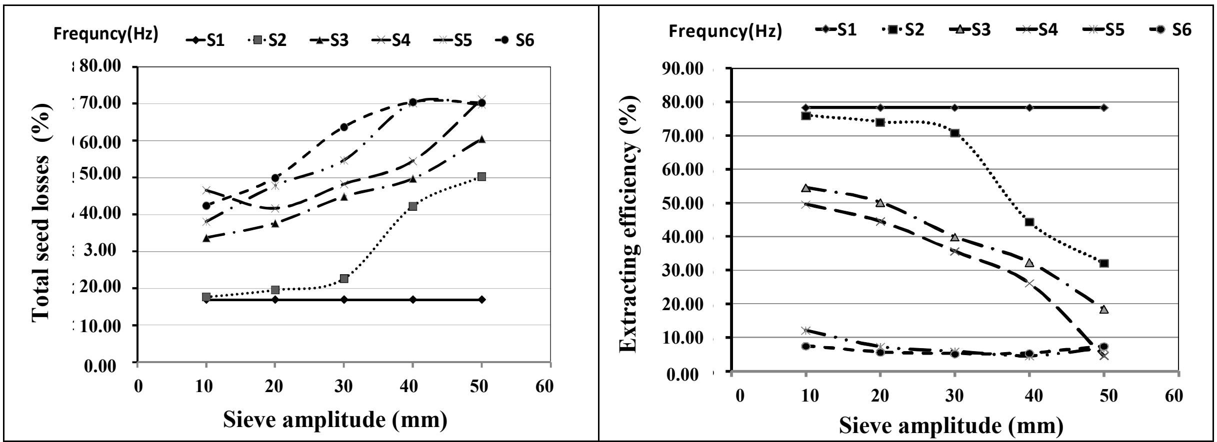
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses	B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

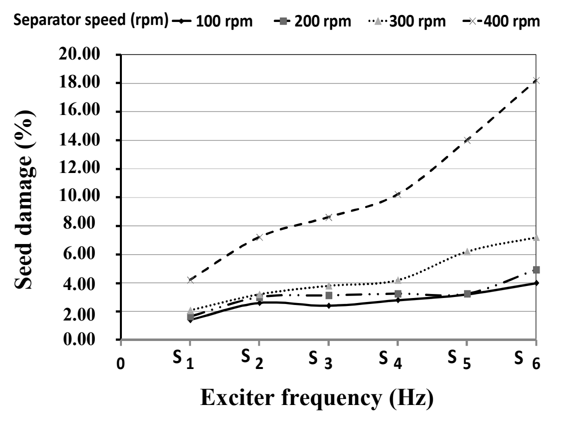
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

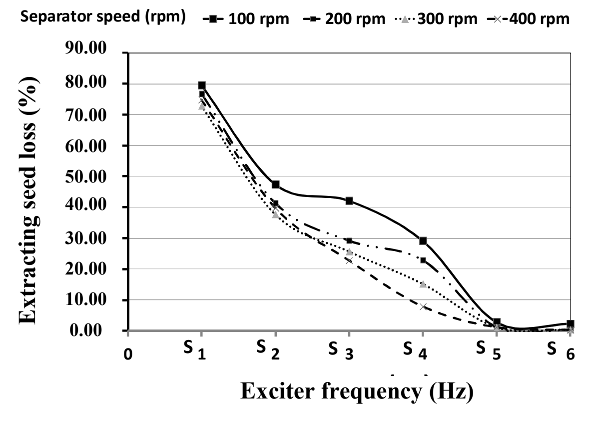
At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage



B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

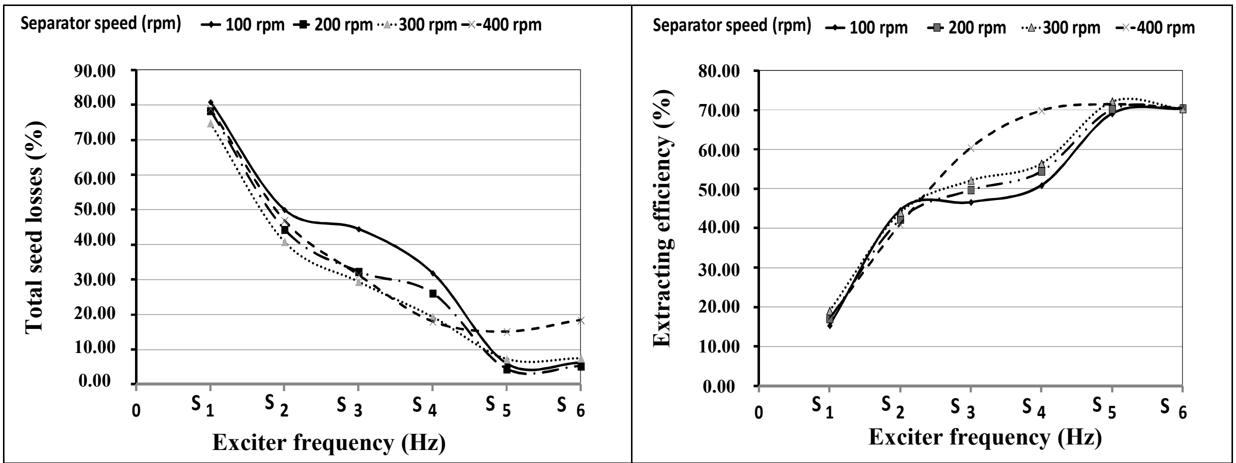
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses	B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

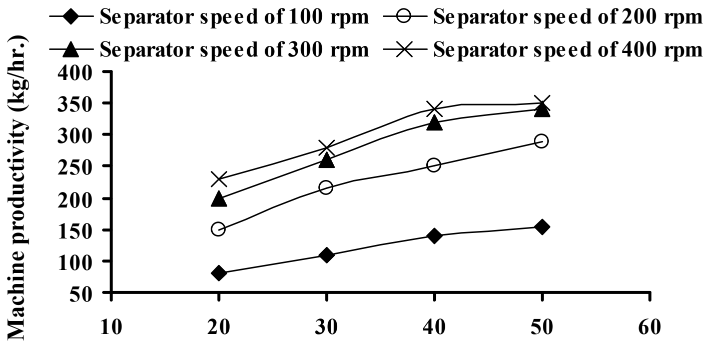


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

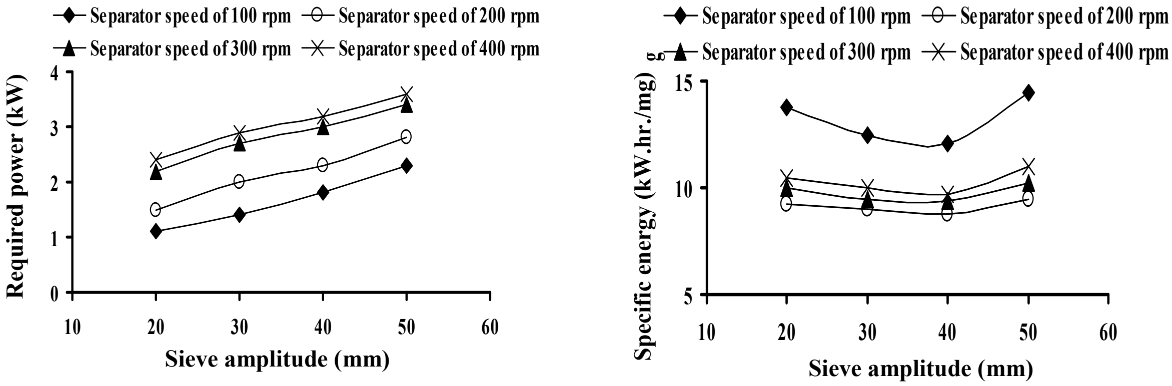


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

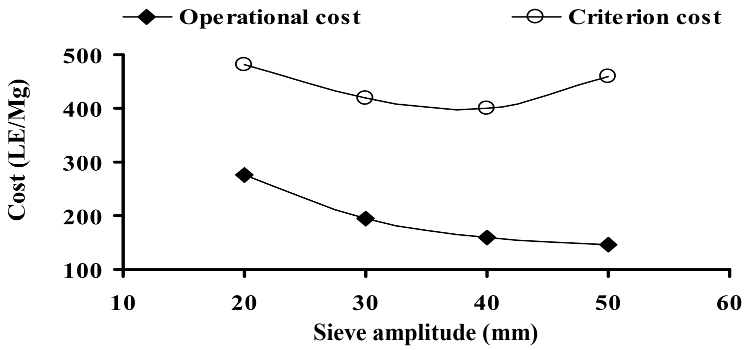


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيــــع وتقييــــــــم أداء آلــــــــــــة محليــــــــــــة الصنـــــع لتفـــريــط بـــذور الـرمـــــان

نجلاء صلاح أنور[1] - محمد محمد مراد حسن[1] - محب محمد أنيس الشرباصي[2]- طارق حسين على[3]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt

3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

* **Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

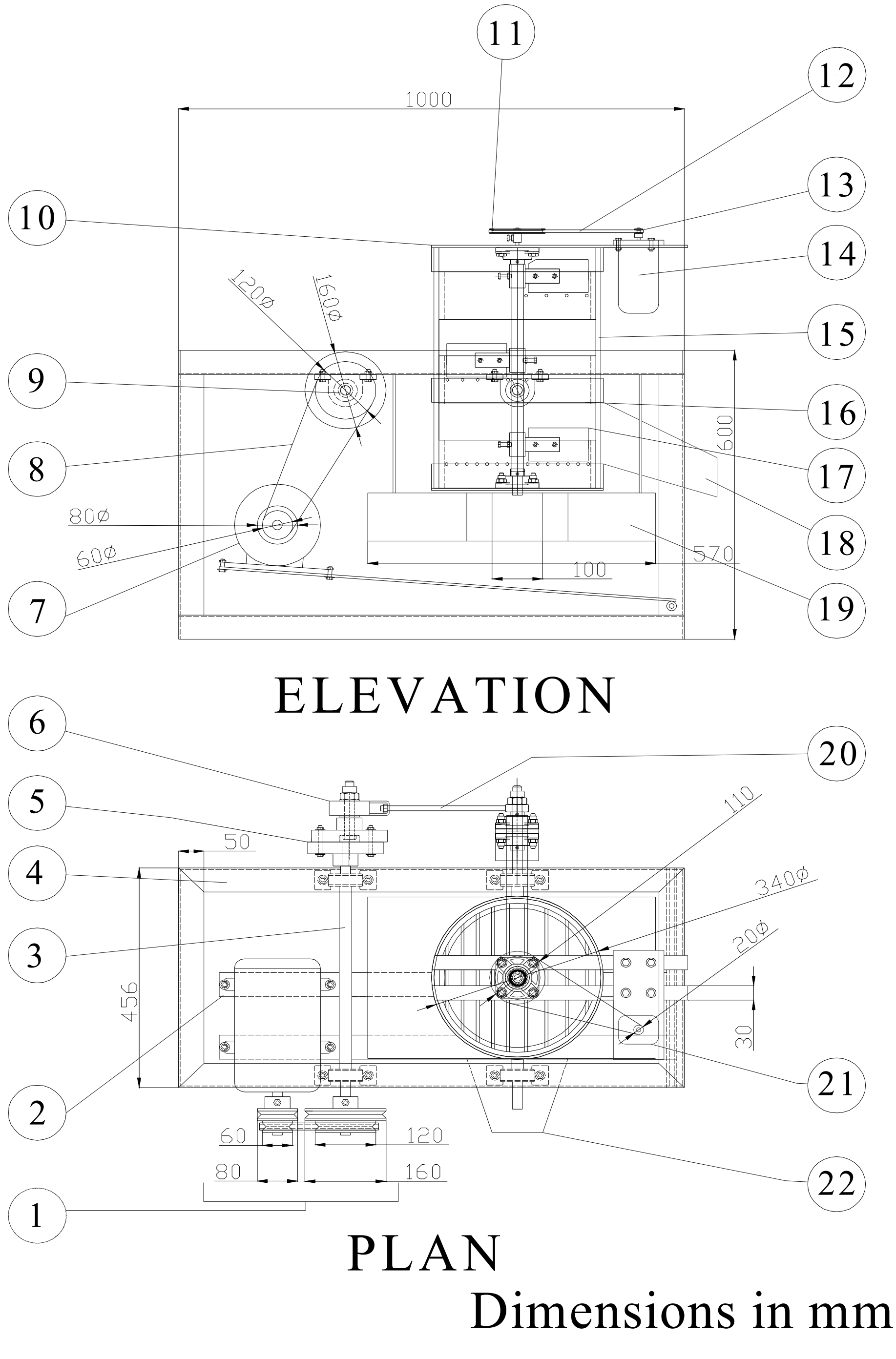
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

$\cos\theta$ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and

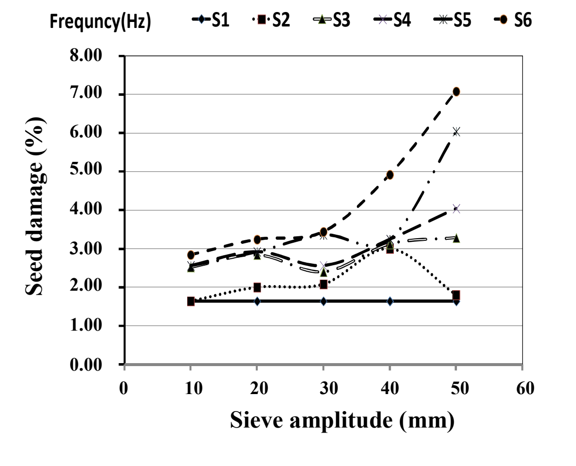
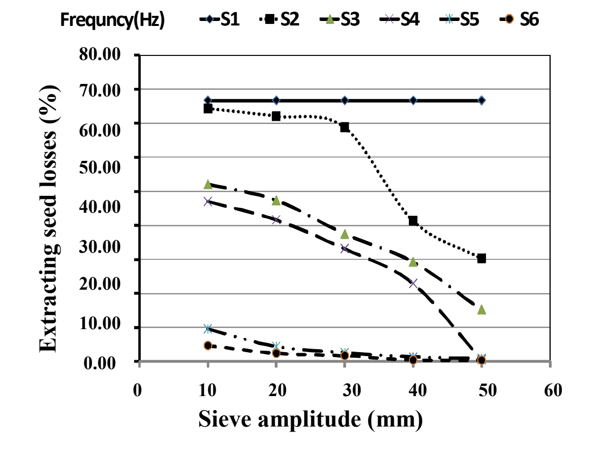
	
