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Factors Affecting the Mechanical Extraction of Jatropha Curcas Oil

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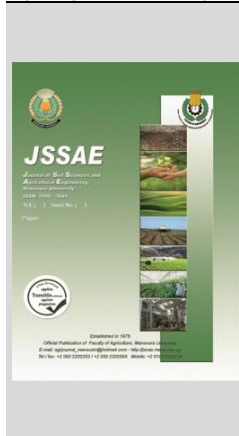


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ABSTRACT

The aim of the present research is to study some different factors affecting the mechanical extraction of jatropha oil. The hydraulic pressing machine was evaluated using (whole seeds or kernel), four pressures of 100, 150, 200 and 250 bar, four seed cooking temperatures of 80, 90, 100 and 110 °C and four extraction times of 15, 20, 25 and 30 min. The evaluation included machine production rate, expression efficiency, oil losses, specific energy and economical costs. The obtained data showed that using the whole seeds the highest value of machine productivity of 3.43 kg/h, the lowest specific energy of 144.46 kW.h/Mg and the lowest cost per mass unit of 7.23 L.E/Mg were recorded with extraction pressure of 250 bar, extraction time of 15 minute and seed temperature of 110 °C. And the highest value of expression efficiency of 85.93% at extraction pressure of 250 bar, extraction time of 30 minute and seed temperature of 110 °C. meanwhile, using kernel seeds under room temperature the highest value of machine productivity of 4.87 kg/h, the lowest specific energy of 100.80 kW.h/Mg and the lowest cost per mass unit of 5.05 L.E/Mg were recorded with extraction pressure of 250 bar and extraction time of 15 minute. And the highest value of expression efficiency of 87.04% at extraction pressure of 250 bar and extraction time of 30 minute.

Keywords: *Jatropha curcas* oil extraction, extraction temperature, extraction (residence) time and extraction pressure.



INTRODUCTION

Jatropha Caracas (Jatropha) is the best sustainable oil source. It is multi-purpose. Jatropha seeds are a good source of oils. It contains approximately 30 to 35 % of oil (Azam *et al.*, 2005) and Jatropha kernel consists of about 47-50 % oil (Ogunleye, 2012). Nobrega and Sinha (2007) stated that it is a genus of more than 170 plants of the Euphorbia family, native to central America but commonly used in most tropical and subtropical regions of the world. The yield per hectare is more than four times of soybean yield and ten times of corn yield.

Pandey *et al.* (2012) mentioned that Jatropha is a semi-evergreen poisonous shrub or small tree up to 6 meters high. It is a native of the Mexican tropics and has now spread and naturalized throughout the tropics of the entire world. Also, Mani (2012) mentioned that jatropha plant can be used for various purposes. For example, it is used in the process of making cleaning fluids and dyes for clothing, organic fertilizers, as anti-snakebites, as well as for other medicinal purposes. Every part of the jatropha plant such as leaves, flowers, fruit, bark, root and seeds has its own uses, making the plant of the multi-purpose type. The fact that jatropha oil cannot be used for food purposes because it is harmful to the human body makes it very attractive as a source of fuel.

Kamel *et al.* (2018) stated that jatropha seeds were the ideal sustainable and low-cost source of oil feedstock for biodiesel production. Where, Juan *et al.* (2003) stated that this species have been shown to have anti-tumor activity and it has a wide range of uses and promises various significant benefits to human and industry. Also, Gubitz *et al.* (1999) said that the jatropha seeds can be used in treatment of constipation and the sap was found effective in accelerating wound healing procedure, the leaves can be used as a remedy for malaria and high fever.

Tiwari *et al.* (2007) Stated that the plant can be used as an ornamental plant, potential feed stock, raw material for

dye, pesticide, soil enrichment manure and more importantly as an alternative for biodiesel production.

Ibrahim *et al.* (2019) reported that the produced oil from jatropha seeds non-edible. This hydraulic press squeezes jatropha seeds to produce oil. It is designed to obtain the maximum oil yield. Time of oil extracted from jatropha seeds is 720 minutes at a yield of 11%. The extracted Jatropha oil gave light color because of its low FFA of 5%. The flash point of the oil is higher than diesel oil. The density and viscosity of the extracted oil decreased as the temperature increases. Calorific value of the produced jatropha oil was 39201kJ/kg. Jatropha biodiesel oxidation instability increased for hydraulic extraction due to its content of oleic and linoleic acids.

