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A prototype for pomegranate arils separation

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ABSTRACT

The aim of this study is to develop and evaluate pomegranate arils (containing the juice and seeds/kernels or the edible portion of fruit) separation prototype by hammering on the peel of half a pomegranate fruit, for the arils fall by gravity. The pomegranate was cut in two halves and the experiment was carried out with half of the fruit, the separation experiments were divided in two groups, the first group was cutting the pomegranate perpendicular to its axis “CV”, and the second group was cutting the pomegranate fruit parallel to its axis “CP”. The two groups experiments were carried out with three hammer frequencies "Hf" (21, 45 and 77 Hz) and three fruit exposure time to strikes "θ" (15, 25 and 35 sec.). Results showed that the highest values of productivity were 15.84 and 14.40 kg/h for “CV” and “CP” cutting respectively at “θ” 15 s and “Hf” 77 Hz. The highest values of separation efficiency “ŋs” were 97.59 % and 93.73 % for "CV" and "CP" cutting respectively at operating time 35s and hammer frequency 77 Hz. The lowest values of damaged pomegranate arils percentage “da” were 2.41 % and 3.85 % for “CV” and “CP” cutting respectively at “θ” 35 s and “Hf” 77 Hz. The minimum values of Specific energy consumption “SEC” were 0.012 and 0.013 kW.h/kg for “CV” and “CP” cutting respectively at “θ” 15 s and “Hf” 21 Hz.

1. Introduction

The Pomegranate (*Punica granatum*) has been cultivated since ancient times in the Mediterranean regions; the native of the Pomegranate goes back to Iran and northern India (Meerts et al., 2009). The pomegranate is a fruit with a hard red outer layer. It is a fruit rich in phytochemicals, as it contains flavonoids and polyphenols. A glass of pomegranate juice contains powerful antioxidants that protect against cancer and heart disease (Immanvel et al., 2014; Mphahlele et al., 2019). The basic method for extracting juice from a pomegranate is to cut the pomegranate fruit (containing the juice and seeds/kernels or the edible portion of fruit) and squeeze them to get the juice, and then the juice is purified to get 45% of the juice .The measurements of height and width in (mm) of hundred arils, randomly selected, were conducted. The highest value of arils height and width were 10.7 and 13.8 mm respectively, while the lowest value of seed height and width were 8.0 and 11.5 mm respectively (Badr, 2016). The common method for extracting pomegranate arils is the manual method, but by reviewing the literature references in this regard, it turned out that there have been some attempts to extract the pomegranate arils, among which are the following: Surbnshanyan (1983) mentioned that Equipment for separating seeds from pomegranate skin consisting of afeed hopper for pomegranates and perforated drum containing impact elements installed on its circumference. The elements are vanes installed at 45° to the axis of shaft to increase separation efficiency. Schmilovitch et al. (2009) developed a method for separating the arils from the pomegranate fruit is based on utilizing an oscillating air current scanning the surfaces of an opened fruit to extract the arils. The efficiency of the separation mechanism depends on factors such as shape, size and arils placement within the fruit. The fruit handling system consist of conveying the fruit to the plant; moving the fruit through various stations to

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perform the operations of opening the fruit; exposing the opened fruit to the extracting mechanism & separating the arils from extraneous material and delivering the clean and sorted arils to the packaging machine. This machine was for commercial use only. Immanvel et al. (2014) designed a striker is made of nylon material. This striker is installed in one of the domestic mixer equipment to be used to separate the pomegranate arils. The results showed that 78% of the trees were separated in this way. Gomathi *et al.* (2015) designed a machine to separate pomegranate arils from the peel consists of electromagnet, the cantilever beam, proximity sensor, microcontroller 89C51 and a tray to collect the arils. Beam is used to provide the tapping force over the fruit and it gets attracted by energizing of the electromagnet and by de-energizing the electromagnet, the beam gets repelled. The pomegranate fruit is kept in inverted position and the beam to the hard outer shell, thus removing the arils from the fruit. Until now, most of the processes of separating pomegranate arils are done manually; witch may expose the fruit to germs and bacteria. Since there are no domestic devices of pomegranate arils separation with small scale this work has been done. The aim of the present study is to develop and evaluate pomegranate arils separation unit to be used in home and small processing unit as juice industry, which could be achieved by:

- Study of some engineering factors affecting the separation process.
- Evaluation of the pomegranate arils separation prototype for higher separation efficiency as affected by different some operational parameters.
- Cost analysis.

2. Materials and methods

A prototype of the pomegranate arils separation is constructed and evaluated at the workshop of the Agricultural Engineering Faculty, Al Azhar University, Nasr City, Cairo.

