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MECHANICAL EXTRACTION OF JOJOBA OIL

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ABSTRACT

A study was carried out to determine the proper condition for mechanical extracting of jojoba oil using laboratory scale hydraulic press. The experimental work was conducted under two different seeds conditions (whole and crushed seeds) , six different piston pressures (75, 150, 225, 300, 375 and 450 bar) that equal (61, 123,184, 246, 307, 368 bar) as actual pressure over the surface of mats having jojoba seeds and six different holding times (20, 40, 60, 80, 100 and 120, min). The results show that, the maximum percentage of extracted oil was obtained at heating temperature of 60 oC and holding time of 30 mints for both whole and crushed seeds conditions. The mesh size of 8 and 10 mesh (2 to 2.36 mm) produced the best particle size of crushed seeds which give the maximum extraction percentage of oil (35.43%). For both whole and crushed seeds conditions, the percentage of oil extraction increased with the increase of applied pressure at all levels of holding time. Meanwhile, the crushed seeds condition recorded higher extracted oil percentage in comparison with the whole seeds condition. The extraction efficiency also increased with increase of applied pressure at all levels of holding times. However, the crushed seeds condition showed higher extraction efficiency in comparison with the whole seeds. The oil extraction efficiency ranged from 16.99 to 92.23 % for the whole seeds in comparison with 27.93 to 99.17 % for the crushed seeds. Also, it should be mentioned that, the crushing process increased the oil extraction efficiency by 6.75 to 29.25 %.

INTRODUCTION

Jojoba (Simmondsia chinensis) belongs to the family simmondsiaceae is considered one of the new industrial oilseeds crops. Selection over years has produced clones having potential seed yield of 3-4 ton per ha. Some of these clones are currently being planted in large areas in different countries **(Botti et al., 1996; Melthorpe, 1998 and Tobares et al., 2004)**.

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According to the **I.J.E.C., 2008,** jojoba plants in the world occupied an area reached about 6100 hectare.

In Egypt the area planted with jojoba is over 762 feddans annually produce about 180 ton of seeds and its plantations are concentrated in El-Ismailia and Sinai south governorates **(MALR, 2007).** Regardless of the forecited economic benefits of jojoba plant products, planting jojoba shrubs in Egypt has a promising future specially because of its low water requirements and its high tolerance to salinity, as well as its ability to be planted in the new reclaimed lands or uncultivated ones. **(Hogan et al., 1980).**

Jojoba seeds constituents have a wide range of industrial uses of great economic value. The wax is used in filtration of natural oils to be a clear liquid, odorless and stable indigestible that can be used in dietary cooking oil, antifoaming agent in the production of penicillin and leather fatliquoring **(Katoh and Kunimoto, 1983).**

Different methods of oil extraction similar to those applied to other oilseeds, have been used for extraction of jojoba oil from the seeds. Those methods are mainly mechanical pressing, mechanical pressing followed by leaching (solvent extraction), or leaching only.

Hydraulic pressing as a mechanical expression method is widely used for oil extraction from rape seed, cotton seed, peanut, coconut and for bran oil extraction also. This method has advantages over solvent method such as the cost of equipment can be much less as the system is simpler and the minimum economic scale is smaller, the operation is easier and does not require skilled labor, the operation does not use volatile solvent, no danger of fire hazard nor explosion, small capacity equipment can be designed so as to be suitable for the present small amount of jojoba seeds production in Egypt **(Hendawy, 2009).**

Some of the oilseeds such as jojoba require pre-treatments / preparation including cleaning, de-hulling, crushing, cooking, etc. before the extraction process. **(Kiritsakis, 1991; Mccabe et al., 1993 and Giovachino, 1999).**

The general objective of the present work is to determine the proper conditions for mechanical extracting of jojoba oil using laboratory scale hydraulic press unit and choose the best seed pre-treatment, the proper applied pressure and holding time for the extraction process.

MATERIAL AND METHODS

Material:

Fresh jojoba seeds were used for the experimental work. It was harvested from the farm of jojoba trees in the Desert Road (90 km Cairo – Alexandra) at moisture content of about 7 ±1% (d.b) . The produced jojoba seeds were temporarily stored in plastic bags in a freezer adjusted at temperature of -5 oC in order to suppress fungal growth and minimize quality changes.

Equipment:

1 - Crushing unit:

A simple laboratory scale electric crusher working at 220 volt with rotated stainless steel knife made in Turkey (Arnica Company) was used for sample crushing.