A. Effect of sieve amplitude and exciter frequency on seed damage	**B. Effect of sieve amplitude and exciter frequency on extracting losses**

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

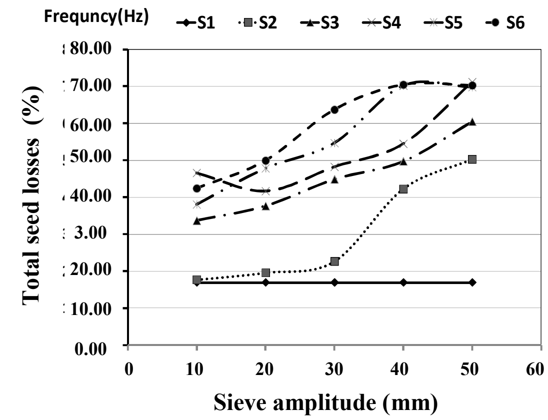
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

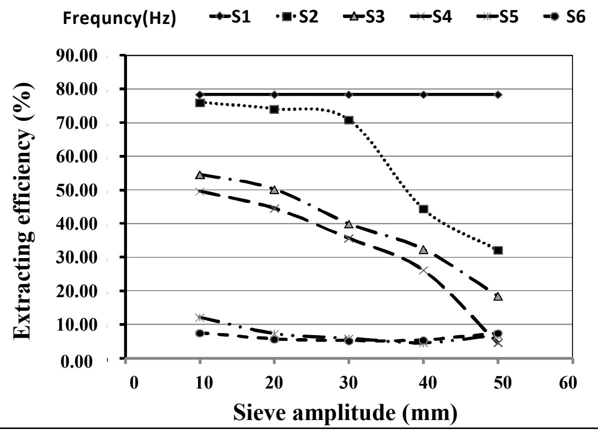
It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses



B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

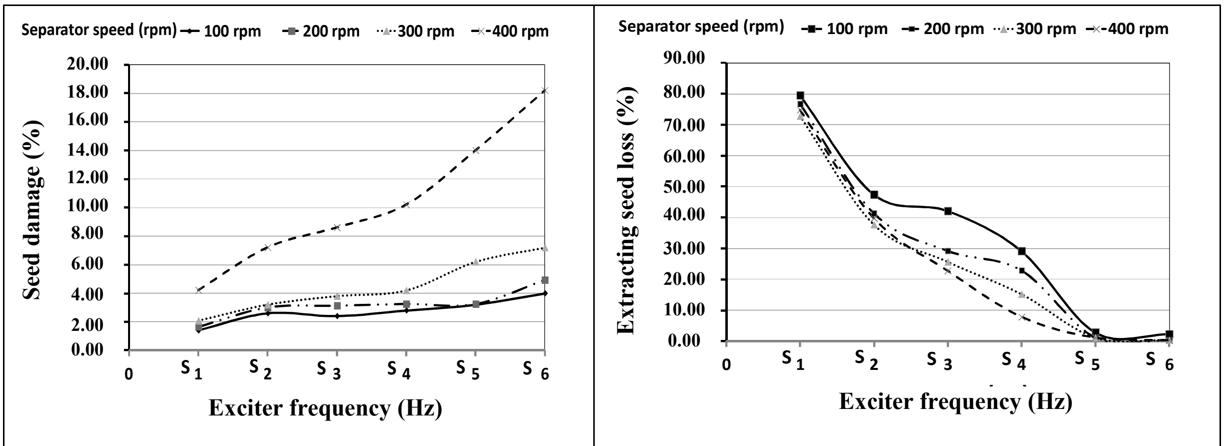
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage	B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

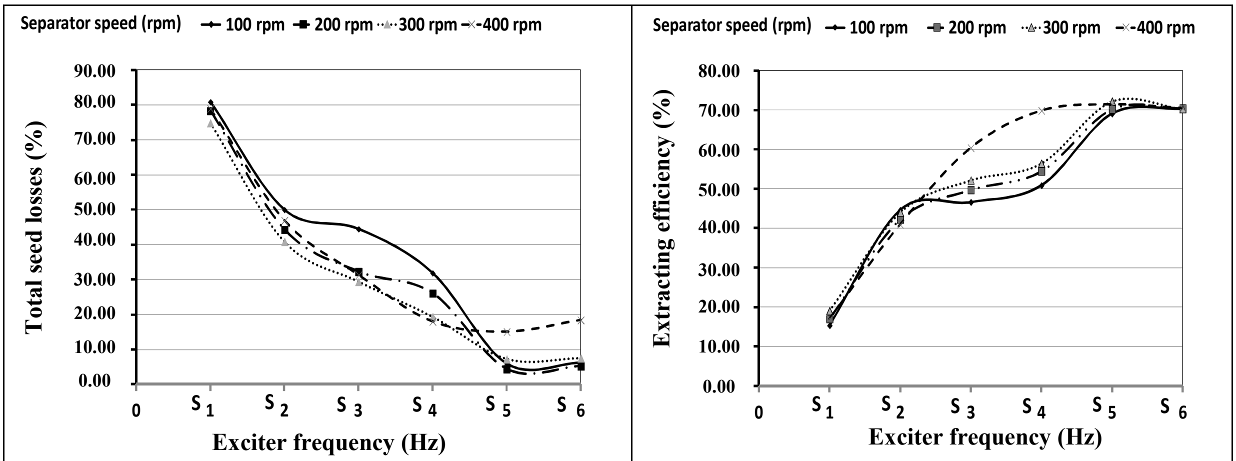
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses

B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

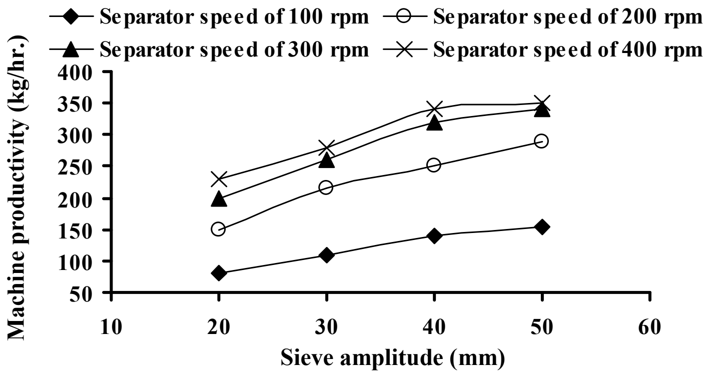


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

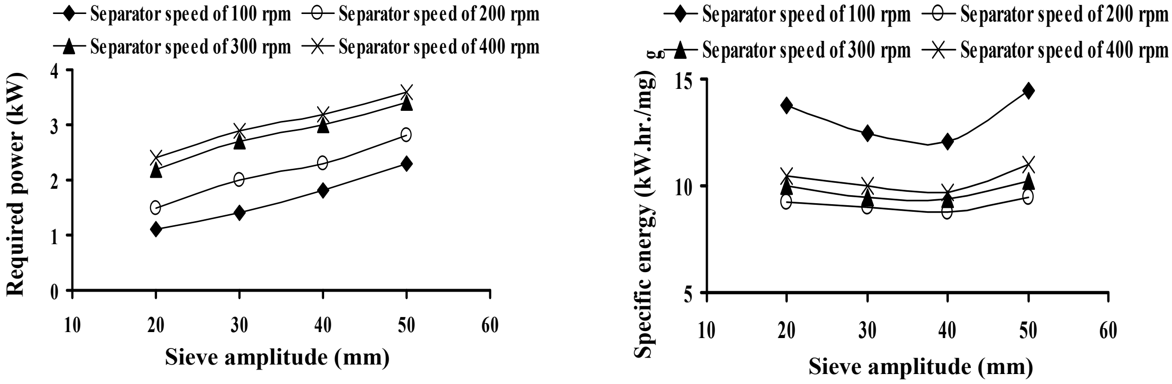


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

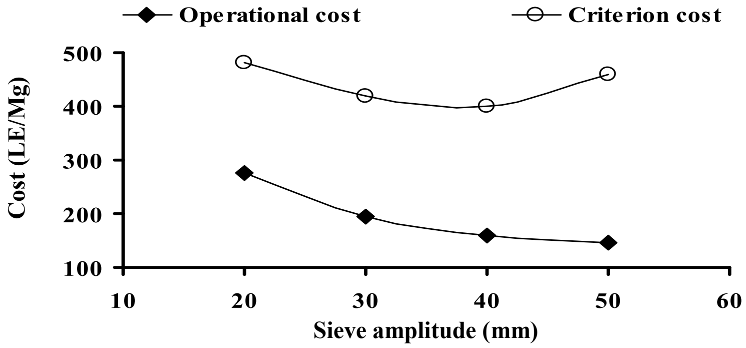


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــــع وتقييـــــــم أداء آلــــــــــة محليـــــــــة الصنـــــع لتفـــريـط بـــذور الـرمــــان

نجلاء صلاح أنور[1] - محمد محمد مراد حسن[1] - محب محمد أنيس الشرباصي[2]- طارق حسين على[3]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علـــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt
2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt
3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

* **Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

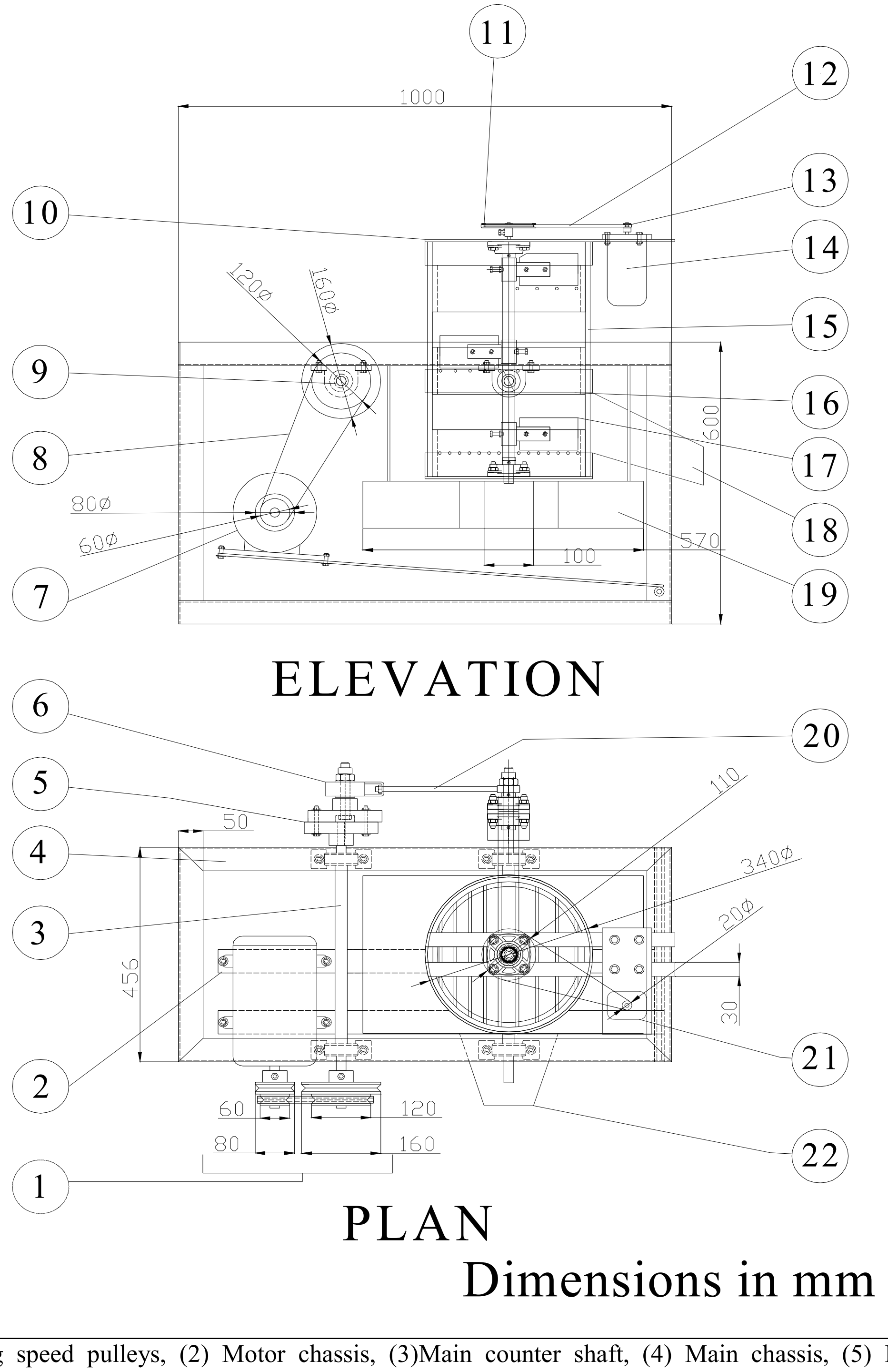
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

$\cos\theta$ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

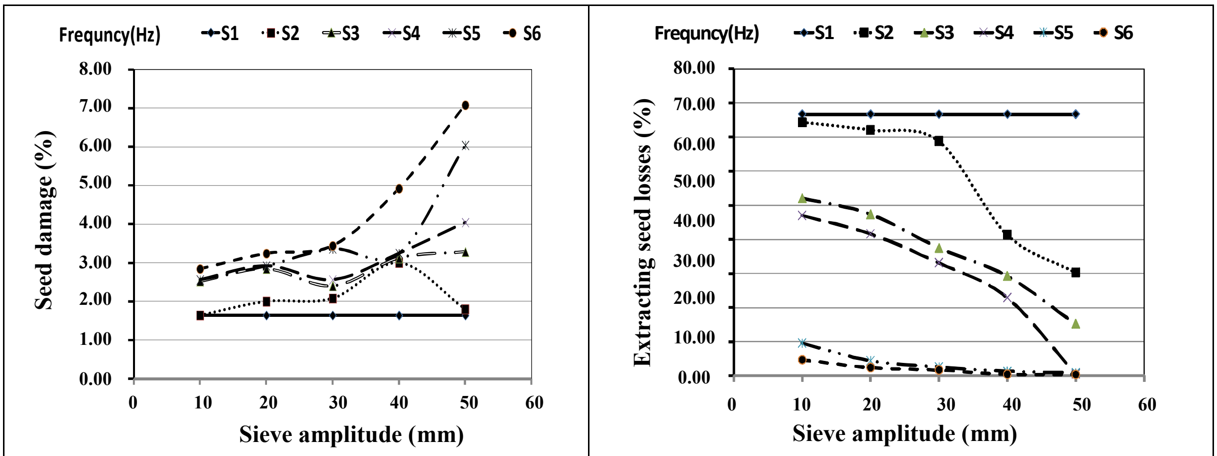
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage

B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

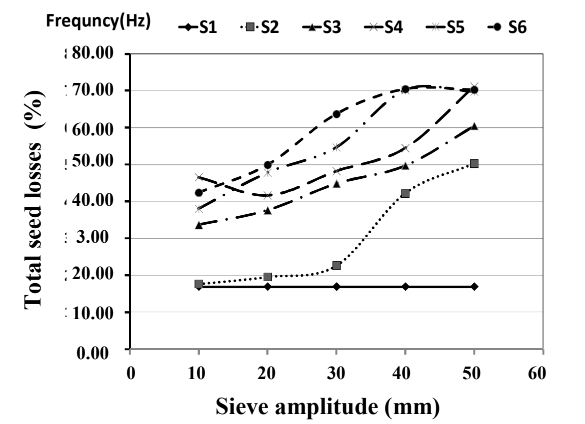
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

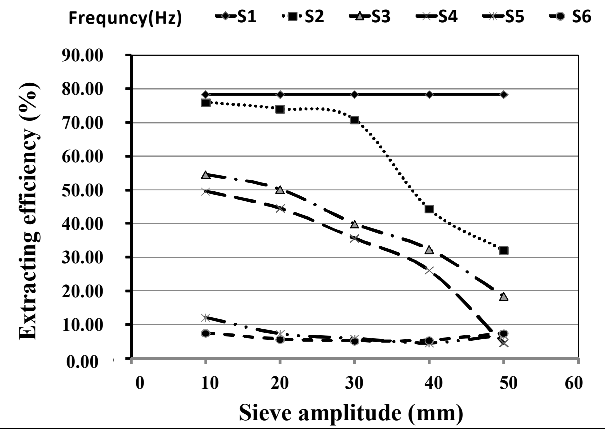
It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses



B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

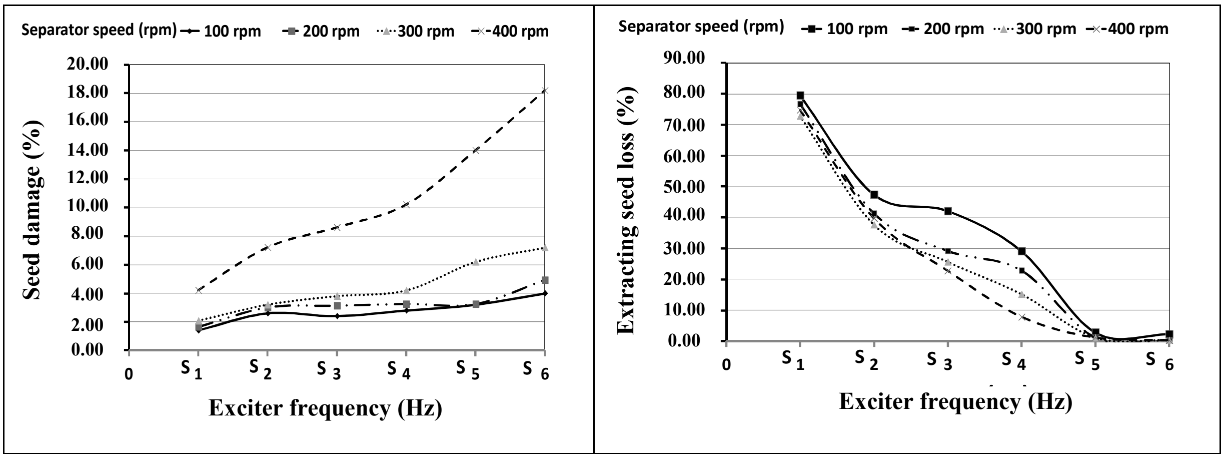
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage	B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

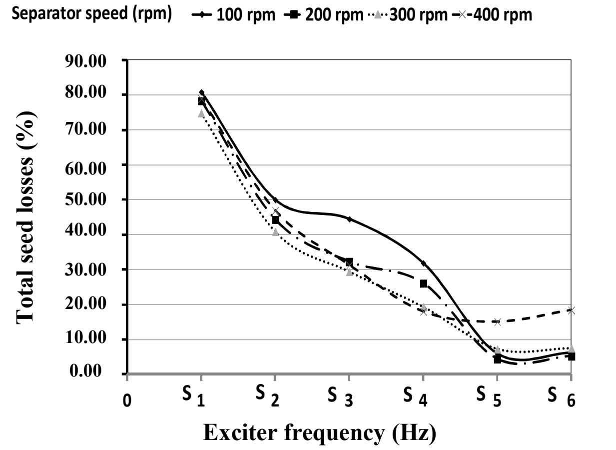
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

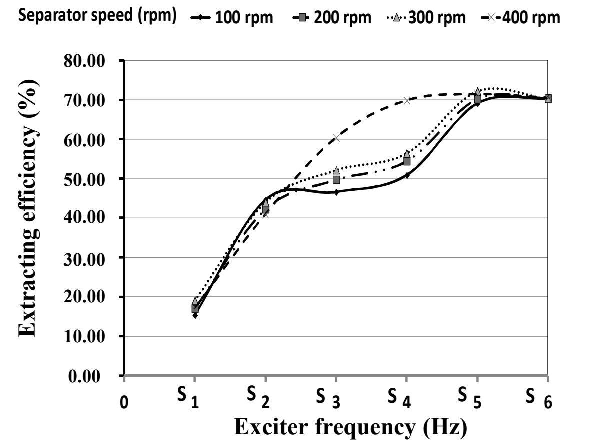
Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses



B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

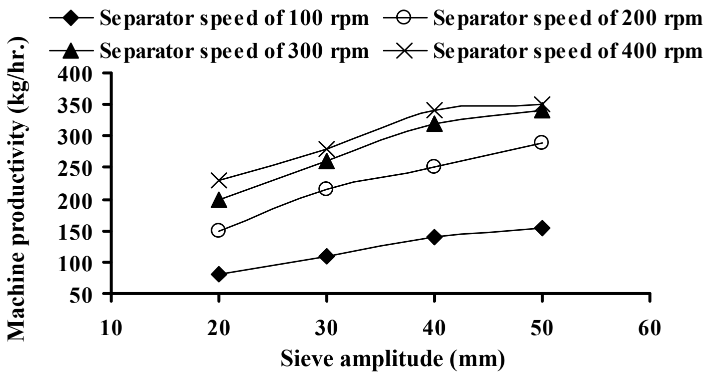


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

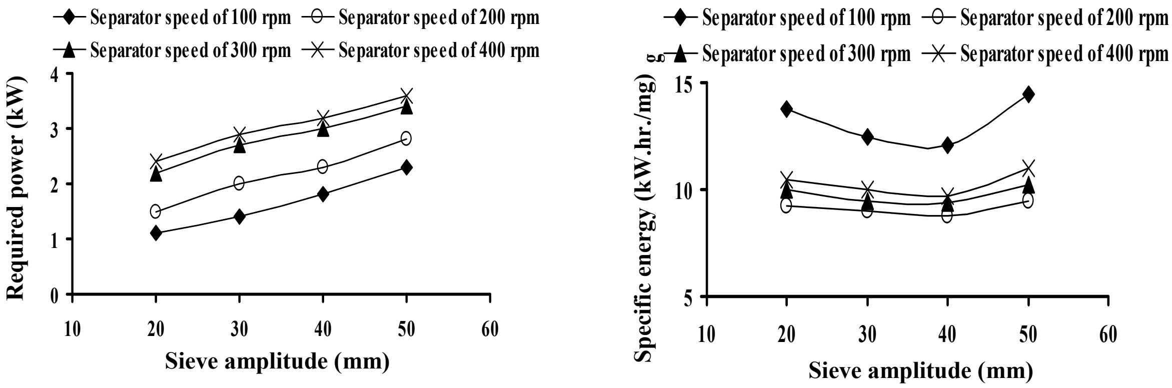


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

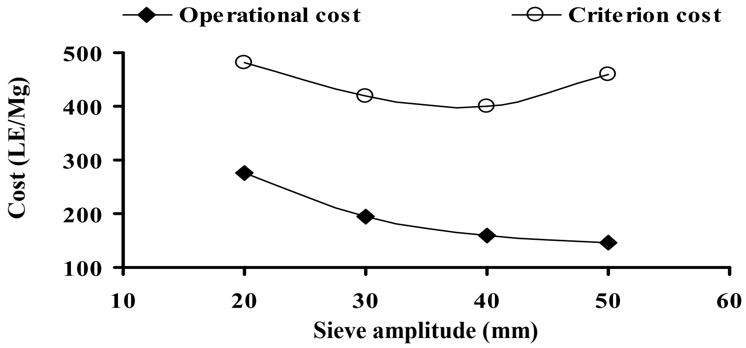


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــــع وتقييـــــــم أداء آلـــــــــــة محليـــــــــة الصنـــــع لتفـــــريـط بـــذور الـرمـــــان

نجلاء صلاح أنور[١] - محمد محمد مراد حسن[١] - محب محمد أنيس الشرباصي[٢]- طارق حسين على[٣]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علـــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt

3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

*** Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

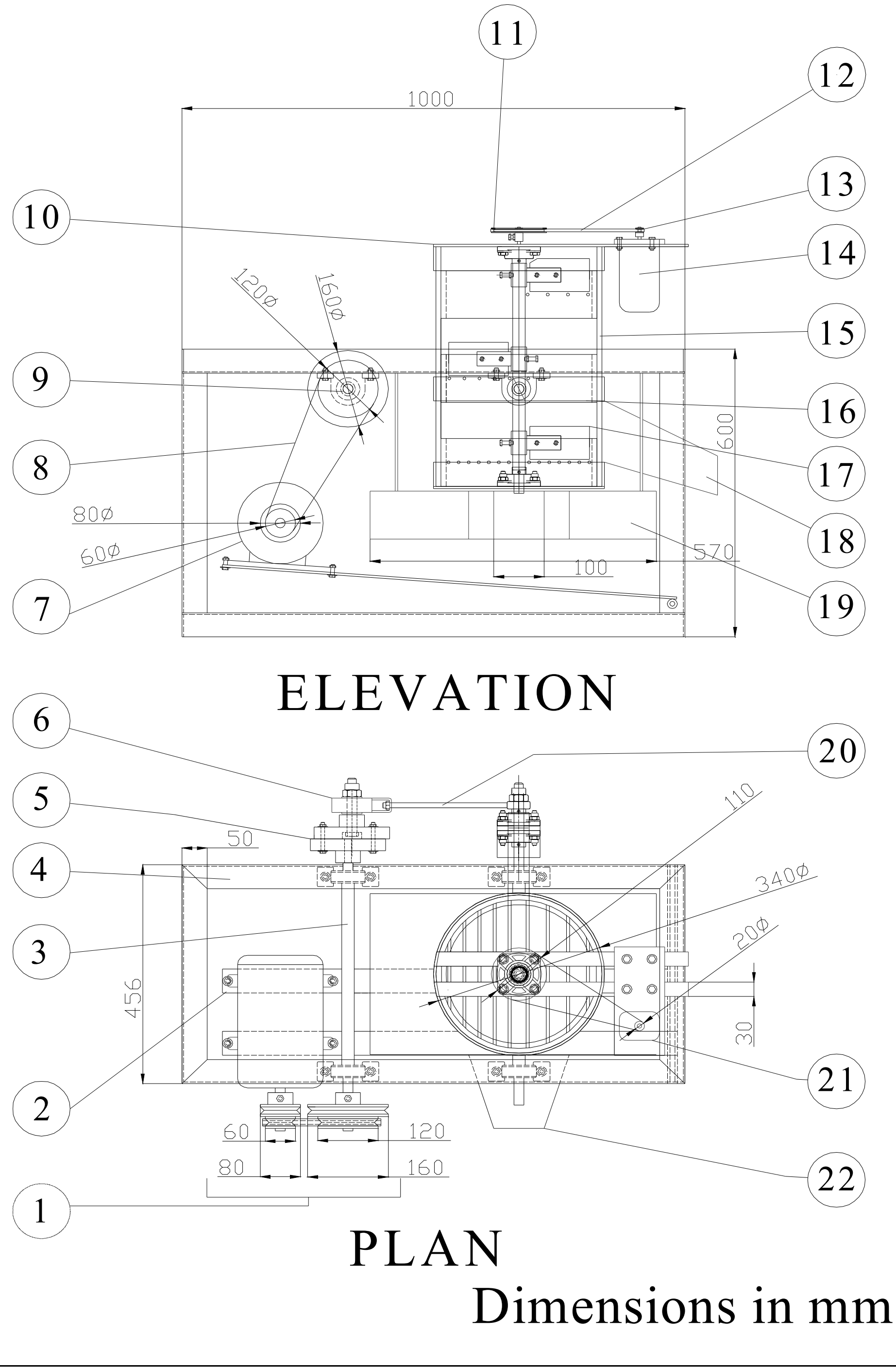
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

$\cos\theta$ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

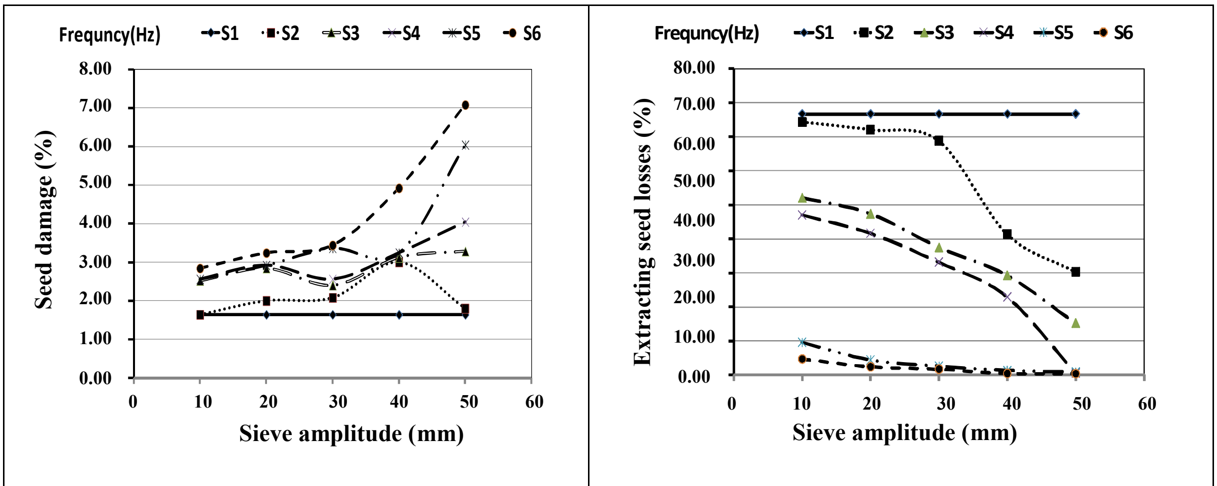
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage	B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