2.1. Materials

2.1.1. Raw materials

The pomegranate fruit sample obtained from a local market, EL Mahalla EL Kubra, Gharbia Governorate, Egypt. The initial moisture content of pomegranate fruit was (72.77 % w.b for peel and 84.10 % w.b for arils)

2.1.2. Pomegranate arils separation prototype setup

A prototype, was manufactured for separation pomegranate arils, is consisted of reciprocating hammer and chamber to collect separated arils installed on a wooden frame. The photograph and schematic diagram of separation prototype are shown in Figs. 1 and 2.

The wooden frame

The wooden frame consists of two bases of dimensions (200 × 300 × 30mm) fixed in a parallel horizontal position by four vertical wooden beams of cross-sectional dimensions (30 × 60 mm). One of the bases is upper and the other lower, the vertical distance between them 200mm. The upper base has a circular hole with a diameter of 100 mm, this circular hole is covered from bottom with a stainless-steel wire mesh with holes (15 × 15 mm). The diameter of the circular hole (100 mm) was selection based on the maximum diameter of the pomegranate fruit as will be shown in the results and discussion, while the dimensions of the mesh wire holes (15× 15 mm) were selected based on the maximum dimension of the pomegranate arils from a previous study on the physical and mechanical properties of the pomegranate seeds (Badr M.M.I., 2016).

Fig. 1. Photograph of separation prototype.

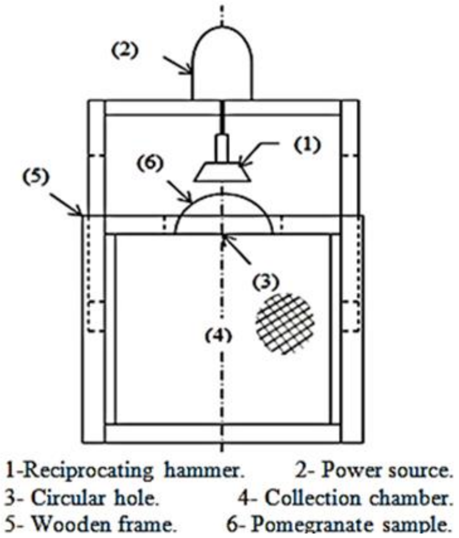

Fig. 2. Schematic diagram separation prototype.

The reciprocating hammer

The reciprocating hammer is a round wooden block with a diameter of 50 mm and a thickness of 30 mm and it's connected to a power source. The power source is reciprocating motor with six speed levels (electric reciprocating saw has been modified to operate the reciprocating hammer with length of reciprocating motion 20 mm), of 220 – 230 V, 50/60 Hz and 650 W, APT CROWN made in china. The hammer is fixed above the center of the circular hole located in the upper base of the wooden frame, and its position can be adjusted at different heights to suit different sizes of pomegranate fruits.

Collection chamber of separated arils

The collection chamber is a box of dimension (180 ×180×200mm) and is made of fiberglass with a thickness 3 mm. the collection chamber is fixed below the circular hole located in the upper base of wooden frame.

Operating mechanism

The pomegranate fruit is cut in half. Half of the fruit is placed above the wire mesh of the circular hole in the upper base; the cut side of the fruit is facing the wire mesh and the outer peel of the fruit towards the reciprocating hammer. The hammer is adjusted above the peel of the fruit and then it is turned on. As a result of the speed of the strikes above the peel of the fruit, the arils are vibrated, and they fall in to the collection chamber through the wire mesh.

2.1.3. Measuring instruments

Caliper

A caliper (accuracy of 0.05) made in china, was used for measuring the pomegranate fruits and arils.

Electrical balance

Weight of the separated pomegranate arils were measured by a Sartorius electrical balance having accuracy 0.0001g, made in Japan.

Digital photo tachometer

A digital photo tachometer was used to measure hammer frequency having accuracy 1 Hz.

Digital AVO meter

Electrical current (Ampere) and potential difference (Volt) were measured by a digital AVO meter made in china having accuracy 0.01 through the range 0 – 40 A.

Stopwatch

Stopwatch having accuracy 1 sec. was used to record the separation time.