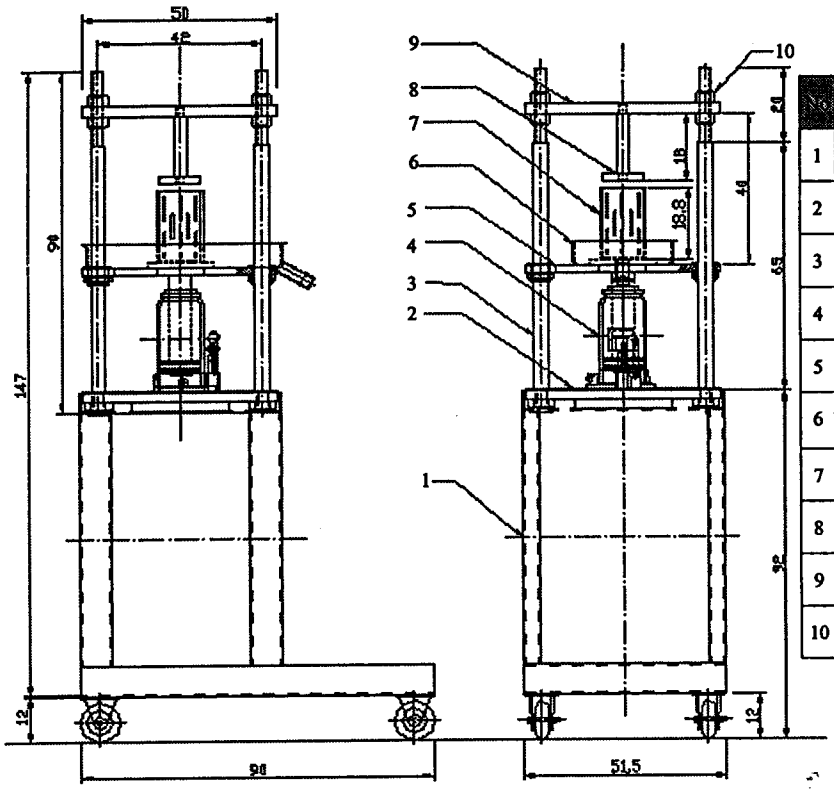
2 - The hydraulic press unit:

A local hydraulic press unit consists of 50 tons manual hydraulic piston with pressure gauge (600 bars) was used for jojoba oil extraction. The hydraulic press unit consists of an iron base with dimensions of 90 x 51.5 x 20cm, welded to a frame with dimensions of 72 x 51.5 x 51.5cm, made of an angle iron7 x 4cm.

The hydraulic press piston was carried out on a 3cm thick horizontal iron plate welded at the top surface of the unit frame. For smooth movement of the pressing plate during the pressing process, four iron steel shafts (3.5cm diameter and 90cm high) were welded to the horizontal iron plate and attached with two pressing plates made of steel iron (2.5cm) thick. The lower pressing plate was rested on the hydraulic piston and allowed to slide up and down through four vertical shafts. While the upper plate was fixed on the frame using a set of nuts and washers.

To proceed the extraction process, the piston of the hydraulic unit was positioned on the center of the upper plate facing the stainless steel cylinder and the lower plate allowed to move up by the hydraulic press arm until reaching the required pressure. The extracted oil was received in a stainless steel tray with dimensions of 52 x 27.5 x 6.5cmand discharge hole of 2.5cm diameter.

Schematic diagram of the hydraulic press unit is shown in Fig (1).



No	Description
1	Main frame
2	Lower plate of the press
3	Steel rods of the press
4	Hydraulic Jake
5	Middle plate of the press
6	Collected liquid phase tray
7	Perforated cylinder
8	Stainless steel pressing piston
9	Upper plate of the press
10	Counter nut

Fig (1) Schematic diagram of the hydraulic press unit.

Experimental Treatments:

The experimental work was carried out under two different seeds conditions (whole and crushed seeds), six different piston pressures (75, 150, 225, 300, 375 and 450 bar) that equal (61, 123,184, 246, 307, 368 bar) as actual pressure over the surface area of mats having jojoba seeds and six different holding times (20, 40, 60, 80, 100 and 120 min).

Measuring Instruments:

1 - Sieves:

A set of sieves with different sizes of mesh was used for sample screening to assess the fraction of different particle diameter of crushed seeds.