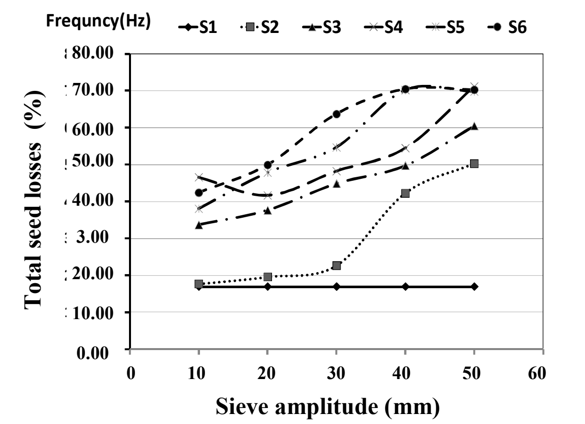
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

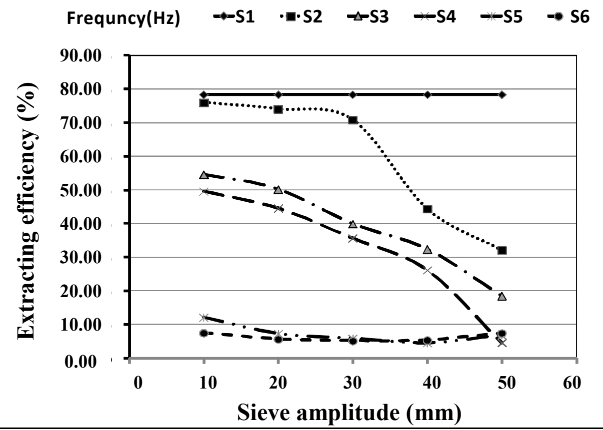
It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses



B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

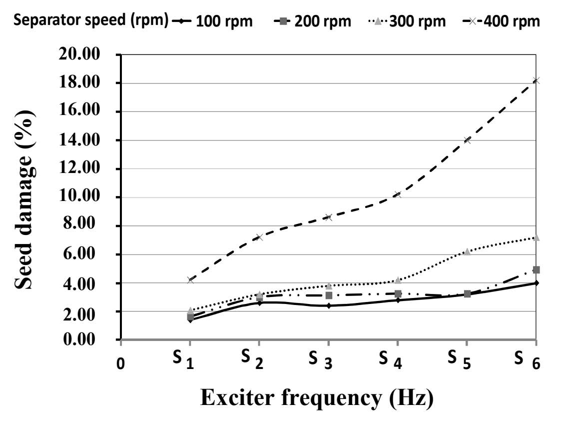
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

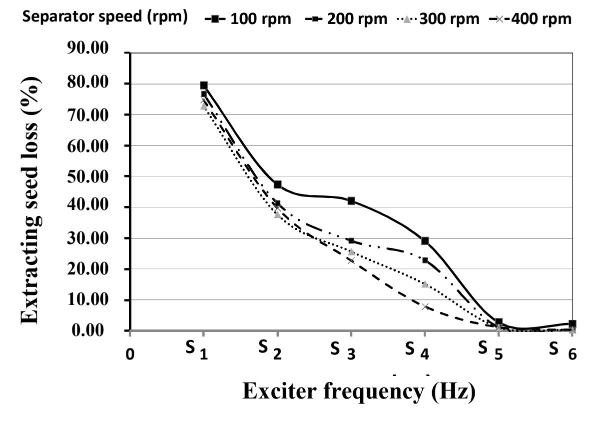
At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage



B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

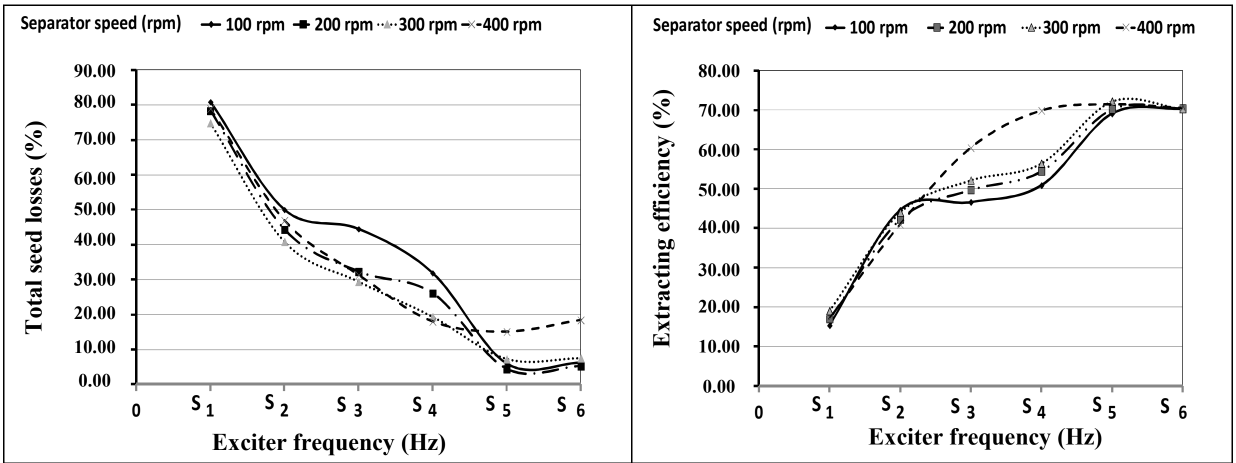
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses

B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

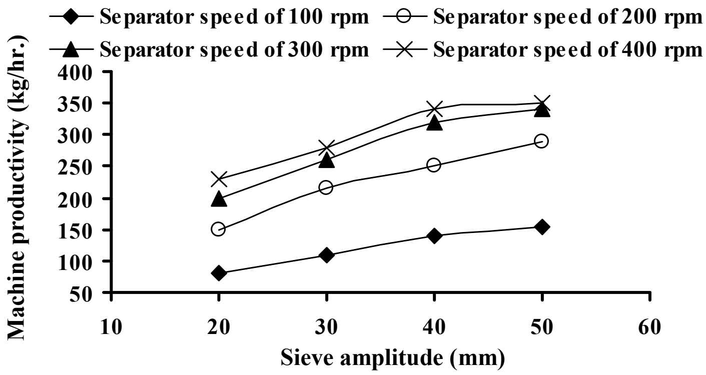


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

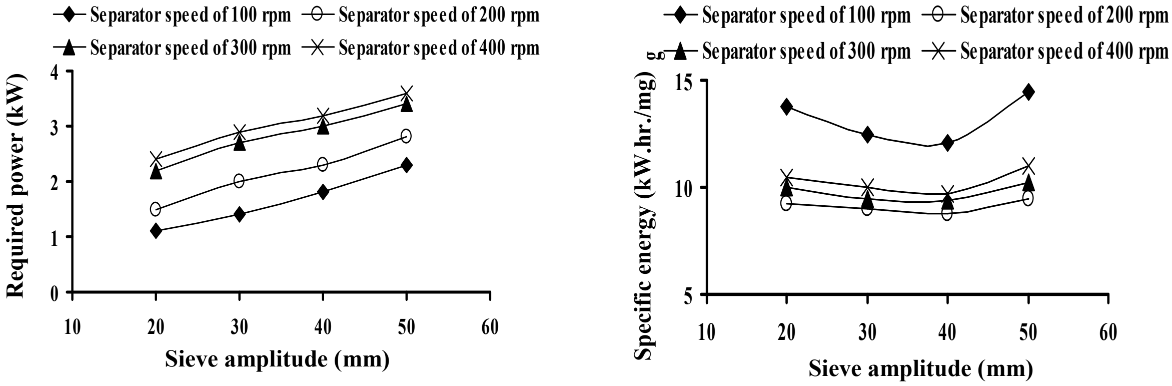


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

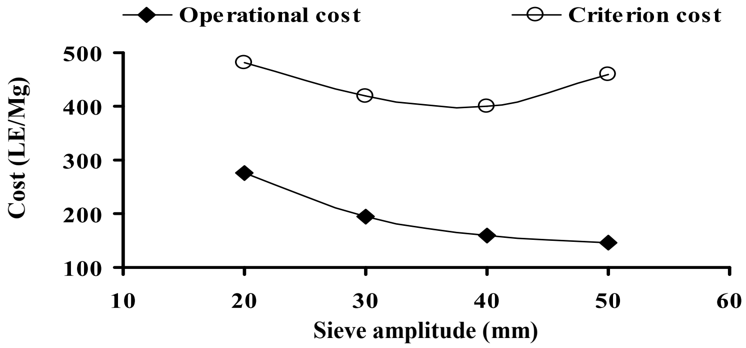


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيــــع وتقييـــــــم أداء آلـــــــــــة محليـــــــــــة الصنــــع لتفـــريـط بـــذور الـرمــــان

نجلاء صلاح أنور[1] - محمد محمد مراد حسن[1] - محب محمد أنيس الشرباصي[2] - طارق حسين على[3]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt

3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

* **Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

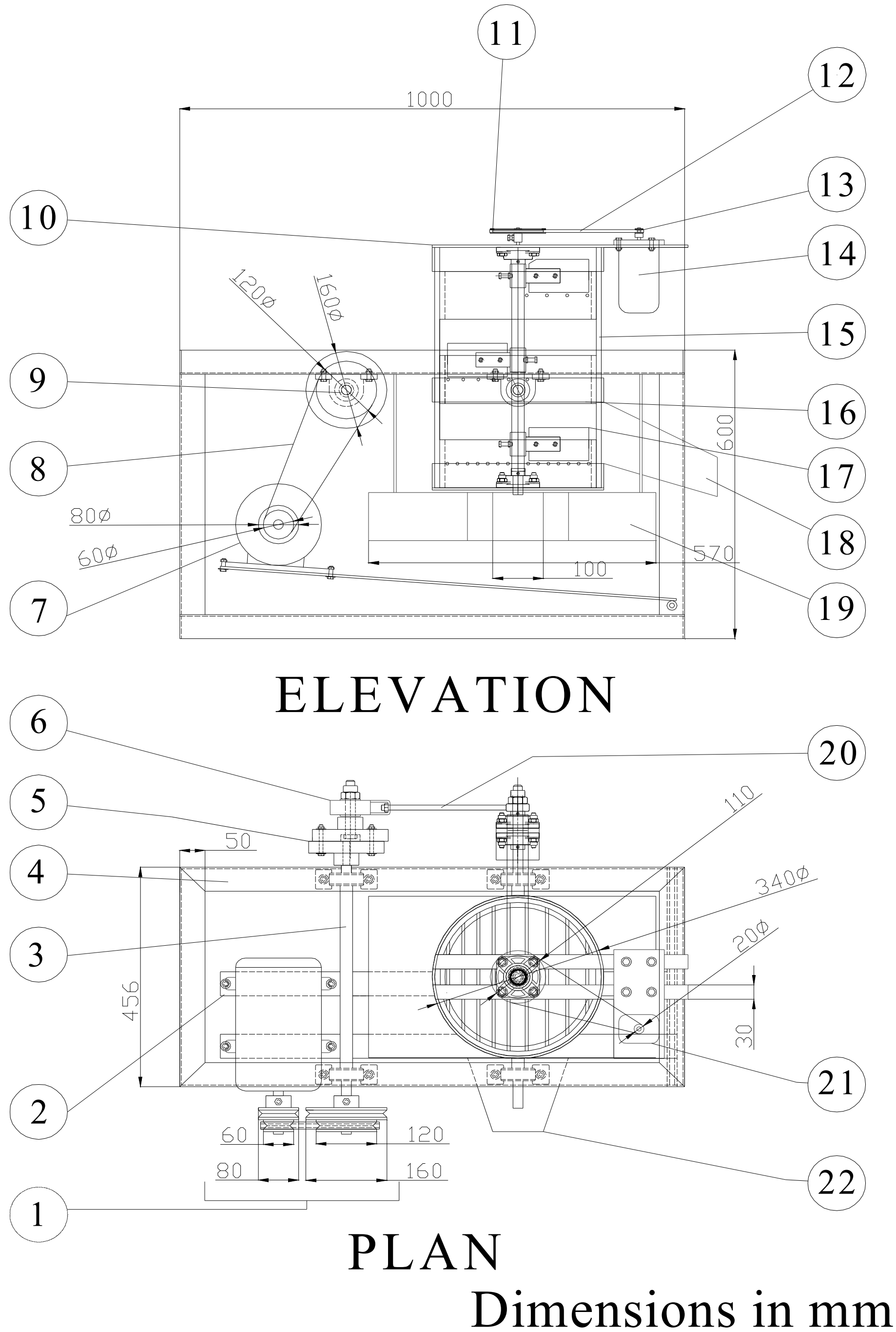
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

$\cos\theta$ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

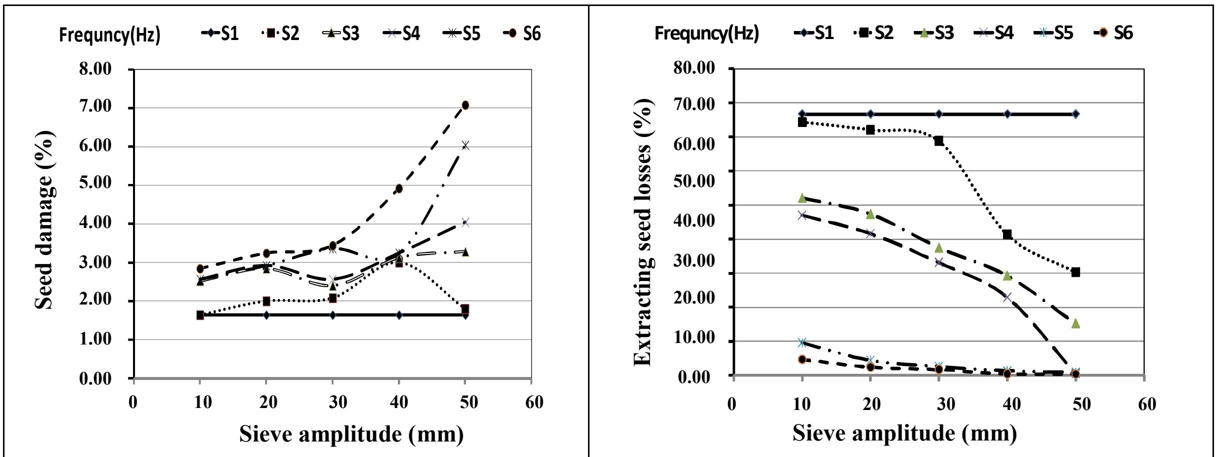
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage	B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.