2.2. Methods

2.2.1. Experiments procedure

- To determine the diameter of the circular hole located at the upper base of the wooden frame, a random sample was taken from 25 pomegranate fruits to determine the parallel and perpendicular diameter to the axis of the fruit.
- The pomegranate was cut in two halves and the experiment was carried out with half of the fruit through three replications, the separation experiments were divided in two groups, the first group was cutting the pomegranate perpendicular to its axis "CV", and the second group was cutting the pomegranate fruit parallel to its axis "CP" as in Fig. 3. The two groups experiments were carried out with three hammer frequencies "*Hf*" (21, 45 and 77 Hz) and three fruit exposure time to strikes or operating time "θ" (15, 25 and 35 sec.), The number of experiments reached 54 experiment.
- Productivity "*P*" (kg/h), separation efficiency "η_s" (%), damaged pomegranate arils percentage "d_a" (%), specific energy consumption "*SEC*" (kW.h/kg) and cost "C_t" (L.E/kg) were calculated for all experiments in this study.

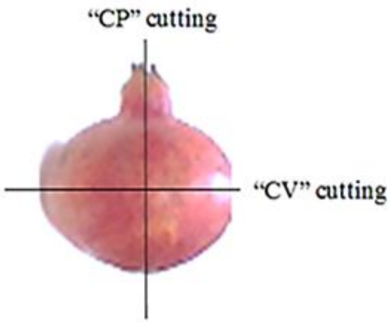

Fig. 3. "CV" and "CP" cutting**.**

2.2.2. Calculations

Productivity **"P"**

Productivity of separated pomegranate arils (kg/h) was calculated as follows:

$$P = \frac{m_1}{\theta} \quad [1]$$

where: m_1: mass of separated pomegranate arils (kg) and θ: operating time (h).

Separation efficiency "η_s"

The separation efficiency (%) was calculated as follows:

$$\eta_s = \frac{m_1}{m} \times 100 \quad [2]$$

where: m**:** total mass of pomegranate arils in the sample (kg).

Damaged pomegranate arils percentage "da"

The damaged pomegranate arils percentage (%) was calculated as follows:

$$d_a = \frac{m_2}{m} \times 100 \quad [3]$$

where: m_2: mass of damaged pomegranate arils (kg).

Specific energy consumption "SEC"

The specific energy consumption for separated pomegranate arils (kW.h/kg) was calculated as following equation:

$$SEC = \frac{\text{the energy consumption "}E_c\text{" (kW.h)}}{\text{total separated mass "m" (kg)}} \times 100 \quad [4]$$

$$E_c = V \times I \times \theta \times \eta_m \times \cos\emptyset$$

where: V: Potential difference (Volt), I: current strength (Ampere), η_m: mechanical efficiency of motor (0.9) and $\cos\emptyset$: power factor (0.8).

Cost analysis

The separation prototype hourly costs were calculated based on fixed and variable costs of prototype by using the following equation (Awady et al., 2003):

$$C = \frac{P_c}{h} \times \left(\frac{1}{a} + \frac{i}{2} + t + r\right) + (W.e) + \left(\frac{m}{100}\right) \quad [5]$$

where: C: separation prototype hourly cost (L.E/h), P_c: Price of prototype, L.E., the fixed costs were 700 L.E, h: Yearly working hours, which were is assumed 1000 h/year, a: Life expectancy of machine, about (10 Year), i: interest rate/Year, which was about 14%, t: taxes and overheads ratio, which is assumed 20 %, r: repair and maintenance ratio, which is assumed 10 %, W: power (kW), e: hourly cost/kW.h (1.0 L.E/kW.h), m: the monthly average wage (700 L.E) and the monthly average working hours (100 h). The price of the dollar was at the time of the execution of the work.

Cost "Ct" (L.E/kg)

$$\text{Cost "}C_t\text{"}(L.E/kg) = \frac{C\ (L.E/kg)}{\text{productivity}\ (kg/h)} \quad [6]$$

3. Results and discussions

3.1. The diameters of pomegranate fruits

The diameter perpendicular and parallel to the axis of pomegranate fruits are shown in Table 1. The measurements of perpendicular and parallel diameter in (mm) of twenty-five pomegranate fruits, randomly selected, were conducted. The highest values of perpendicular and parallel diameter for fruits were 92.35 and 81.34 mm, while the lowest values were 82.61 and 71.30 mm respectively.

Table 1
The diameters of pomegranate fruits.

Diameters (mm)	Max.	Min.	Ave.
Perpendicular to the axis	92.35	82.61	88.61
Parallel to the axis	81.34	71.30	75.97

3.2. Effect of the operating time "θ" and hammer frequencies "Hf" on the prototype productivity "P":

Figs. 4 and 5 illustrate relation between separation prototype productivity "P" (kg/h) and operating time "θ" (s) at different hammer frequencies "Hf" (Hz) for "CV" and "CP" cutting. Prototype productivity decrease by increasing operating time from 15 to 35 s this may be because productivity is dependent on the operating time and the proportional between them is inversely, while its increases by increases hammer frequencies from 21 to 77 Hz. It is clear from Figs. 4 and 5 that the highest values of productivity were 15.84 and 14.40 kg/h for "CV" and "CP" cutting respectively at "θ" 15 s and "Hf" 77 Hz, while the lowest values for productivity were 6.07 and 5.97 kg/h for "CV" and "CP" cutting respectively at "θ" 35 s and "Hf" 21 Hz.