Ogunleye and Eletta (2012) stated that different methods were used to obtain jatropha oil from its seeds as chemical extraction and mechanical extraction; the common methods used for the extraction of the oil include mechanical pressing, solvent extraction and supercritical fluid extraction. Mechanical extraction is the most widely used method.

Achten (2010) reported that a mechanical extraction is the most popularly used due to its easiness, low maintenance and economical. The mechanical extraction needs further treatments, such as filtering and degumming. These techniques can kernels or whole seeds. The chemical extraction is used only kernels as a material.

Subroto *et al.* (2015a) tested that a hydraulic presses to investigate the effect of process parameters on oil recovery. The tested parameters were compression speed of oil extraction of 0.5 - 25 bar/s, pressing temperature of 25 - 105 °C, applied pressure of 50 - 250 bar, pressing time of 1 - 30 min and preheating time of 0 - 30 min. Oil recovery increased with the increase in pressing time and temperature. The optimum oil recovery of 86.1 % was obtained when jatropha seeds were temperature of 90 °C and pressed at 150 bar for 10 min of pressing.

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Subroto *et al.* (2015a) decided that The Mechanical extraction is considered to be the best option for oil expression of jatropha in rural areas. The optimum oil recovery with respect to oil quality and time of pressing was obtained when jatropha seeds were 90°C for 10 min of pressing and pressed at 150 bar. The oil recovery obtained at these processing conditions was 86.1 %.

Willems *et al.* (2008) evaluated the influence of temperature profile, pressure, moisture content and cake thickness on the oil yields and rate of pressing for a variety of seeds (sesame, linseed, palm kernel, jatropha and rapeseed) by using hydraulic press. The results showed that when the pressure is increased using a temperature of 100 C, the oil yield increases for all tested oil seeds. The oil yield obtained for the hulled seeds were considerably higher than that obtained for the seeds with husks. This can be explained by the absorption of oil by fibers present in the hulls.

Bamgboye and Adejumo (2011) studied that variables were the pressure applied during pressing, heating temperature of the grains, heating time and pressing time. Both processing parameters and size of the material affected the oil yield, which increased with increased in the processing parameters of pressure up to 200 bar and temperature of 100 °C and decreased beyond these points. The oil yield increases with an increase in moisture content, a higher oil yield for different process parameters.

Tambunan *et al.* (2012) mentioned that there are some different factors affecting the mechanical extraction of jatropha oil. Is pressing time, pressing temperature and seeds case on oil recovery. The experiment was conducted in factorial arrangement, sample (seeds and kernel), extraction temperature (ambient, 50, 60 and 80 °C), and preheating time (600, 1200, and 2400 s). The results show that the kernel of jatropha before extracting the oil mechanically will give higher oil yield and higher expression efficiency. Higher temperature and longer time increased the oil yield. And the maximum applicable temperature for mechanical extraction is 60 °C, since the viscosity and free fatty acid content of the extracted oil will increase if the extraction temperature increased above the temperature.

Subroto *et al.* (2015 b) studied that the effect of pressure temperature, pressing applied and moisture content on oil recovery. Pressing temperature had the most significant effect on the recovery followed by applied pressure and quadratic of moisture content. The optimum extraction condition for oil yield within the experimental range of the variables researched was at 190 bar applied pressure, and 90 °C pressing temperature. At this condition, the yield of oil was 87.8 %.

The objectives of this study were:

- (1) Extract oil from jatropha seeds mechanically using the hydraulic pressing extraction machine.
- (2) Study some different operating factors affecting the mechanical extraction of jatropha oil such as case of seeds, extraction pressure and time, seed cooking temperature.
- (3) Evaluate the Pressing machine from the economic point of view.

MATERIALS AND METHODS

The main experiments were carried out in Alkanz Company for oil extraction, Banaiuos village, zagzig at Sharkia Governorate.