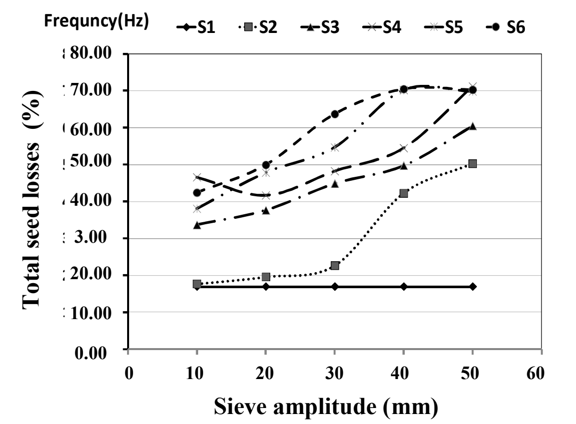
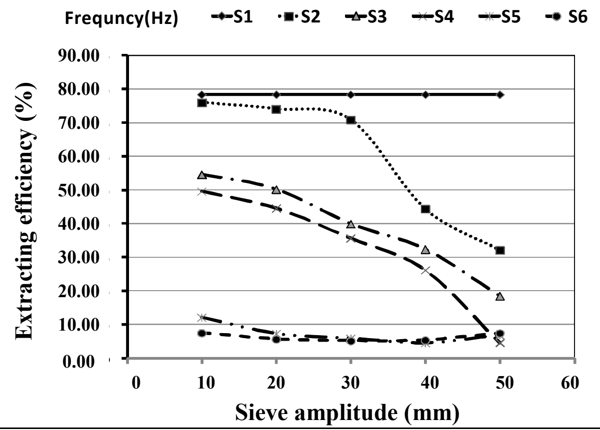
	
A. Effect of sieve amplitude and exciter frequency on total seed losses	**B. Effect of sieve amplitude and exciter frequency on extracting efficiency**

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

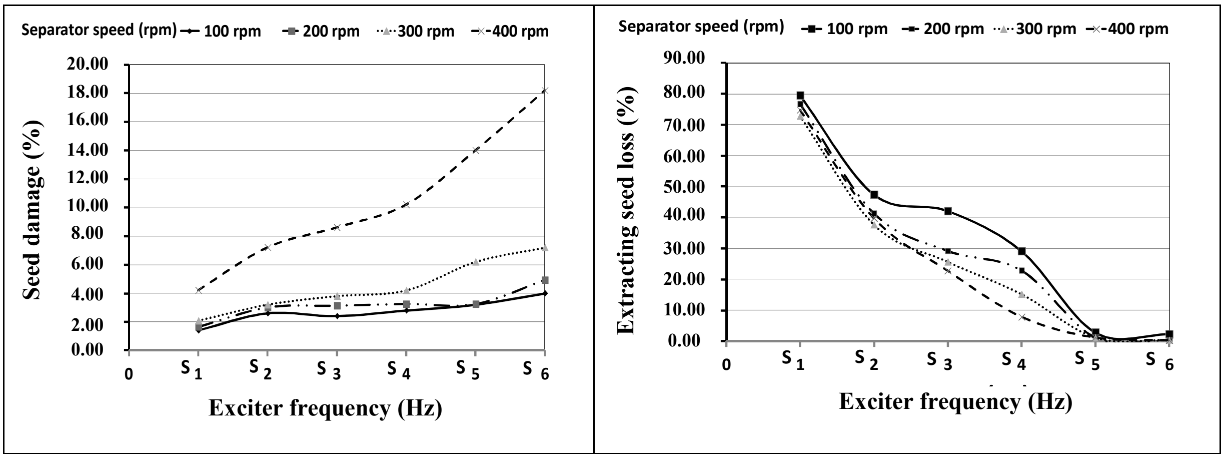
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage	B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

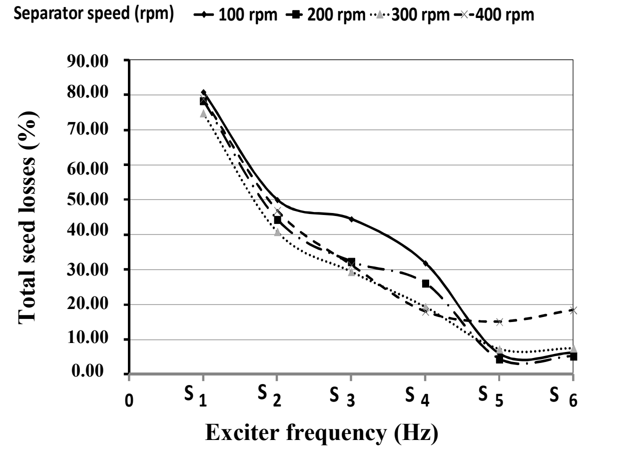
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

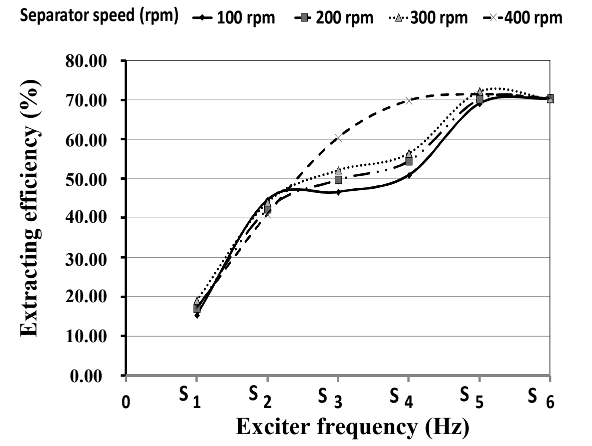
Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm



A. Effect of separator shaft speed and exciter frequency on total seed losses



B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

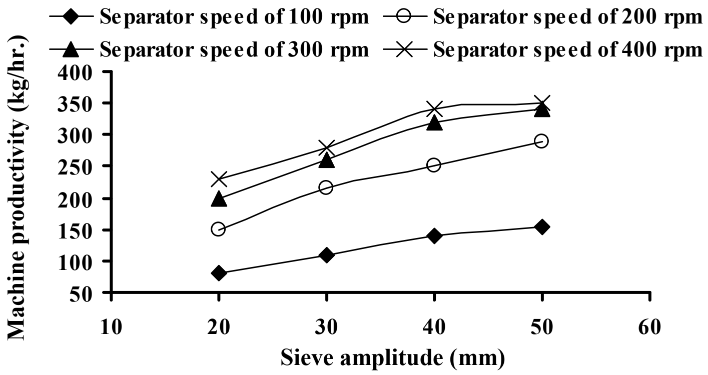


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz

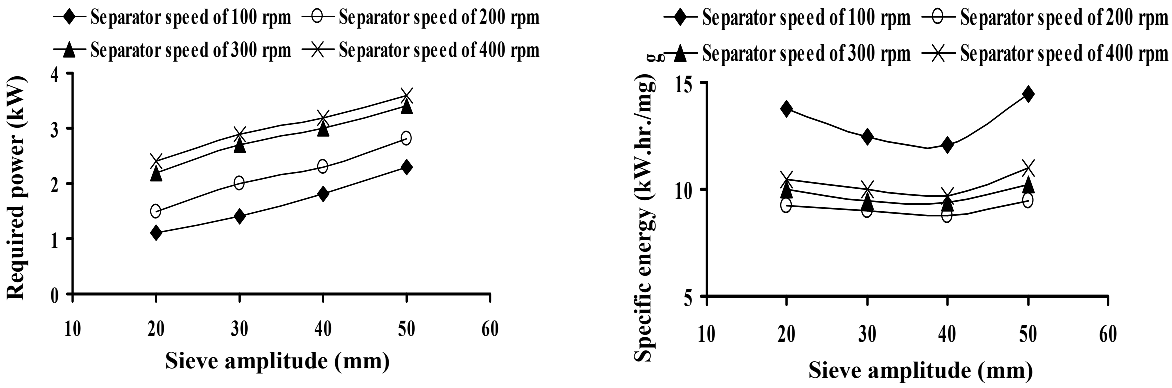


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

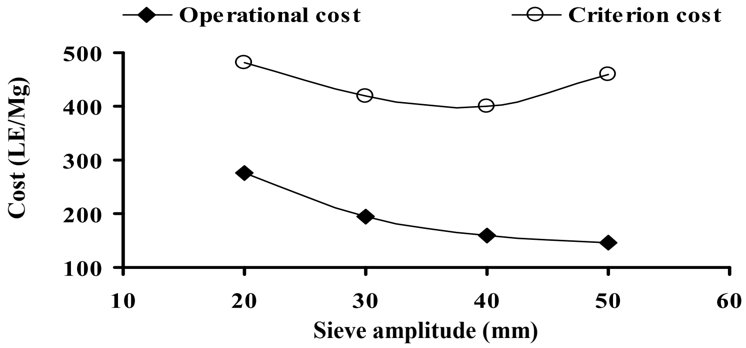


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــــع وتقييـــــــم أداء آلـــــــــــة محليـــــــــة الصنـــــع لتفـــريـط بـــذور الـرمــــــان

نجلاء صلاح أنور[1] - محمد محمد مراد حسن[1] - محب محمد أنيس الشرباصي[2]- طارق حسين على[3]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوراني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر	أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.
٢- أ.د. محمود مصطفى علــي	أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.

Zagazig J. Agric. Res., Vol. 46 No. (1) 2019 51-63

Soil Science and Agricultural Engineering

http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

MANUFACTURING AND PERFORMANCE EVALUATION OF A LOCAL MACHINE FOR EXTRACTING POMEGRANATE SEEDS

Naglaa S. Anwar[1*], M.M. Morad[1], M.M.A. El-Sharabasy[2] and T.H. Ali[3]

1. Agric. Eng. Dept., Fac. Agric., Zagazig Univ., Egypt

2. Agric. Eng. Dept., Fac. Agric., Damita Univ., Egypt

3. Agric. Eng. Dept., Agric. Eng. Inst., Agric, Res. Cent., Egypt

Received: 03/12/2018; Accepted: 15/01/2019

ABSTRACT: An innovated machine was manufactured for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage. The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh by vibration. Experiments were carried out to study some different operating parameters which were six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2 and 121.4 Hz respectively, five different sieve amplitudes of 10, 20, 30 40 and 50 mm and four different separator shaft speeds of 100, 200, 300 and 400 rpm, affecting the performance of the manufactured machine. The machine performance was evaluated in terms of machine productivity, total seed losses, extracting efficiency, specific energy and criterion cost. The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions of 101.2 Hz exciter frequency, 40 mm sieve amplitude and 200 rpm separator speed.

Key words: Pomegranate extracting, pomegranate deseeding, pomegranate.

INTRODUCTION

Pomegranate (*Punica grantum* L.) is one of the oldest known fruits found written and mentioned in artifacts of many cultures and religions. The fruit is rich in nutrient dense and has very high levels of antioxidants. Pomegranate seeds extracting for juice, on the other hand the peel was used for extracting some medical compounds. In Egypt, pomegranate is considered as one of the most important horticulture plants cultivated in reclaimed areas. Pomegranate seeds are a very rich source of vitamins, proteins, fats, amino and fatty acids.

Ministry of Agriculture and Land Reclamation (2016) mentioned that in Egypt, the total cultivated area of pomegranate was 32995 fad., with productivity of 8.15 Mg/fad., and the total production was 269070 Mg.

Morton (1987) developed a machine for separation of arils from wild pomegranate, which is made of stainless steel centrifugal wire basket moves at a speed of 400 rpm. Mature pomegranate fruits are halved manually and fed into the rind mechanically because of centrifugal action. The rotor cum seed separator was equipped with 80 Watt 220 Volt AC exhaust fan. **Safa and Khazaei (2003)** indicated that pomegranate fruits contain considerable amounts of seeds ranging between 518 to740 g/kg of fruit weight depending on the cultivar. Seeds were the edible part of pomegranate fruit that represents 50–70% total weight of the fruit. It was composed of 10% sugar (mainly fructose and glucose), 1.5% organic acids (principally ascorbic acid, citric, and malic acid) and bioactive compounds such as anthocyanins and other phenolic compounds. **Javad *et al.* (2008)** employed an impingement method for extracting

* **Corresponding author: Tel.** : +201025717893
E-mail address:naglasalah95@yahoo.com

pomegranate seeds. The method was based on opening the fruit, separating it into two halves, and extracting the seeds with the help of pressurized air-jets. The best results of extraction of pomegranate seeds were obtained when the nozzle travelled in a figure of eight route. At 500-kPa air pressure, a nozzle diameter of 3.5 mm, and 4 passes of the nozzle the percentage of extracted seeds was equal to 86%. **Sarig *et al.* (2009)** developed a novel method and a system, which enable opening the fruit without cutting, extracting the arils with minimum damage, separating the arils from extraneous materials and delivering clean arils to a packaging machine. A Beta-site machine has been constructed and has undergone extensive testing. The results obtained so far indicate that it is possible to extract 1.5 to 2 Mg of arils a day in a one-lane machine operated by 1-2 persons with an extraction efficiency of 95% and < 5% mechanical damage. **Thakur *et al.* (2011)** mentioned that hand tool for easy separation of seeds from pomegranate depends on the cultivars and conditions of the pomegranate fruit. The separation efficiency was higher in case of fresh fruit in comparison to the cold stored fruits. The tool was capable to break the pomegranate fruit in a manner of two irregular halves, separates seeds about 35-40% during the breaking process and makes the remaining seeds loosen which allows for easy separation further by finger tips, for easy extraction of seeds. So, the local market is needed a machine for extracting pomegranate seeds suitable for exportable seeds. This requires researches and practical work to manufacture a machine for extracting pomegranate seeds with high efficiency and minimum energy and cost.