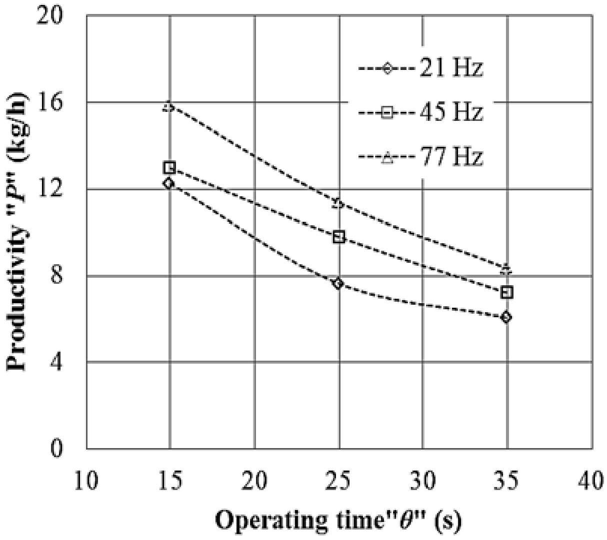

Fig. 4. The relationship between productivity of separated arils and "θ" at different "Hf" for "CV" cutting.

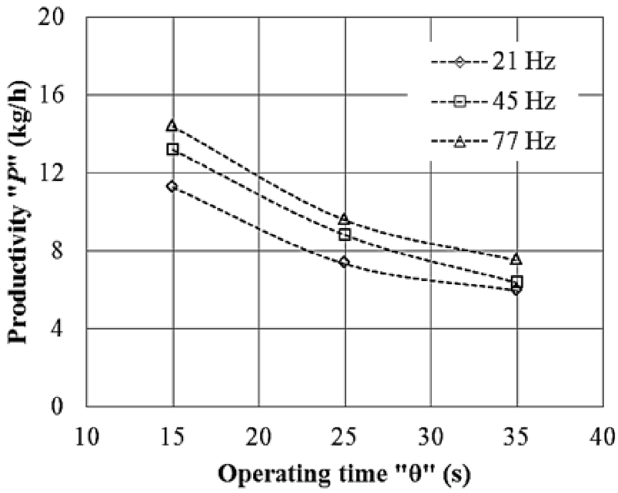

Fig. 5. The relationship between productivity of separated arils and "θ" at different "Hf" for "CP" cutting.

3.3. Effect of the operating time "θ" and hammer frequencies "Hf" on the separation efficiency "ηs"

Figs. 6 and 7 illustrate relationship between separation efficiency "η_s" (%) and operating time "θ" (s) at different hammer frequencies "*Hf*" (Hz) for "CV" and "CP" cutting. Generally, it can be observed that the separation efficiency increases by increasing operating time and hammer frequencies for each "CV" and "CP", perhaps the higher frequency with the increase in the operating time works on the speed of the vibration of the arils, which separates most of them and leads to an increase in the efficiency of the separation. The highest values of "η_s" were 97.59 % and 93.73 % for "CV" and "CP" cutting respectively at operating time 35s and hammer frequency 77 Hz, while the lowest values of "η_s" were 64.56 % and 62.58 % for "CV" and "CP" cutting respectively at operating time 15 s and hammer frequency 21 Hz.

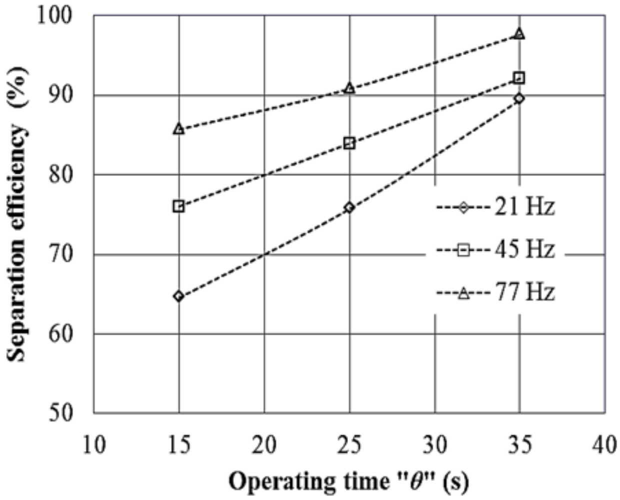

Fig. 6. Effect of operating time "θ" and hammer frequencies "Hf" on separation efficiency "η_s" for "CV" cutting.