Pressing machine

The hydraulic pressing machine was used in this study, which it locally made. The main dimensions of Pressing machine are 1310 mm length, 760 mm width and 1910 mm height as shown in Fig. 1. It consists of the following:

- (1) Two pistons with diameter of 200 mm and maximum hydraulic pressure of 250 bar.
- (2) Electrical motor of 3 hp and 380 Volt. The windings number of 1470 r/min, Hz of 50 and IP of 50 with type of YC112M-4.

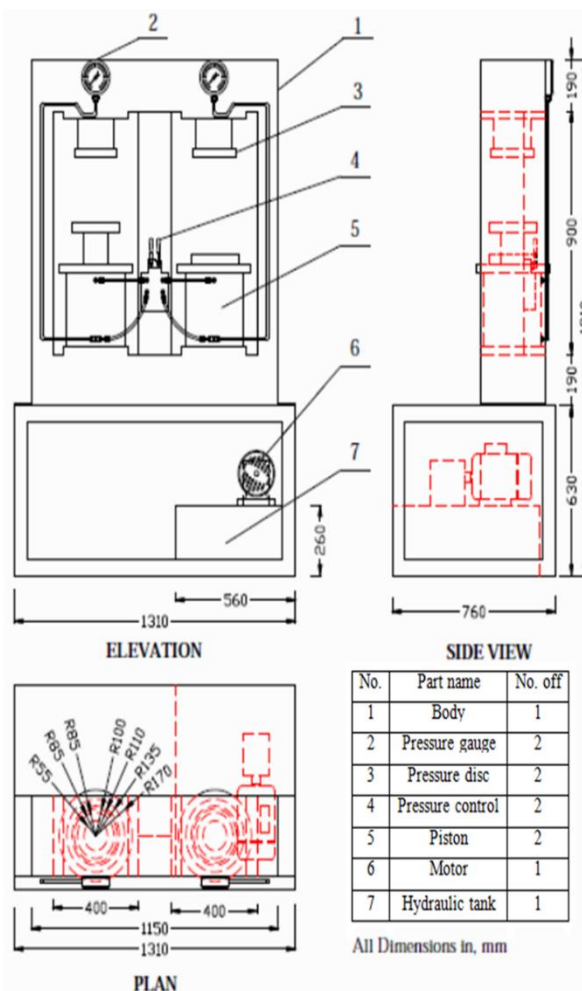


Fig. 1. Views of tested hydraulic pressing machine.

Experimented procedures

The hydraulic pressing machine is tested under the following factors at seed batch mass of 3 kg:

- (1) **Case of the seeds:** Whole and kernel (whole seed without husk) jatropha seeds are tested under room temperature of 26 °C. Fig.2 shows the seed parts and shape of jatropha seeds.
- (2) **Seed cooking temperature:** The whole seeds only are cooked at temperature of 80, 90, 100 and 110 °C. The tested temperatures are chosen because of increasing the darkness of oil sharply at cooking temperature more than 80 °C. The duration of cooking time is 20 min.
- (3) **Extraction pressure:** The investigated Jatropha oil extraction-pressures are 100, 150, 200 and 250 bars.
- (4) **Extraction (residence) time:** The tested jatropha oil extraction-times are 15, 20, 25 and 30 minute.



Fig. 2. Parts and shape of jatropha seeds

Measurements

Evaluation of the extraction machine was carried out taken into consideration the following indicators:

Physical properties of tested jatropha seeds

Table 1 shows moisture content, diameter, shape and mass of 1000 jatropha seeds. These data were measured for 1000 seeds sample according to the standards set in (Mousa *et al.*, 2016).

Table 1. Physical properties of jatropha seeds

Physical properties	whole seed
Moisture content, d. b., %	8.25
Seed (length, width, thickness, arithmetic and geometric mean diameter) mm.	17.28 - 11.06 - 8.11 - 12.15 - 11.57 respectively.
Shape	Oval
Mass of 1000	551.1 g
kernels mass percentages relative whole seeds %	60.84

Machine productivity: Extracted oil was collected under the different operating conditions, weighed by analog balance and machine productivity was calculated using the following equation:

$$\text{Machine productivity (kg / h)} = \frac{\text{Extracted oil (kg)}}{\text{Extraction time (h)}} \dots\dots\dots(1)$$

Oil losses: It was calculated using the following equation;

$$\text{Oil losses, \%} = \frac{O_c}{O_t} \times 100 \quad (\%) \dots\dots\dots(2)$$

Where:

O_c = Mass of remaining oil in cake, kg.