Therefore, the aim of the present research is to manufacture a local machine, which applies the theory of vibration to extract pomegranate seeds. This aim was planned to be realized through the following stages:

- Manufacturing an innovated machine for extracting pomegranate seeds distinguished of high productivity, simple design and low seed damage.
- Evaluating the performance of the manufactured extracting machine technically and economically.

MATERIALS AND METHODS

The main experiments were carried out in Agricultural Engineering Institute workshop, Dokki, Cairo, Egypt. Agricultural Research Center (ARC), Ministry of Agriculture.

Materials

Pomegranate fruits

The experiments were carried out on a common cultivar of pomegranate (Manfaluti). The common cultivar of pomegranate was selected from a pomegranate private farm in Ismailia Governorate, Egypt. The maximum fruit length was 70-80 mm, the maximum diameter was 80-90 mm, while the maximum fruit mass was 340-420 g.

The manufactured extracting machine

A local machine, suitable for extracting pomegranate seeds, was manufactured from low cost, local material to overcome the problems of high power and cost requirements under the use of the imported machines.

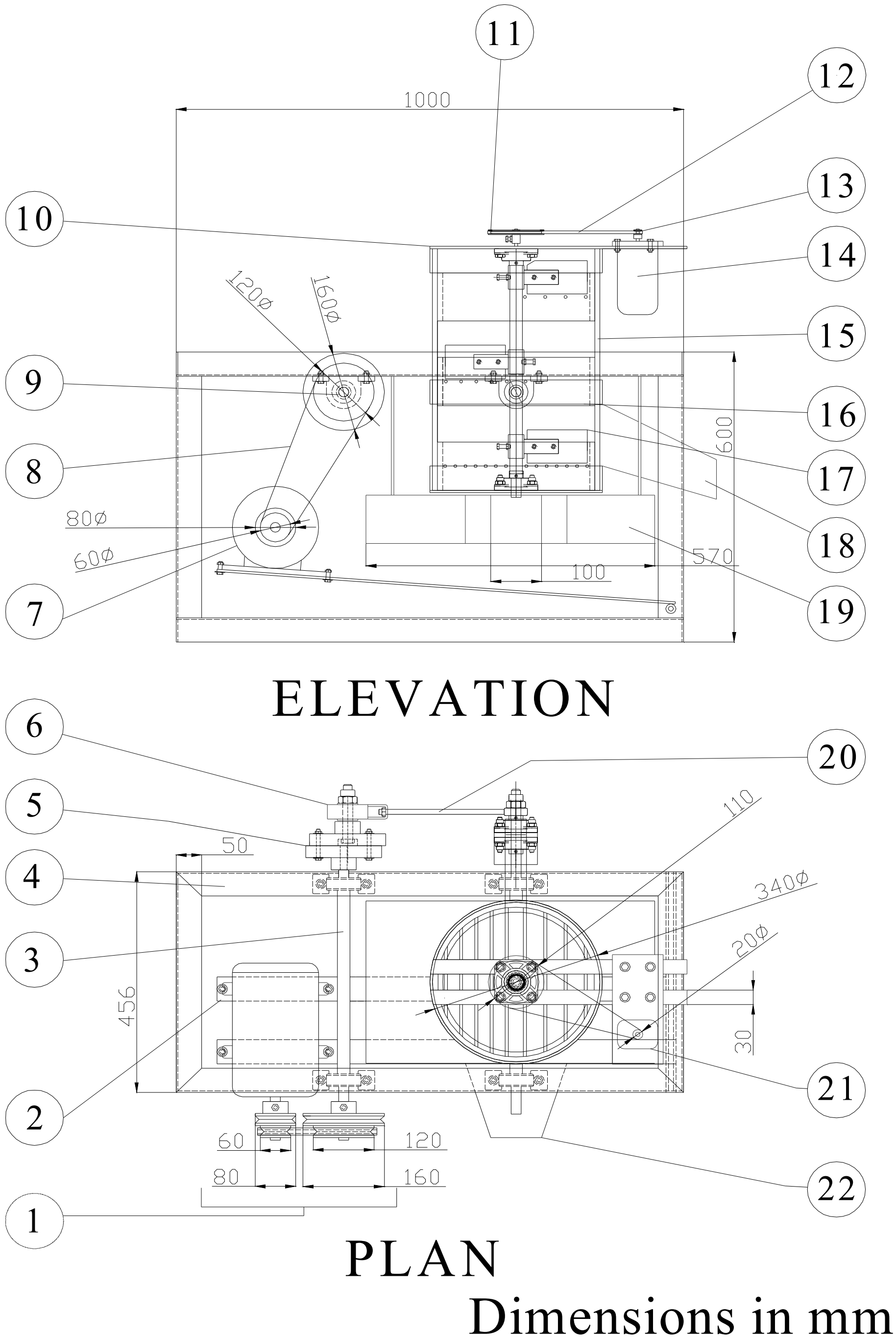
The extracting machine was depending on an innovative system to extract the seeds from the peels and flesh. The fruit halves were placed in a reciprocated plastic pan equipped with three different size sieves to separate the seeds from the peels and white flesh. The pan was equipped with three beaters to clean the sieves. The third beater that located in the bottom of the reciprocating pan was designed to clean the final sieve and throw the peels from side outlet orifice. While the cleaned seeds were dropped from the third sieve to a collecting seed pan. Fig. 1 shows a Schematic of the components of the innovated machine and its components.

The innovated machine consists of the following main parts:

Frame

The frame was manufactured from steel right angle with dimensions of 50 ×50 × 3 mm width, height and thickness, respectively.

The frame dimensions were (1000× 500× 600) mm length, width and height, respectively.



(1) Changing speed pulleys, (2) Motor chassis, (3)Main counter shaft, (4) Main chassis, (5) Eccentric, (6) Bearing holder, (7) Motor, (8) V belt, (9) Counter shaft bearing housing, (10)Separation pan, (11) Driven pulley, (12) Belt, (13) drive pulley, (14) Multi speed motor, (15) pan, (16) Sieve, (17) Beater, (18) Peel outlet, (19) Seed pan, (20)Reciprocating arm, (21) Separation motor holder, (22) Seeds outlet.

Fig. 1. Schematic diagram of the components of the innovative machine

Transmission system

The motion was transmitted from 5.0 hp (3.68 kW) electrical 2-phase motor with 1450 rpm to the rotating parts *via* pulleys and V belts. A set of idler pulleys made of aluminum with different diameters were fitted to the motor shaft to change the speed. A steel counter shaft with 25 mm diameter and 380 mm length was rotated on two bearing housing P204 with roll bearing UC204 with inner diameter of 20 mm.

Vibration system

The vibration system was an eccentric consisted of two follower discs fitted on the side of the counter shaft. The discs were made of aluminum alloy with 150 mm diameter and 25 mm thickness. There was a groove drilled diagonally on the radius of the outer follower. A rod was moved inside the groove and equipped with a lock nut to determine the amplitude length. In the other side of the rod, a bearing housing T204 equipped with ball bearing UC204 was fitted. A threaded arm with 400 mm long was fitted on the bearing to convert the rotating motion to a reciprocating motion. Two steel shafts were welded on steel ring clamp outside the pan and rotated reciprocally on two ball bearing housing P204 equipped with ball bearing UC204. The other end of the reciprocating arm was reciprocated on a steel shaft reciprocated on two flanged ball bearing housing F204 equipped with ball bearing UC204. Both flanged housing were fitted on a steel arm to make a reciprocating exciter. The exciter was fitted on the shaft of the ring clamp and transferred the reciprocating motion to the separating pan.

Separation unit

The separation unit consists of a plastic pan with outer diameter of 340 mm with 5 mm thickness and 500 mm length. Three sieves made of stainless steel rods were arranged inside the vibrating pan. The first and second sieves shape was half circle and arranged mutually to allow the materials to pass between sieves. Meanwhile, the third sieve had a circular shape. The distances between rods from up to bottom were 40 mm, 30 mm and 20 mm, respectively. Three rubber skimmers were fitted on a shaft with 250 mm diameter. The shaft was rotated on two four bolts Flanged type bearing housing size of F204 equipped with ball bearing UC204.

Rubber skimmers were rotated between sieves to get ride and clean the pomegranate fruit skin above the sieves. The distance between sieves in the vertical direction was 175 mm bigger than maximum fruit diameter (104.55 mm) to allow the fruits to move between sieves.

A multi speed motor 77-Watt 220V 2 phase was fitted on the separation pan in steel and Teflon housing. The motor transmit the motion to the separation shaft by two pulleys and belt. The idler diameter was 10 mm. Meanwhile, the sprocket diameter was 110 mm.

Methods

Experiments were carried out through the year of 2017 to evaluate the performance of the manufactured pomegranate-extracting machine technically and economically

Experimental conditions

Experiments were conducted to study the performance of the innovative machine in terms of the following parameters:

- Six different exciter frequencies S1, S2, S3, S4, S5, and S6 corresponding to 0.0, 28.1, 52.0, 75.9, 101.2, and 121.4 Hz, respectively.
- Five different sieve amplitudes of 10, 20, 30, 40 and 50 mm.
- Four different separator shaft speeds of 100, 200, 300 and 400 rpm.

Measurements and calculations

The performance of the innovative machine was evaluated taking into consideration the following indicators:

Extracting seed losses (%)

Seed loss percentages were determined by rescuing the expelled seeds from the pomegranate peels which were not extracted by the machine.

The percentages of seed loss were determined by using the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting seed losses}(\%) = \frac{M_u}{M_u + M_c} \times 100$$

Where:

M_u-Mass of seeds mixed with the expelled peels, g;

M_c- Mass of undamaged seeds from output opening, g.

Seed damage (%)

Seed damage percentage was determined as the seed which has any visible crack due using extracting machine. Seed damage was determined by extracting the damaged seeds by hand from a mass of 250 grams working sample, which was taken randomly from the extracted seeds.

The percentage of seed damage was calculated based on the original weight of sample as follows:

$$\text{Seed damage (\%)} = \frac{M_b}{M_t} \times 100$$

Where:

M_b - Mass of the broken seeds in the sample, g;

M_t - Total mass of seeds in the sample, g.

Total seed losses (%)

Total seed losses percentage includes both of seed damage and extracting seed losses according to **Zinash and Vandi (2012):**

Total seed losses (%) = seed damage (%) + Extracting seed losses (%).

Extracting efficiency

The extracting efficiency was calculated as a function of total seed losses according to the following equation according to **Zinash and Vandi (2012):**

$$\text{Extracting efficiency (\%)} = (M_c / M_t) \times 100$$

Where:

M_c - Mass of undamaged seeds collected from the output opening, g;

M_t - Mass of total extracted seeds from output opening, g.

Machine productivity

Machine productivity was estimated according to **Abdrabo (2014)** as the following equation:

$$\text{Machine productivity (kg/hr.)} = \frac{60 \times M_C}{T_e \times 1000}$$

Where:

M_c- Mass of undamaged seeds collected from the output opening, g;

T_e- Machine operation time, min.

Required power

Required power was calculated from the following equation **(Chancellor, 1981):**

$$\text{Required power (kW)} = \frac{I \times V \times \cos\theta}{1000}$$

Where:

I - Current strength, Amperes;

V - Potential difference, Voltage;

$\cos\theta$ - Power factor = constant= 0.85

Specific energy

The specific energy was calculated as following:

$$\text{Specific energy (kW.hr./Mg)} = \frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/hr.)}}$$

Extracting cost

The extracting machine hourly cost is estimated according to the conventional method of estimating both fixed and variable costs. While operational cost was calculated using the following formula:

$$\text{Operational cost (LE/Mg)} = \frac{\text{Machine hourly cost (LE/hr.)}}{\text{Machine productivity (Mg/hr.)}}$$

The criterion cost was estimated according to **Kumar and Goss (1980)** as following:

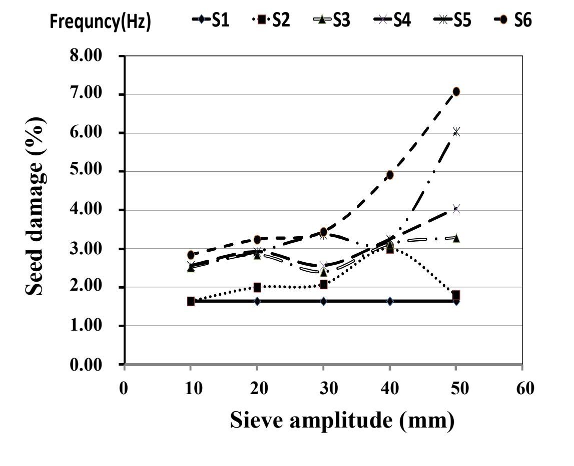
Criterion cost (LE/Mg) = Operational cost + Total seed losses cost

RESULTS AND DISCUSSION

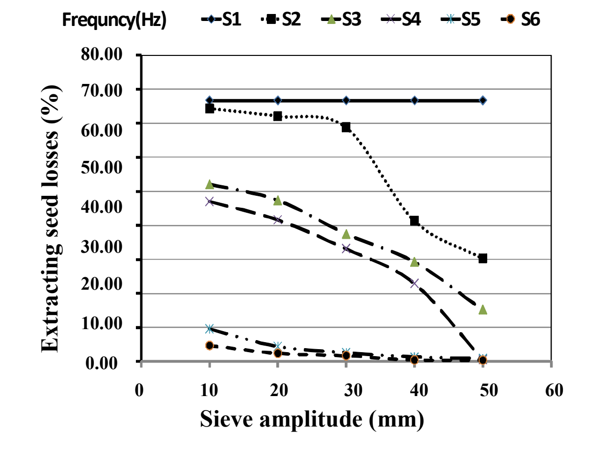
The discussion will cover the obtained results under the following headlines:

Effect of Sieve Amplitude and Exciter Frequency on Seed Damage and Extracting Losses

Fig. 2 shows the effect of sieve amplitude and exciter frequency on seed damage and



A. Effect of sieve amplitude and exciter frequency on seed damage



B. Effect of sieve amplitude and exciter frequency on extracting losses

Fig. 2. Effect of sieve amplitude and exciter frequency on seed damage and extracting losses under constant separator speed of 200 rpm

extracting losses under constant separator speed of 200 rpm. The obtained results indicated that the increasing of the exciter frequency and sieve amplitude tends to increase seed damage percentage. The obtained results showed that the general average of seed damage percentages were 2.29, 2.59, 2.58, 3.19 and 3.98% at amplitudes 10, 20, 30, 40 and 50 mm, respectively. From Fig. 2-A, at amplitude 10 mm, the seed damage increased by 0.00, 34.92, 35.94 and 42.25% by increasing the frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the seed damage increased by 21.95, 42.25, 43.84, 43.84 and 49.38%. At amplitude 30 mm, the seed damage increased by 26.83, 31.67, 35.94, 51.19 and 52.33%. At amplitude 40 mm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At amplitude 50 mm, the seed damage increased by 9.76, 50.00, 59.41, 72.85 and 76.84% under the same previous conditions of exciter frequencies.