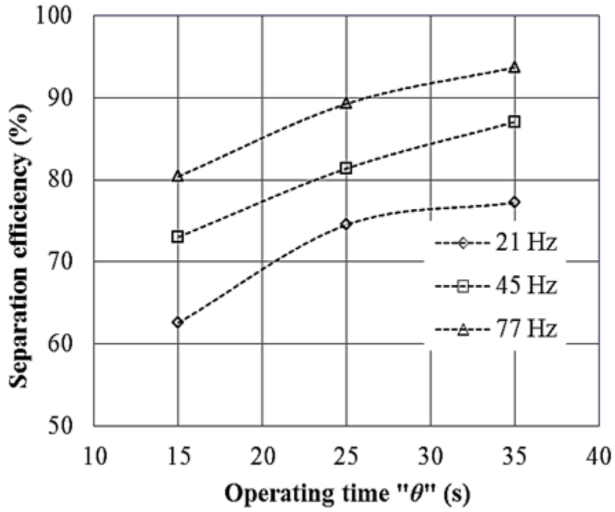

Fig. 7. Effect of operating time "θ" and hammer frequencies "Hf" on separation efficiency "η_s" for "CP" cutting.

The separation efficiency with "CV" cutting was better than "CP" cutting, so, the following equation is derived, which can be helpful in operating criterion. Fig. 6 shows the relationship between "η_s" and "θ" when "*Hf*" varied satisfied a liner function of the form:

$$\eta_s = a(\theta) + b$$

Figs 8 and 9 show that the best fit relationship of the parameter "*a*" and "*b*" as affected by "*Hf*"" for "CV" cutting were power function of the form:

$$a = 13.005\ (Hf)^{-0.718} \quad \text{and} \quad b = 6.7541\ (Hf)^{0.5696}$$

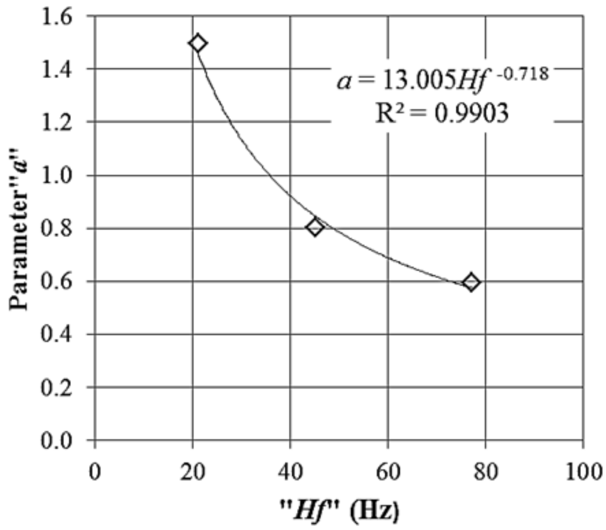

Fig. 8. The relation between parameter "a" and hammer frequencies "Hf".

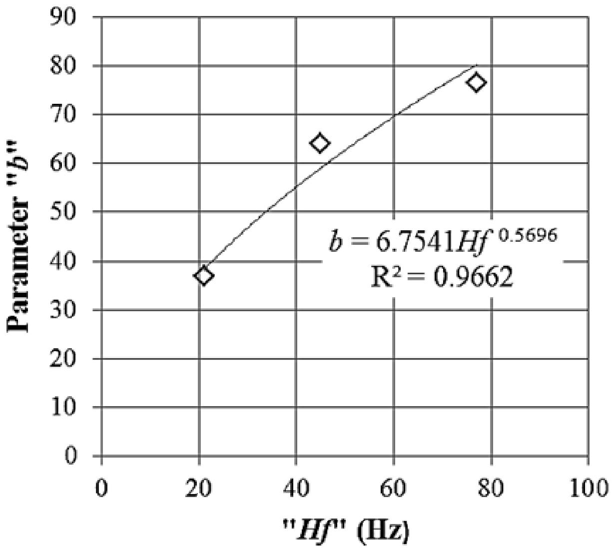

Fig. 9. The relation between parameter "b" and hammer frequencies "Hf".