O_t = Mass of total oil (extracted + in cake), kg.

Expression efficiency: It was conformed from the following Equation;

$$\text{Expression efficiency, \%} = 100 - \text{Oil losses} \dots\dots\dots(3)$$

Specific energy: The power requirement was estimated by the following equations (Kurt, 1979):

$$P, \text{ kW} = \sqrt{3} \cdot I \cdot V \cdot \eta \cdot \text{Cos } \Theta / 1000 \dots\dots\dots(4)$$

Where:

I = Line current strength in amperes.

V = Potential difference (Voltage) being equal to 380 V.

$\text{Cos } \Theta$ = Power factor (being equal to 0.84).

$\sqrt{3}$ = Coefficient current three phase (being equal 1.73).

η = Mechanical efficiency assumed (90 %).

Hence, the specific energy can be calculated as follows:

$$\text{Specific energy, kW.h/Mg} = \frac{\text{Engine power (kW)}}{\text{Machine productivity (Mg/h)}} \dots\dots\dots(5)$$

Operating cost: The total cost of mechanical jatropha oil extraction was estimated using the following equation (Awady, 1978):

$$\text{Operating cost} = \frac{\text{Machine cost (L.E/h)}}{\text{Machine productivity (Mg/h)}}, \text{ L.E./Mg} \dots\dots\dots(6)$$

Machine cost was determined by using the following equation:

$$C = \frac{P}{h} \left(\frac{1}{a} + \frac{i}{2} + t + r \right) + (W \cdot e) + \frac{m}{144} \dots\dots\dots(7)$$

Where:

C = Machine cost, L.E/h.

h = Yearly working hours, h/year.

i = Interest rate/year.

t = Taxes, over heads ratio.

m = Monthly average wage, L.E

144 = Reasonable estimation of monthly working hours.

P = Price of machine, L.E.

a = Life expectancy of the machine, h.

e = hourly cost/kW.h.

r = Repairs and maintenance ratio.

W = Power of motor in kW.

RESULTS AND DISCUSSION

Machine productivity and expression efficiency

Case of the seeds

Figs. 3 and 5 display the relation between seeds case with machine productivity and expression efficiency under temperature of 26 °C (room temperature). Hence, it appears that the machine productivity and expression efficiency increased by changing the seeds case from whole seeds to kernel seeds. The results showed that, the maximum machine productivity of 4.87 kg/h was achieved with using the kernel seeds at extraction pressure of 250 bar and extraction time of 15 minute. Meanwhile, the maximum expression efficiency of 87.04% was recorded at the kernel seeds with extraction pressure of 250 bar and extraction time of 30 minute. It is obvious that the machine production rate increased at use kernel seeds.

Seed cooking temperature

Figs. 4 and 6 indicate a clear increase in the values of machine productivity for whole seeds as the seed cooking temperature was increased. Also, the expression efficiency was increased by increasing the seed cooking temperature .Hence, from the results it is clear that the maximum machine productivity of 3.43 kg/h was recorded at extraction pressure of 250 bar and extraction time of 15 minute with temperature of 110°C . While, the maximum expression efficiency was recorded of 85.93% at extraction pressure of 250 bars under extraction time of 30 minute and temperature of 110°C. The increasing of oil productivity by increasing seed temperature is due to stimulate the oily cells occurs more oil extraction.

Extraction pressure

Also, Figs. 4 and 6 show the effect of extraction pressure on productivity and expression efficiency at whole seeds. The productivity increased from 3.16 to 3.43kg/h when extraction pressure increased from 100 to 250 bars at extraction time of 15 minute with temperature of 110°C. While the expression efficiency increased from 79.50 to 85.93 % by increasing the pressure from 100 to 250 bars at extraction time of 30 minute with temperature of 110°C. The increasing of oil productivity by increasing extraction pressure is lead to increasing the expression efficiency.