2 - Drying oven:

An electrical drying oven was used to dry Jojoba samples of both crushed and whole seeds and also the resulted cake after the pressing process in

order to determine the moisture content and prepare the samples for particle analysis.

3 - Soxhlet apparatus:

Soxhlet apparatus with siphon capacity of 100 ml (33 * 80 thimble) and flask of 250 ml was used to extract the remaining oil from the cake of different pressed samples.

Test Procedure and Measurements:

Before each experiment, jojoba samples were taken out from the freezing room and left at the ambient temperature until the initial temperature of the seeds approached a level (at or around) that of the ambient temperature.

A - Preliminary experiments:

1 - determination of the pressing pressure over the mats surface:

The actual effective pressure over the mats surface of the pressed sample as related to the pressure or the effective force over the surface area of the piston was theoretically calculated, as shown in Fig (2).

The effective force over the surface area of the piston (F_2) can be calculated as follows :

$$F_2 = P_P . A_2 \quad \text{..... (1)}$$

Where :

P_P = The piston pressure, bar

A_2 = the area of piston, mm2

Also, the extraction force over the surface area of mats (F_1) can be calculated as follows :

$$F_1 = Pe . A_1 \quad \text{..... (2)}$$

Where :

P_e = the extraction pressure, bar

A_1 = the surface area of mats, mm2

Considering the applied force over the surface area of the piston is equal to the extraction force over the surface area of the mats:

$$F_1 = F_2 \quad \text{or} \quad P_e.A_1 = P_p.A_2$$

So that

$$P_e = (P_p.A_2)/A_1 \quad \text{..... (3)}$$

$A_1 = 8654.625 \ mm^2$

$A_2 = 7048.625 \ mm^2$

When P_2 , A_2 and A_1 is known, the extraction pressure or the pressure over the surface area of Jojoba mats could be calculated and presented in table (1).

Table (1) The extraction pressure over the surface area of Jojoba mats.

Piston pressure (bar)	Extraction pressure (bar)
75	61
150	123
225	184
300	246
375	307
450	368

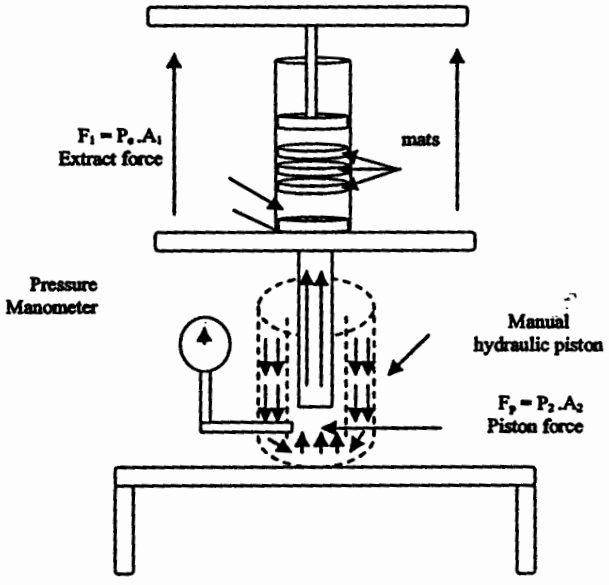


Fig. (2) Relation between the extraction pressure over the pressed sample mats and the piston pressure.

2 - Determination of the best particle size for crushing Jojoba seeds:

A sample of jojoba seeds (around 200 g) was crushed by the laboratory electric crusher for 20 seconds and then it was sieved by sieves of Sizes 4, 6, 8, 10, 12, 14 mesh (mesh is the number of opening per inch of a

screen) and divided into three groups: (4 and 6 mesh) – (8 and 10 mesh) – (12, 14 and over 14 mesh)

Each fraction of seeds particles was collected and prepared for oil extraction using the hydraulic press unit at constant pressure of 204 bar and holding time of 60 min. The extracted oil of each treatment was collected and weighed to assess the most appropriate particles size group of crushed seeds for the extraction process.

3 - Determination of the suitable seeds temperature

Before starting of Jojoba oil extraction, the suitable seed temperature for both seeds condition (whole & crushed seeds) was also determined by heating samples of about 200 g jojoba seeds (whole & crushed seeds) inside the oven at different heating temperatures (50, 60 and 70 oC) for heating period of 25,30 and 35 min . The quantity of extracted oil of every sample was determined to assess the optimum heating temperature of jojoba seeds for both conditions (whole and crushed seeds).