The complete prediction equation regarding the collected data of this study for "CV" cutting was as the follows:

$$\eta_s = (13.005 \times Hf^{-0.718} \times \theta) + (6.7541 \times Hf^{0.5696})$$
$$R^2 = 0.9393$$

Fig. 10 shows the relationship of predicted and observed separation efficiency "η_s" for "CV" cutting.

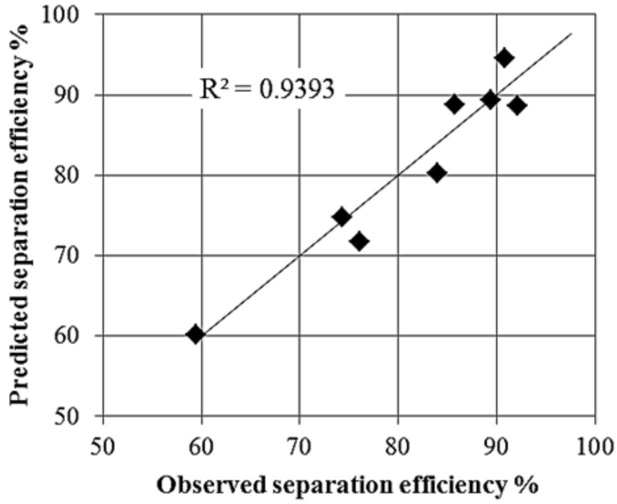

Fig. 10. Predicted and observed separation efficiency of the prototype.

3.4. Effect of the operating time "θ" and hammer frequencies "Hf" on damaged pomegranate arils percentage "da"

Figs. 11 and 12 illustrate relationship between damaged pomegranate arils percentage "*da*" (%) and operating time "*θ*" (s) at different hammer frequencies "*Hf*" (Hz) for "CV" and "CP" cutting. Results showed that the pomegranate arils damaged percentage decreases proportionally with increasing operating time and hammer frequencies. The lowest values of "*da*" were 2.41 % and 3.85 % for "CV" and "CP" cutting respectively at "*θ*" 35 s and "*Hf*" 77 Hz, while the highest values of "*da*" were 14.56 % and 17.44 % for "CV" and "CP" cutting respectively at "*θ*" 15 s and "*Hf*" 21 Hz.

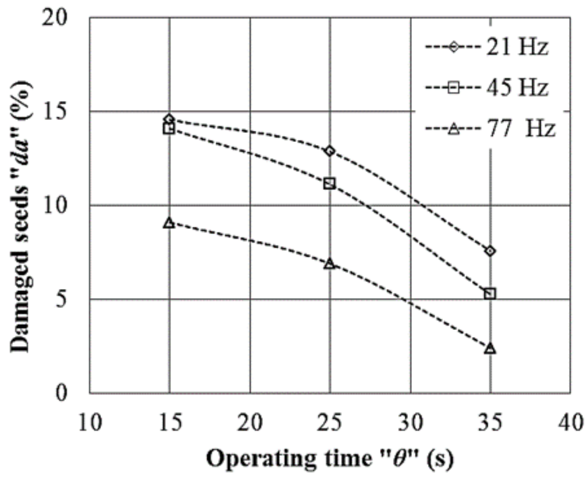

Fig. 11. The relationship between damaged arils percentage "da" and "θ" at different "Hf" for "CV" cutting.

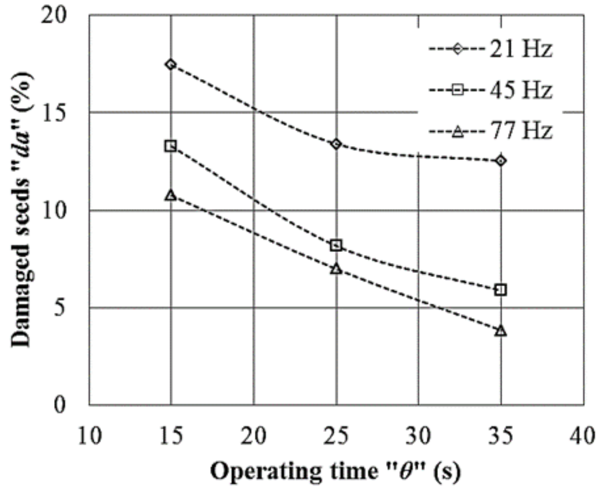

Fig. 12. The relationship between damaged arils percentage "da" and "θ" at different "Hf" for "CP" cutting.