Extraction time

The productivity as it affected by extraction time was illustrated in Figs 4 and 6. It noted that the productivity decreased

from 3.43 to 1.80 kg/h by increasing the extraction time from 15 to 30 minute at extraction pressure 250 bar with temperature of 110°C while, increasing extraction time lead to increase of the expression efficiency from 81.67 and 85.93% at extraction pressure 250 bar with temperature of 110°C .

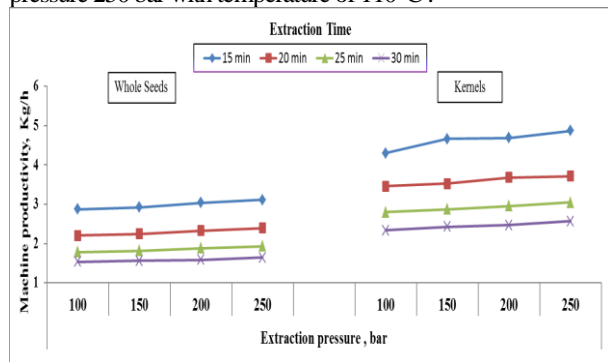


Fig. 3. Effect of some operating parameters on machine productivity for whole and kernel jatropha seeds at room temperature of 26 °C

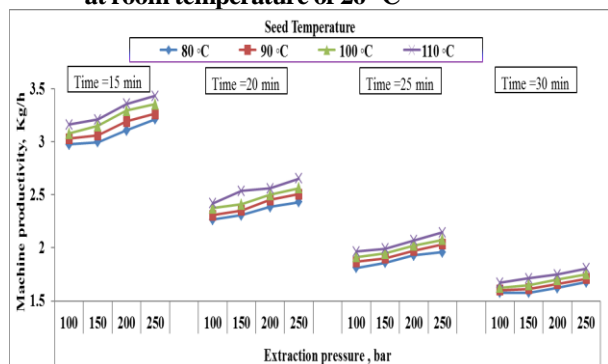


Fig. 4. Effect of some operating parameters on machine productivity for jatropha whole seeds

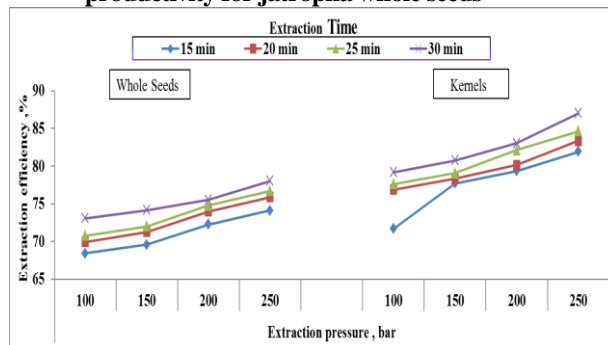


Fig. 5. Effect of some operating parameters on expression efficiency for whole and kernel jatropha seeds at room temperature of 26 °C

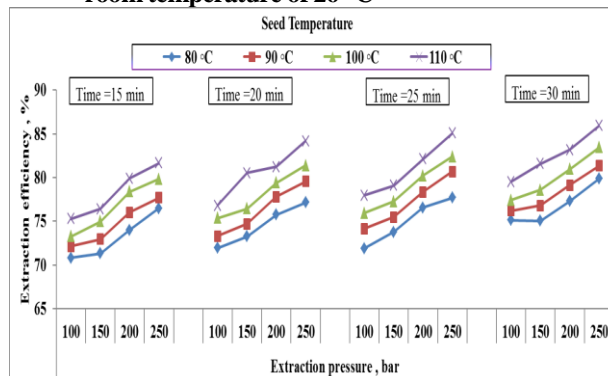


Fig. 6. Effect of some operating parameters on expression efficiency for jatropha whole seeds

Machine oil losses

Case of the seeds

Fig. 7 shows the effect of extraction pressure and extraction time on oil losses for whole and kernel seeds with temperature of 26 °C.