From Fig. 2-A it was obvious that when operating the machine with no frequency (S1) = 0, the seed damage percentage was only equal 1.64%. On the other hand, the effect of increasing the selected frequencies gradually from S2 to S4 seed damage was ranged from 1.64% to 3.2% at the selected amplitude from 10 to 40mm gradually. Then, at S5 and S6, seed damage ranged from 2.58% to 4.97% at different selected amplitudes. At 40 mm amplitude, it was noticed that the seed damage percentage was increased slowly from 0.30% to 3.12, 3.24, 3.24 at the selected frequencies from S2 to S5, then increased sharply to 4.92% at frequency S6. At 50mm amplitude, the seed damage increased to 6.04% and 7.08% at frequency S5 and S6 that gave acceptable losses at 40mm amplitude.

The results in Fig. 2-B also indicate that the increasing of the exciter frequency and sieve amplitude decreased the extracting seed losses. It could be realized that the general average of extracting seed losses percentages were 44.02, 40.72, 36.69, 28.63 and 20.62% at amplitudes 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting seed losses (%) decreased by 3.18, 32.16, 38.76, 87.62 and 93.99% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the extracting seed losses decreased by 6.12, 38.34, 45.81, 94.38 and 96.95%. At amplitude 30 mm, the extracting seed losses decreased by 10.38, 51.18, 56.90, 96.76 and 97.83%. At amplitude 40 mm, the extracting seed losses decreased by 46.09, 61.93, 70.16, 98.41 and 99.53%. At amplitude 50 mm, the extracting seed losses decreased by 60.58, 80.23, 99.38, 98.98 and 99.60% under the same previous conditions of exciter frequencies.

The percentage of seed extracting seed losses was decreased by increasing the frequency and amplitude. From Fig. 2-B it realize when operating the machine with no frequency (S1) = 0, the extracting seed losses percentage was equal 76.7%. On the other hand, the effect of increasing the steeply frequency gradually from S2 to S4 was not effective on extracting process which ranged from 74.29% to 22.89% at different selected amplitude from 10 to 40mm gradually. The effect of the frequency begins to appear on extracting losses at S5 and S6 it ranged from 9.5% to 0.31%. When operating the machine on amplitude of 50 mm, it really the extracting seed losses was decreased gradually at the selected frequencies from 30.2% to 0.31% but the seed damage was increased from 1.08% to 7.08%.

Effect of Sieve Amplitude and Exciter Frequency on Total Seed Losses and Extracting Efficiency

Fig. 3 shows the effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm. The results indicated that increasing exciter frequency and sieve amplitude decreased the total seed losses. Results in Fig. 3-A show that the general average of the total seed losses values were 46.32, 43.31, 39.27, 31.82 and 24.60% at sieve amplitudes of 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the total seed losses percentages were decreased by 3.11, 30.37, 36.77, 84.61 and 90.49% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At amplitude 20 mm, the total seed losses percentages were decreased by 5.53, 36.00, 43.22, 90.77and 92.87%. At amplitude 30 mm, the total seed loss percentages were decreased by 9.60, 49.14, 54.54, 92.54 and 93.49%. At amplitude 40 mm, the total seed loss percentages were decreased by 43.39, 58.75, 66.65, 94.31 and 93.26%. At amplitude 50 mm, the total seed loss percentages were decreased by 59.11, 76.46, 94.24, 91.30 and 90.5%% under the same previous conditions of exciter frequencies.

From Fig. 3-A it was realized when operating the machine with no frequency (S1)=0, the total seed loss percentage was only equal 78.36%. On the other hand, the effect of increasing the selected frequencies on total seed losses gradually appeared from S2 to S4 was ranged from 75.93% to 26.13% at the selected amplitude from 10 to 30mm gradually. Then, at S5 and S6, it ranged from 4.49% to 5.28% at 40 mm amplitude. At 50mm amplitude, the total seed losses increased to 6.82 % and 7.39% at S5 and S6, respectively with no change in extracting efficiency.

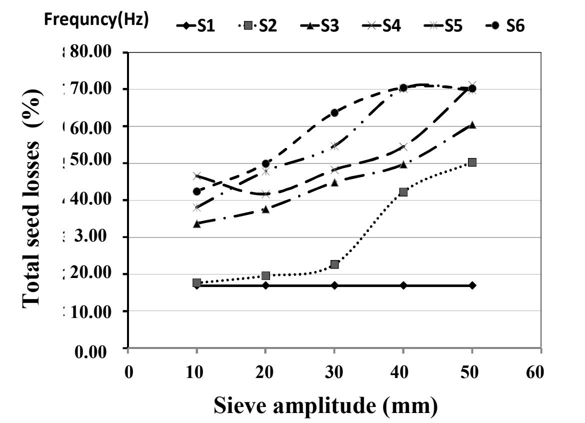
The results in Fig. 3-B indicate that increasing exciter frequency and sieve amplitude, increased the extracting efficiency. Results realized that the general average of extracting efficiency was 32.54%, 35.58%, 41.83%, 50.66% and 56.47% at amplitude 10, 20, 30, 40 and 50 mm, respectively.

At amplitude 10 mm, the extracting efficiency was increased by 4.06, 49.62, 63.58%, 55.40 and 59.58 by increasing the exciter frequency from S1 to S2, S3, S4, S5, S6, respectively. At amplitude 20 mm, the extracting efficiency was increased by 15.29, 54.91, 59.29, 62.52 and 66.01%. At amplitude 30 mm, the extracting efficiency was increased by 33.41, 62.19, 64.83, 68.98 and 73.36%. At amplitude 40 mm, the extracting efficiency was increased by 149.02, 65.89, 68.85, 75.84, and 75.92. At amplitude 50 mm, the extracting efficiency was increased by 196.39, 71.95, 76.16, 75.70 and 75.86% under the same previous conditions of exciter frequencies.

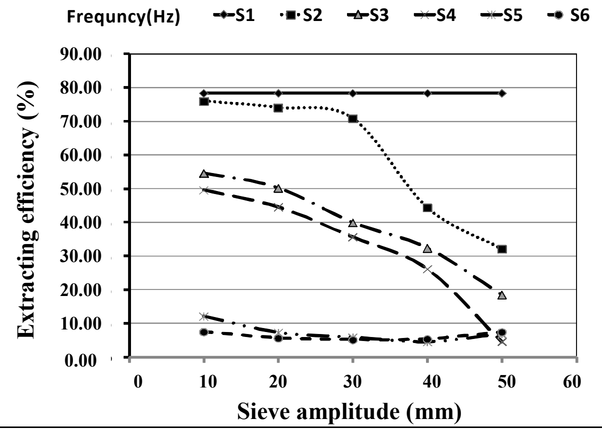
It could be realized that, the results were taking the same trends at exciter frequencies of S4, S5, and S6. From the results, the optimum amplitude was 40 mm at frequency S5=101.2 Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

From Fig. 3-B, the effect of increasing the selected frequencies on extracting efficiency gradually appeared from S2 to S4. It was ranged from 17.65% to 54.45% at the selected amplitude from 10 to 40mm gradually.

At amplitude 40mm and 50mm, the increasing of frequency from S5 to S6 was not effective on the extracting efficiency. It was nearly 70.00% at all these treatments. From Fig. 2 and Fig. 3, the optimum exciter frequency S5=101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46%, and with extracting efficiency of 70.19% at amplitude of 40 mm.



A. Effect of sieve amplitude and exciter frequency on total seed losses



B. Effect of sieve amplitude and exciter frequency on extracting efficiency

Fig. 3. Effect of sieve amplitude and exciter frequency on total seed losses and extracting efficiency under constant separator speed of 200 rpm

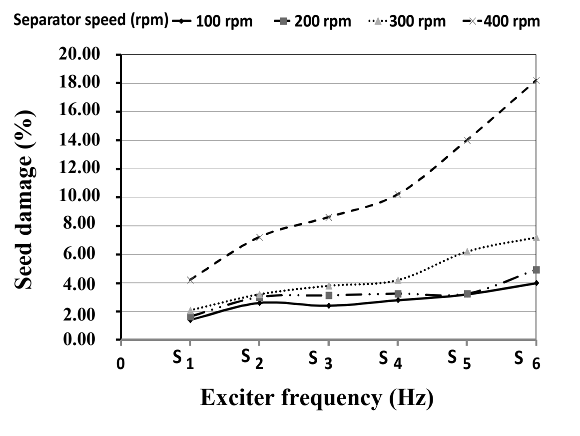
Effect of Separator Shaft Speed and Exciter Frequency on Seed Damage and Extracting Losses

The experiments were carried out under constant amplitude of 40 mm at different frequencies and different separator speeds to find out the effect of separator speed on seed damage and extracting losses. Fig. 4-A shows the effect of separator shaft speed and exciter frequency on seed damage percentage and extracting losses percentage. The results indicated that increasing the exciter frequency and separator speed increased seed damage. Fig. 4-A realized that the general average of seed damage percentage was 2.73, 3.19, 4.45 and 10.40% at separator speeds of 100, 200, 300 and 400 rpm, respectively.

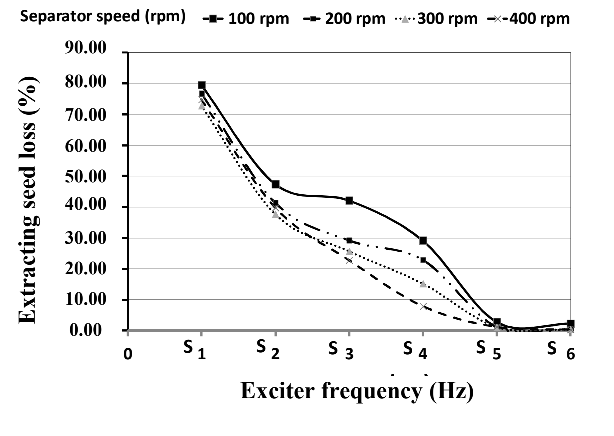
At separator speed of 100 rpm, the seed damage increased by 85.71, 41.67, 50.00, 56.25 and 65.00% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed of 200 rpm, the seed damage increased by 82.93, 47.44, 49.38, 49.38 and 66.67%. At separator speed of 300 rpm, the seed damage increased by 53.85, 45.26, 50.48, 66.45 and 71.11%. At separator speed of 400 rpm, the seed damage increased by 71.43, 51.16, 58.82, 70.00 and 76.92% under the same previous conditions of exciter frequencies. From Fig. 4-B, results indicated that increasing exciter frequency and separator speed, decreased the extracting seed losses percentage. it realized that the general average of the extracting seed losses percentages were 36.61, 31.82, 29.61, and 34.83 at separator speed 100, 200, 300, and 400 rpm, respectively.

At separator speed 100 rpm, the seed damage percentage was decreased by 38.17, 44.98, 60.54, 91.57 and 92.28% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separator speed 200 rpm, the extracting seed losses percentage was decreased by 43.39, 58.57, 66.65, 94.31 and 93.26%. At separator speed 300 rpm, the extracting seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separator speed 400 rpm, the extracting seed losses percentage was decreased by 40.54, 60.29, 77.15, 80.84 and 76.60% under the same previous conditions of exciter frequencies.

From Fig. 4-A it was realized when operating the machine with no frequency (S1) = 0, and changing the separator speed the seed damage (%) increased from 1.40% to 4.20%. On the other hand, the effect of increasing the selected exciter frequencies on seed damage percentage gradually appeared from S2 to S6 was ranged from 2.60% to 7.20% at the selected separator speed from 100 to 300 rpm gradually. Then 400 rpm, it sharply increased with rang of 7.20% to 18.20%. It means the 400 rpm is not suitable as a separation speed.



A. Effect of separator speed and exciter frequency on seed damage



B. Effect of separator speed and exciter frequency on extracting seed loss

Fig. 4. Effect of separator shaft speed and exciter frequency on seed damage and extracting losses under constant amplitude40mm

Effect of Separator Shaft Speed and Exciter Frequency on Total Seed Losses and Extracting Efficiency

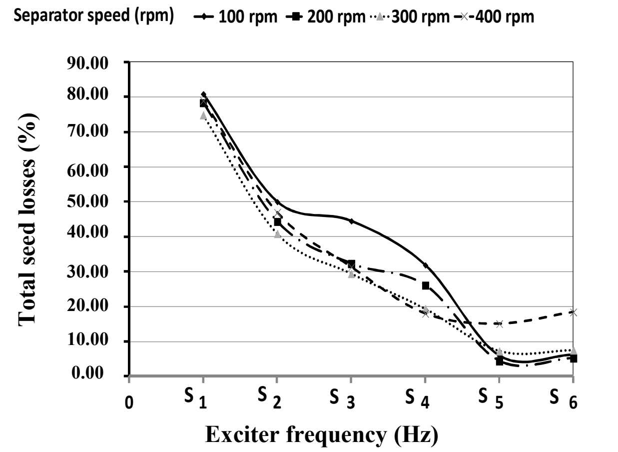
Fig. 5 shows the effect of separator speed and exciter frequency on seed extracting efficiency and total seed losses. The results indicated that the increasing of the exciter frequency and separator speed decreased the total seed losses percentage. From Fig. 5-A, it realized that the general average of the total seed losses percentages were 36.61, 31.82, 29.91 and 34.83% at separation speed 100, 200, 300, and 500 rpm, respectively.