3.5. Specific energy consumption "SEC"

Table 2 shows the Specific energy consumption "SEC" (kW.h/kg) affected by operating time "θ" (s) at different hammer frequencies "Hf" (Hz) for "CV" and "CP" cutting. It is clear that the "SEC" increases by increasing the "θ" and "Hf" for "CV" and "CP" cutting. The minimum values of "SEC" were 0.012 and 0.013 kW.h/kg for "CV" and "CP" cutting respectively at "θ" 15 s and "Hf" 21 Hz, while the maximum values of "SEC" were 0.038 and 0.042 kW.h/kg for "CV" and "CP" cutting respectively at "θ" 35 s and "Hf" 77 Hz.

Table 2
Specific energy consumption "SEC" at different separation conditions for this study.

"Hf" (Hz)	"θ" (s)	"*SEC*" (kW.h/kg) "CV" cutting	"CP" cutting
21	15	0.012	0.013
	25	0.018	0.019
	35	0.026	0.024
45	15	0.016	0.017
	25	0.023	0.025
	35	0.031	0.035
77	15	0.020	0.022
	25	0.028	0.033
	35	0.038	0.042

3.6. Effect of the operating time "θ" and hammer frequencies "Hf" on cost "Ct"

Table 3 shows the Criterion cost "C_t" (L.E/kg) affected by operating time "θ" (s) at different hammer frequencies "Hf" (Hz) for "CV" and "CP" cutting. Results showed that the costs increases with increasing the "θ" and decreases by in increasing the "Hf". The lowest values of "C_t" were 0.463 and 0.509 L.E/kg for "CV" and "CP" cutting respectively at "θ" 15 s and "Hf" 77 Hz, while the highest values of “C_t” were 1.208 and 1.229 L.E/kg for “CV” and “CP” cutting respectively at “θ” 35 s and “Hf” 21 Hz.

Table 3
Cost “Ct”at different separation conditions for this study.

“Hf” (Hz)	“θ” (s)	“C_t” (L.E/kg) "CV" cutting	"CP" cutting
21	15	0.599	0.650
	25	0.960	0.998
	35	1.208	1.229
45	15	0.566	0.555
	25	0.749	0.830
	35	1.018	1.150
77	15	0.463	0.509
	25	0.644	0.764
	35	0.880	0.975

3.7. Effect of fruit cutting method on the separation process

From the results of this study, it was noted that cutting fruits perpendicular to their axis “CV” had better to results than cutting fruits parallel to their axis “CP” with all evaluation factors, this may be due to nature of the structure of the arils inside the pomegranate fruit.

4. Conclusions

The aim of the present study is to develop and evaluate pomegranate arils separation unit to be used in home and small processing unit as juice industry. The pomegranate was cut in two halves and the experiment was carried out with half of the fruit through three replications, the separation experiments were divided in two groups, the first group was cutting the pomegranate perpendicular to its axis “CV”, and the second group was cutting the pomegranate fruit parallel to its axis “CP”. The two groups experiments were carried out with three hammer frequencies "Hf" (21, 45 and 77 Hz) and three fruit exposure time to strikes or operating time "θ" (15, 25 and 35 sec.), The number of experiments reached 54 experiment.

Productivity “P” (kg/h), separation efficiency “η_s” (%), damaged pomegranate arils percentage “d_a” (%), specific energy consumption “SEC” (kW.h/kg) and cost “C_t” (L.E/kg) were calculated for all experiments in this study.

The results can be summarized as follow:

1. The highest values of productivity were 15.84 and 14.40 kg/h for “CV” and “CP” cutting respectively at “θ” 15 s and “Hf” 77 Hz, while the lowest values for productivity were 6.07 and 5.97 kg/h for “CV” and “CP” cutting respectively at “θ” 35 s and “Hf” 21 Hz.
2. The highest values of “η_s” were 97.59 % and 93.73 % for "CV" and "CP" cutting respectively at operating time 35s and hammer frequency 77 Hz, while the lowest values of “η_s” were 64.56 % and 62.58 % for "CV" and "CP" cutting respectively at operating time 15 s and hammer frequency 21 Hz. A mathematical relationship was reached to predict the efficiency of the separation at different operating conditions in the case of the perpendicular cut on the fruit axis, as it achieved the form:

$$\eta_s = (13.005 \times Hf^{-0.718} \times \theta) + (6.7541 \times Hf^{0.5696})$$

$$R^2 = 0.9393$$

3. The lowest values of “da” were 2.41 % and 3.85 % for “CV” and “CP” cutting respectively at “θ” 35 s and “Hf” 77 Hz, while the highest values of “da” were 14.56 % and 17.44 % for “CV” and “CP” cutting respectively at “θ” 15 s and “Hf” 21 Hz.
4. The minimum values of “SEC” were 0.012 and 0.013 kW.h/kg for “CV” and “CP” cutting respectively at “θ” 15 s and “Hf” 21 Hz, while the maximum values of “SEC” were 0.038 and 0.042 kW.h/kg for “CV” and “CP” cutting respectively at “θ” 35 s and “Hf” 77 Hz.
5. The lowest values of “C_t” were 0.463 and 0.509 L.E/kg for “CV” and “CP” cutting respectively at “θ” 15 s and “Hf” 77 Hz, while the highest values of “C_t” were 1.208 and 1.229 L.E/kg for “CV” and “CP” cutting respectively at “θ” 35 s and “Hf” 21 Hz.