The oil losses decreases by using kernel seeds compared with the whole seeds at the same parameters. The minimum oil loss of 12.96 % is obtained with extraction pressure of 250 bars, extraction time of 30 minute and kernel seeds. Meanwhile, the maximum oil losses of 31.57 % is obtained with extraction pressure of 100 bar, extraction time of 15 minute and whole seeds.

The decreasing of oil losses by using kernel seeds is due to stimulate the oily cells occurs more oil extraction.

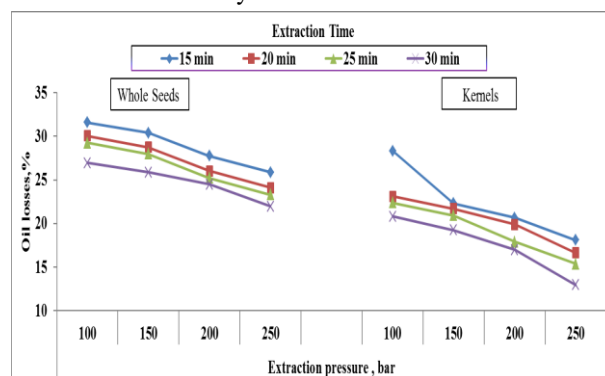


Fig. 7. Effect of some operating parameters on oil losses for whole and kernel jatropha seeds at room temperature of 26 °C

Seed cooking temperature

Fig. 8 displays the relation between seeds temperature with oil losses for whole seeds. Hence, it appears that the oil losses decreased by increasing seed temperature with whole seeds. The results showed that, the minimum oil loss of 14.07% is obtained at extraction pressure of 250 bar, extraction time of 30 minute and whole seeds with 110°C seeds temperature. The maximum oil loss of 29.19% was recorded at extraction pressure of 100 bar, extraction time of 15 minute and whole seeds with 80°C seeds temperature.

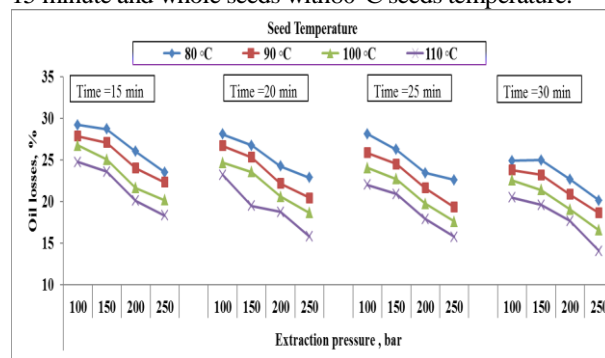


Fig. 8. Effect of some operating parameters on oil losses for jatropha whole seeds

Extraction pressure

Fig. 8 shows the effect of extraction pressure on oil losses at whole seeds. The increasing extraction pressure from 100; 150; 200 to 250 bar leads to decreasing the oil losses from 20.50; 19.59; 17.67 to 14.07 % at extraction time of 30 minute with temperature of 110°C.

The decreasing of oil losses by increasing extraction pressure is due to increasing the productivity and expression efficiency.

Extraction time

Fig. 8 illustrates that, the oil losses as it affected by extraction time at using whole seeds. It noted that the oil losses decreased from 18.33 to 14.07% by increasing the extraction time from 15 to 30 minute at extraction pressure 250 bar with temperature of 110°C.

Specific energy

Results in Figs.9 and 10 showed, the effect of jatropha seed extraction pressure, seed case, seed temperature and extraction time on specific energy. The obtained results show that increasing extraction pressure lead to increase the consumed power and the contrarily was noticed with the required energy. According to the obtained data it appears that the lowest specific energy were obtained at extraction pressure of 250 bar but the highest specific energy were recorded at extraction pressure 100, meanwhile the other parameter remained constant. The decrease in specific energy by increasing extraction pressure can be attributed to the increase of the machine productivity. The recorded results show that the specific energy decreases with using kernel seed. Also results show specific energy increases by increasing extraction time. While, the required energy increases by decreasing seed temperature. The results indicate that the lowest values of specific energy were 115.21; 106.29; 104.08 and 100.80 kW.h/Mg for extraction pressure of 100; 150, 200 and 250 bars respectively at the extraction time 15 minute and seed temperature of 26°C with kernel seeds. Meanwhile, the highest values of specific energy were 365.30; 365.68; 354.90 and 343.56 kW.h/Mg for extraction pressure of 100; 150, 200 and 250 bars respectively at the extraction time of 30.0 min at seeds temperature of 80 °C with whole seeds.