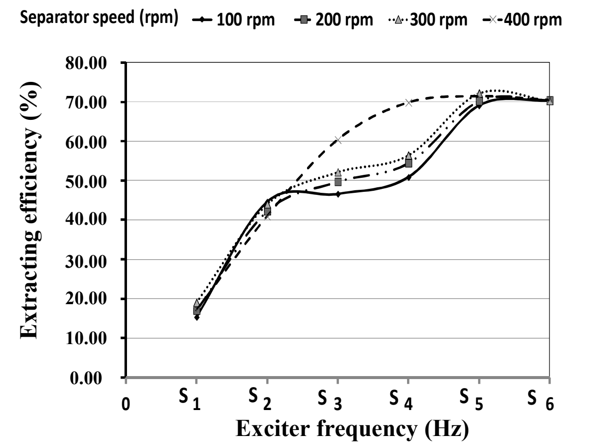
At separation speed 100 rpm, the total seed losses percentage was decreased by 38.17, 44.98, 60.54, 92.57 and 92.28% by increasing the vibration frequency from S1 to S2, S3, S4, S5 and S6, respectively. At separation speed 200 rpm, the total seed losses percentage was decreased by 43.39, 58.75, 66.65, 94.31 and 92.26%. At separation speed 300 rpm, the total seed losses percentage was decreased by 45.42, 60.69, 74.13, 90.23 and 89.93%. At separation speed 400 rpm, the total seed losses percentage was decreased by 40.45, 60.29, 77.15, 80.84, and 76.60% under the same previous conditions of exciter frequencies.

Also, from Fig. 5-B, results indicated that the increasing of the exciter frequency and separation shaft speed, the extracting efficiency was increased. It realized that the general average of the extracting efficiency were 49.44, 50.66, 52.34 and 54.98% at sieve speed of 100, 200, 300 and 400 rpm, respectively. At separation speed of 100 rpm, the extracting efficiency increased by 191.19, 67.14, 69.90, 77.82 and 78.23% by increasing the exciter frequency from S1 to S2, S3, S4, S5 and S6, respectively. At a separation speed of 200 rpm, the extracting efficiency increased by 149.02, 65.89, 68.85%, 75.84% and 75.92%. At separation speed of 300 rpm, the extracting efficiency increased by 131.04, 63.50, 66.27, 73.62 and 72.89. At separation speed of 400 rpm, the extracting efficiency increased by 140.20, 71.78, 75.59, 76.13 and 85.81% under the same previous conditions of exciter frequencies.

The results were taking the same trends at vibration frequencies S5, S6. This means that there are no need to examine higher speeds.

From Fig. 5-B it realized that operating the machine with no frequency (S1)=0, and changing the separator speed the extracting efficiency increased from 15.31% to 17.30%. It means that values are the maximum extracting efficiencies that the rotary separator could fulfill without exciter frequency. Then, the effect of increasing the selected exciter frequencies on extracting efficiency gradually appeared from S2 to S6 was ranged from 44.57% to 70.23% at the selected separator speed from 100 to 300 rpm gradually. Then at 400 rpm, the extracting efficiencies were very near to the results of 300 rpm





A. Effect of separator shaft speed and exciter frequency on total seed losses	B. Effect of separator shaft speed and exciter frequency on extracting efficiency

Fig. 5. Effect of separator shaft speed and exciter frequency on total seed losses and extracting efficiency under constant amplitude 40 mm

rotary separator. When increasing the rotary speed from 300 rpm and 400 rpm at speed S5 and S6 the extracting efficiencies were decreased from 72.1 to 71.36 and increased from 70.23 to 70.43 with total seed losses from 7.32% to 15.13% and from 7.54% to 18.48%. Meanwhile, at 200 rpm separator speed at S5 and S6, the results indicated that the extracting efficiency was 70.19% with total seed losses of 4.46% and 70.43% with total seed losses of 5.28%, respectively.

This means that, the optimum separation speed is 200 rpm at exciter frequency S5 = 101.2Hz that occurs seed damage percentage of 3.24%, extracting seed losses of 1.22%, with total seed losses of 4.46 %, and with extracting efficiency of 70.19%.

Machine Productivity

Fig. 6 shows the machine productivity values at different sieve amplitudes and different separator shaft speeds. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased machine productivity from 80 to 155, from 150 to 290, from 200 to 340 and from 230 to 350 kg/hr., under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

The increase in machine productivity by increasing both sieve amplitude and separator shaft speed was attributed to that the extracting operation was highly improved under higher values of both sieve amplitudes and separator shaft speeds. Results also showed that machine productivity values under sieve amplitudes of 40 and 50 mm were very close, so, it is preferable to operate the machine under sieve amplitudes of 40 mm.

Required Power and Specific Energy

Fig. 7 shows the values of both required power and specific energy at different sieve amplitudes. Results indicated that increasing sieve amplitude from 20 to 50 mm (at constant exciter frequency of 101.2 Hz), increased the required power from 13.1 to 2.3, from 1.5 to 2.8, from 2.2 to 3.4 and from 2.4 to 3.6 kW, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively.

Results also indicated that increasing sieve amplitude from 20 to 40 mm (at constant exciter frequency of 101.2 Hz), decreased specific energy from 13.8 to 12.1, from 9.2 to 8.8, from 10.0 to 9.4 and from 10.5 to 9.7 kW.hr./Mg, under different separator shaft speeds of 100, 200, 300 and 400 rpm, respectively. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase specific energy from 12.1 to 14.5, from 8.8 to 9.5, from 9.4 to 10.2 and from 9.7 to 11.0 kW.hr./Mg.

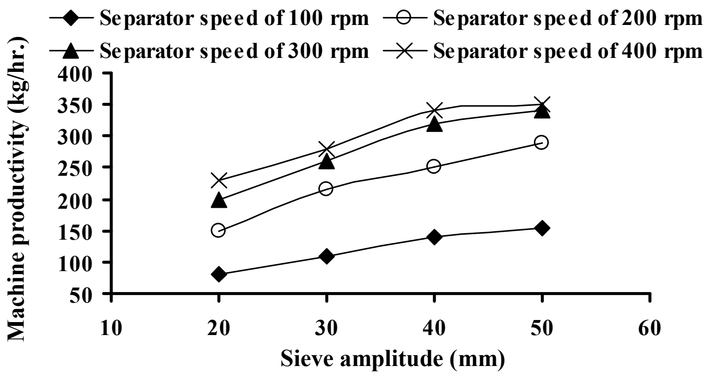
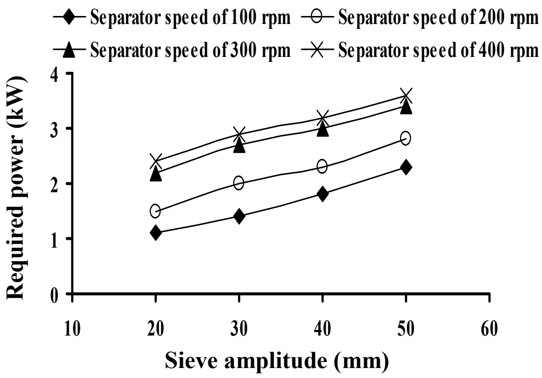


Fig. 6. Effect of sieve amplitude and separator shaft speed on machine productivity (kg/hr.) under constant exciter frequency of 101.2 Hz



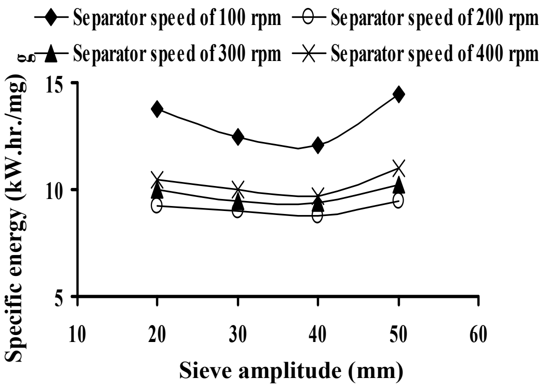


Fig. 7. Effect of sieve amplitude and separator shaft speed on required power and specific energy (exciter frequency of 101.2 Hz)

The decrease of specific energy by increasing sieve amplitude from 20 to 40 mm could be attributed to the increase in machine productivity. While the increase of specific energy by increasing sieve amplitude from 40 to 50 mm is attributed to that, the increase in the required power is higher than the increase in machine productivity.

Cost Analysis and Economical Feasibility

The total fabrication cost of the extracting machine was 15000 LE with the year of 2018 price level. Fig. 8 shows the values of both operational and criterion costs at different sieve amplitudes.

Results showed that the operational cost decreased from 275 to 145 LE/Mg, by increasing sieve amplitudes from 20 to 50 mm under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm. This decrease is due to the increase in machine productivity. Meanwhile the criterion cost decreased from 480 to 40 LE/Mg, by increasing sieve amplitudes from 20 to 40 mm. Any further increase in sieve amplitude more than 40 mm up to 50 mm, tends to increase criterion cost from 400 to 460 LE/Mg due to the increase in extracting losses cost.

Conclusion

The experimental results revealed that machine productivity (0.25 Mg/hr.), total seed losses (6.01%), extracting efficiency (70.19%), specific energy (8.8 kW.hr./Mg) and criterion cost (400 LE/Mg) were in the optimum region under the following conditions:

- 101.2 Hz exciter frequency.
- 40 mm sieve amplitude.
- 200 rpm separator shaft speed.

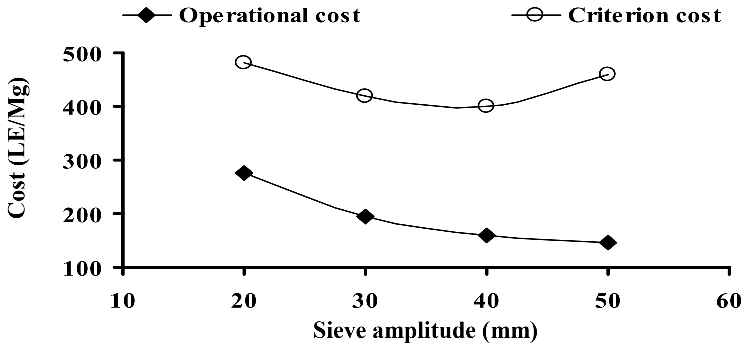


Fig. 8. Effect of sieve amplitude on operational and criterion costs under constant exciter frequency of 101.2 Hz and constant separator sieve speed of 200 rpm

REFERENCES

Abdrabo, A.F.A. (2014). Manufactured prototype to separate the seeds of water melon plup. Egypt. J. Agric. Res., 92 : 1.

Chancellor, W.J. (1981). Substituting information for energy in agricultural. Trans. ASAE, Paper No. 0001-2351.

Javad, K., N. Ekrami-Rada, M. Safab and S. Nostratic (2008). Effect of air-jet impingement parameters on the extraction of pomegranate arils. Bio-system Eng., 100: 214: 226.

Kumar, R. and J.R. Goss (1980). Total combine harvester cost optimization in Alfalfa seed harvesting. Trans. ASAE, 23 (1) : 39-42.

Ministry of Agriculture and Land Reclamation (2018). Agricultural statistics. The Economic affairs. Egypt.

Morton, J. (1987). Pomegranate. In: Fruits of warm climates, MiamiFL. www. hort.purdue. edu/ new crop /morton / pomegranate.html., 352–355.

Safe, M. and J. Khazaei (2003). Determining and modeling some physical properties of pomegranate fruits of Saveh area, Iran, related to peeling and packaging. Int. Cong. Inform. Technol. Agric. Food and Environ., Izmir, Turkey, 331–337.

Sarig, Z., Y. Ronen, B. Hoffman, A. Egozi, H. Beres, H.E. Bar-Lev and F. Grosz (2009). Development of a method and a system for extracting the seeds (arils) from pomegranate fruits from concept to commercial utilization. Acta Hort., (818): 363-372.

Thakur, A.K., R.T. Patil, D.B. Singh and R.K. Gupta (2011). Development of tool and machine for safe separation of arils from pomegranate. Acta Hort., (890): 425-431.

Zinash, D.O. and K.P. Vandi (2012). Development of Egusi melon seed extractor. International Conference on Agricultural and Food Engineering for Life (Cafei2012) 26-28 November 2012. Putrajaya, Malaysia. e-ISBN 978-967-960-322-4. 51-61.

تصنيـــــع وتقييــــــــم أداء آلـــــــــــة محليــــــــــة الصنـــــع لتفــــريـط بـــذور الـرمــــــان

نجلاء صلاح أنور[1] - محمد محمد مراد حسن[1] - محب محمد أنيس الشرباصي[2]- طارق حسين على[3]

١- قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق – مصر

٢- قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط – مصر

٣- قسم الهندسة الزراعية – معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية - مصر

تم تصنيع آلة مبتكرة لتفريط بذور الرمان تتميز بالإنتاجية العالية وبساطة التصميم وانخفاض نسبة تلف البذور، حيث تعتمد آلة التفريط على نظام مبتكر لاستخراج البذور من القشور واللب عن طريق التردد، تم دراسة تأثير مختلف العوامل التشغيلية على عملية التفريط تمثلت متغيرات التجربة فى ستة ترددات للجزء الفعال (صفر، ٢٨,١، ٥٢,٠ ، ٧٥,٩، ١٠١,٢ و ١٢١,٤ هيرتز)، خمسة أطوال لمشوار التردد (١٠، ٢٠ ،٣٠ ،٤٠ ،٥٠ مم) أربعة سرعات لعمود الفصل (١٠٠، ٢٠٠، ٣٠٠، ٤٠٠ لفة فى الدقيقة)، وتم تقييم أداء الآلة من حيث إنتاجية الآلة وإجمالي نسبة فواقد و تلف البذور وحساب كفاءة التفريط ومتطلبات القدرة والطاقة النوعية المستهلكة وتكاليف التشغيل، حيث أظهرت النتائج التجريبية أن إنتاجية الآلة كانت (٠,٢٥ ميجاجرام/ساعة)، نسبة البذور الكلية المفقودة (٦,٠١%)، وكفاءة الإستخلاص (٧٠,١٩%)، ومتطلبات الطاقة (٨,٨ كيلووات. ساعة/ميجاجرام) وتكلفة ميجاجرام (٤٠٠ جنيه/ميجاجرام) تحت ظروف التشغيل التالية: تردد الجزء الفعال ١٠١,٢ هيرتز، مشوار التردد للجزء الفعال المسبب للتردد ٤٠ مللمتر وسرعة عمود الفصل الدوارني ٢٠٠ دورة /الدقيقة.

المحكمـــــون:

١- أ.د. جمال الدين محمد نصر أستاذ الهندسة الزراعية – كلية الزراعة – جامعة القاهرة.

٢- أ.د. محمود مصطفى علـــي أستاذ الهندسة الزراعية – ووكيل كلية الزراعة للشئون البيئة – جامعة الزقازيق.