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نموذج أولي لفصل حبات الرمان

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الملخص العربي

تهدف هذه الدراسة إلى تصنيع نموذج أولي لفصل حبات الرمان عن قشرتها لاستخدامه منزليا أو لوحدات التصنيع الصغيرة. وتتمثل فكرة عمل النموذج في الطرق على القشرة لنصف ثمرة رمان فتهتز حبيبات الرمان وتسقط سقوطاً حراً. كما تهدف الدراسة إلى تقييم هذا النموذج بناءً على الإنتاجية وكفاءة الفصل والنسبة المئوية للحبات المهشمة أثناء عملية الفصل والاستهلاك النوعي للطاقة والتكلفة.

وتتمثل متغيرات الدراسة فيما يلي:

١. تردد المطرقة (٢١, ٤٥, ٧٧ هرتز).

٢. زمن التشغيل (١٥, ٢٥, ٣٥ ثانيه).

٣. طريقة قطع ثمرة الرمان (عمودياً على محورها، موازياً لمحورها).

وتتلخص النتائج فيما يلي:

- أعلى قيم لإنتاجية النموذج كانت ١٥,٨٤ و ١٤,٤٠ كجم/ساعة للقطع العمودي والموازي على التوالي عند زمن تشغيل ١٥ ثانيه وتردد ٧٧ هرتز. بينما كانت أقل قيم للإنتاجية ٦,٠٧ و ٥,٩٧ كجم/ساعة للقطع العمودي والموازي على التوالي عند زمن تشغيل ٣٥ ثانيه وتردد ٢١ هرتز.
- أعلى قيم لكفاءة الفصل كانت ٩٧,٥٩ و ٩٣,٧٣ % للقطع العمودي والموازي على التوالي عند زمن تشغيل ٣٥ ثانيه وتردد ٧٧ هرتز. بينما كانت أقل قيم الكفاءة ٦٤,٥٦ % و ٦٢,٥٨ % للقطع العمودي و الموازي على التوالي عند زمن تشغيل ١٥ ثانيه وتردد ٢١ هرتز. وتم التوصل لعلاقة رياضية للتنبؤ بكفاءة الفصل عند ظروف التشغيل المختلفة لهذه الدراسة في حالة القطع العمودي على محور الثمرة حيث حقق الصورة:

$$\eta_s = (13.005 \times Hf^{-0.718} \times \theta) + (6.7541 \times Hf^{0.5696}) \qquad R^2 = 0.9393$$

- أقل قيم للنسبة المئوية للحبات المهشمة كانت ٢,٤١ و ٣,٨٥ % للقطع العمودي والموازي على التوالي عند زمن تشغيل ٣٥ ثانيه وتردد ٧٧ هرتز. بينما كانت أعلى قيم ١٤,٥٦ و ١٧,٤٤ % % للقطع العمودي والموازي على التوالي عند زمن تشغيل ١٥ ثانيه وتردد ٢١ هرتز.
- أقل قيم للاستهلاك النوعي للطاقة كانت ٠,٠١٢ و ٠,٠١٣ كيلووات. ساعة /كجم للقطع العمودي والموازي على التوالي عند زمن تشغيل ١٥ ثانيه وتردد ٢١ هرتز. بينما كانت أعلى قيم ٠,٠٣٨ و ٠,٠٤٢ كيلووات. ساعة/كجم للقطع العمودي والموازي على التوالي عند زمن تشغيل ٣٥ ثانيه وتردد ٧٧ هرتز.
- أقل قيم لتكلفة فصل حبات الرمان لهذا النموذج كانت ٠,٤٦٣ و ٠,٥٠٩ جنيه/كجم للقطع العمودي والموازي على التوالي عند زمن تشغيل ١٥ ثانيه وتردد ٧٧ هرتز. بينما كانت أقل قيم ١,٢٠٨ و ١,٢٢٩ جنيه/كجم للقطع العمودي والموازي على التوالي عند زمن تشغيل ٣٥ ثانيه وتردد ٢١هرتز.