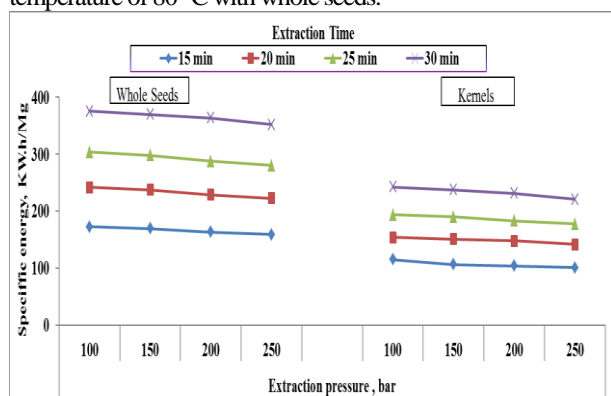


Fig. 9. Effect of some operating parameters on specific energy for whole and kernel jatropha seeds at room temperature of 26 °C

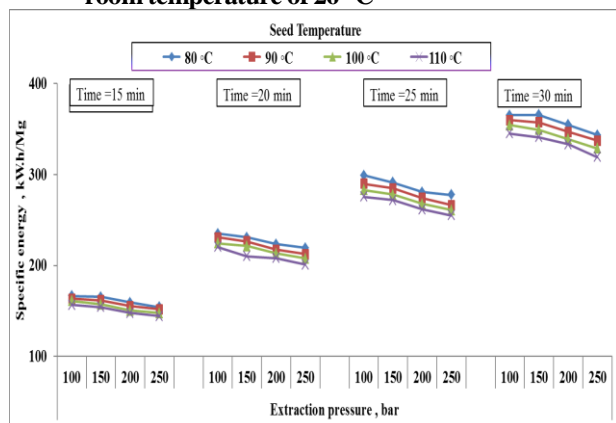


Fig. 10. Effect of some operating parameters on specific energy for jatropha whole seeds

Operational cost of mechanical oil extraction

Results in Figs.11 and 12 showed that, the effect of extraction pressure, seed temperature and extraction time on operational cost of mechanical oil extraction at whole and kernel seed. Operational cost decreases by increasing extraction pressure and also increasing seeds temperature with using kernel compared with the whole seeds, while the total cost production decreases by decreasing extraction time. This decrease may be due to the great increase occurred in machine productivity. The minimum operational cost of mechanical oil extraction of 5.05 L. E/kg is obtained with extraction pressure of 250 bar, extraction time of 15 minute and seed temperature of 26°C with kernel seeds. While, the maximum operation cost of mechanical oil extraction of 15.77 L. E/kg is obtained with extraction pressure of 100 bar, extraction time of 30 minute and seed temperature of 80 °C with whole seeds.

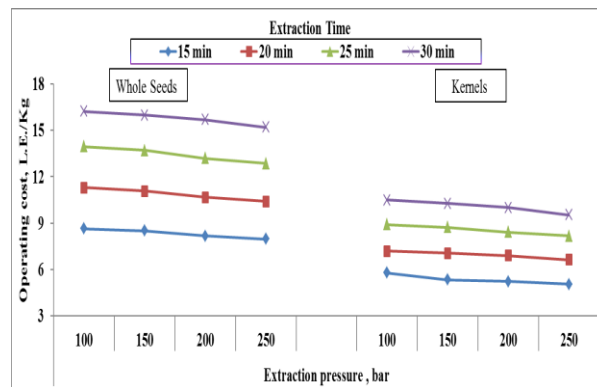


Fig. 11. Effect of some operating parameters on operational cost for whole and kernel jatropha seeds at room temperature of 26 °C

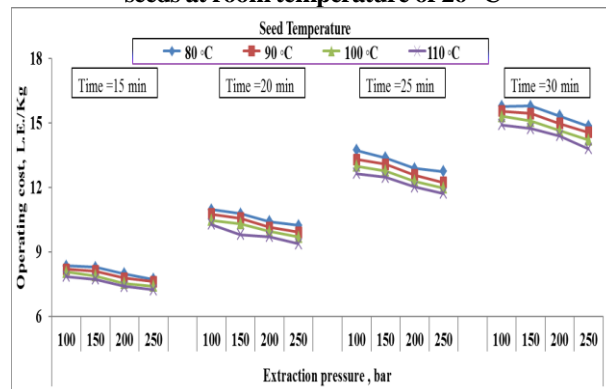


Fig. 12. Effect of some operating parameters on operational cost for jatropha whole seeds

CONCLUSION

It is concluded that the optimum conditions for mechanical extraction of jatropha oil by using the hydraulic pressing machine are the following:

- **using whole seeds:** extraction pressure of 250 bar, extraction time of 15 min and seed temperature of 110 °C recorded the optimum parameter. Results at above parameters are productivity of 3.43 kg/h, expression efficiency of 81.67 % specific energy of 144.46 kWh/Mg and operating cost of 7.23 L.E/kg.
- **using kernel seeds:** extraction pressure of 250 bar, extraction time of 15 min with temperature room of 26 °C conducted the optimum operations. Productivity of 4.87 kg/h, expression efficiency of 81.93 % specific energy of

100.80 kWh/Mg and operating cost of 5.05 L/E/kg consider the best results.

- Expression efficiency and costs may be improved by increase the diameter and number of the machine cylinder.

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عوامل مؤثرة على الإستخلاص الميكانيكي لزيت الجatroفا أحمد إبراهيم إمام ، ميرفت محمد عطالله وعادل أحمد الجيزاوي معهد بحوث الهندسة الزراعية، مركز البحوث الزراعية، مصر

يهدف هذا البحث إلى دراسة بعض العوامل المؤثرة على الإستخلاص الميكانيكي لزيت الجatroفا. وأجريت التجارب الرئيسية في شركة الكنز لاستخلاص الزيوت بقرية بنايوس مركز الزقازيق بمحافظة الشرقية. تم استخدام آلة استخلاص زيوت محلية الصنع تتكون من مكبس هيدروليكي أقصى ضغط 250 بار قطر المكبس 200 مم مصدر القدرة موتور كهربائي 3 حصان 380 فولت، عدد اللفات 1470 لفة/الدقيقة. وتم دراسة تأثير المتغيرات الآتية: 1- حالة وشكل البذور: استخلاص الزيت من الحبوب الكاملة واستخلاص من اللب في درجة حرارة الغرفة 26 °م درجة مئوية. 2- درجة حرارة البذور: استخلاص على الساخن للبذور فقط عند درجات حرارة 80، 90، 100، 110 °م مطبوخة لمدة 20 دقيقة. 3- ضغط الإستخلاص: أربعة ضغوط مختلفة هي 100، 150، 200 و250 بار. 4- زمن الإستخلاص: 15، 20، 25 و30 دقيقة. - وقد أوضحت النتائج أن أفضل القيم المتحصل عليها أثناء التشغيل كانت كالتالي: * استخلاص الزيت من البذور الكاملة: أعلى إنتاجية 3.43 كجم/س زيت و أقل طاقة نوعية 144.46 ك.وات ساعة أقل تكلفة 7.23 جنيه/كجم سجلت عند ضغط 250 بار درجة حرارة 110 °م وزمن 15 دقيقة. وأعلى كفاءة كان 85.93% كانت عند ضغط 250 بار درجة حرارة 110 °م وزمن 30 دقيقة. * استخلاص الزيت من اللب: أعلى إنتاجية 4.87 كجم/س زيت و أقل طاقة نوعية 100.80 ك.وات ساعة أقل تكلفة 5.05 جنيه/كجم سجلت عند ضغط 250 بار وزمن 15 دقيقة. وأعلى كفاءة كان 87.04% كانت عند ضغط 250 بار وزمن 30 دقيقة. يمكن زيادة إنتاجية وكفاءة الآلة وكذلك تقليل تكاليف الاستخلاص عن طريق زيادة قطر وعدد الاسطوانات التي يتم فيها كيس البذور.