B - Hydraulic press extraction:

For each experimental run, samples of jojoba seeds (whole or crushed) were dispersed inside cotton mats for the hydraulic press extraction. All samples were heated up to (60 oC) for exposure time of 30 min. The mats were vertically placed inside a perforated stainless steel cylinder and the hydraulic press unit was manually operated to increase the pressure load gradually over the mat surface until reaching the required pressure which kept constant all over the experimental run. The separated oil from jojoba samples was received in the stainless tray and the jojoba mats were removed by changing the position of pressing plate down and the jojoba cake was taken out from the mats and manually crushed for determination of remaining oil percentage using the soxhelt apparatus.

The percentage of extracted oil was determined as follow:

$$\text{Percentage of extracted oil \%} = (wo / wt) \times 100 \quad \ldots\ldots\ldots\ldots (4)$$

Where:

Wo = weight of extracted oil, g.

Wt = weight of jojoba sample, g.

C - Extraction efficiency

The extraction efficiency was determined using the following equation:

$$\text{Extraction efficiency (\%)} = O_t - O_r / O_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where:

O_r = percentage of remained oil, %

O_t = percentage of total oil in sample, %

RESULTS AND DISCUSSION

1 - Proper seeds temperature for the extraction process:

As shown in fig (3) (A and B), the maximum percentage of extracted oil was obtained at heating temperature of 60 oC, while the heating period of 30 and 35 min showed very close values of the percentage of extracted oil. So, the heating period of 30 min was selected in order to save the heating energy and heating time. At this time (30 min), the percentages of extracted oil approached about 15.57 and 32.22 % for the whole and crushed seed conditions, respectively.

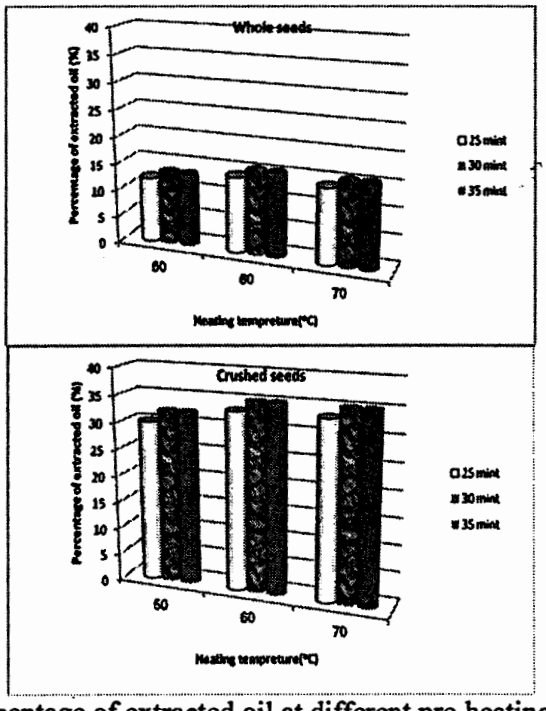


Figure (3) Percentage of extracted oil at different pre-heating temperatures and periods (A, for whole seeds and B, for crushed seeds).

2 - Optimum particle size for the crushed seeds:

The most proper particle size for the crushed jojoba seeds was determined. The evaluation base included the maximum percentage of extracted oil obtained at different size groups. As shown in table (2), the mesh size of 8 and 10 showed the highest extraction percentage of oil (35.43%).

3 - Effect of seeds condition on the percentage of extracted oil :

Fig. (4) illustrates the effect of different seeds condition (whole and crushed seeds) on the percentage of extracted oil at different levels of applied pressure and holding time.

Table (2) The optimum particle sizes for the crushed seeds.

Code	Replicates	Weight before pressing, g	Weight after pressing, g	extracted oil percentage, %	Average Percentage of extracted oil, %
4 & 6 mesh	1	163.19	105.40	29.49	29.59 ± 0.5
	2	163.11	106.29	28.87	
	3	163.18	104.00	30.40	
8 & 10 mesh	1	163.45	97.05	34.93	35.43 ± 0.5
	2	163.15	96.00	35.81	
	3	163.78	96.09	35.56	
12 , 14 & up 14 mesh	1	163.10	103.23	31.09	29.94 ± 0.5
	2	163.88	105.05	29.71	
	3	163.95	106.16	29.01	

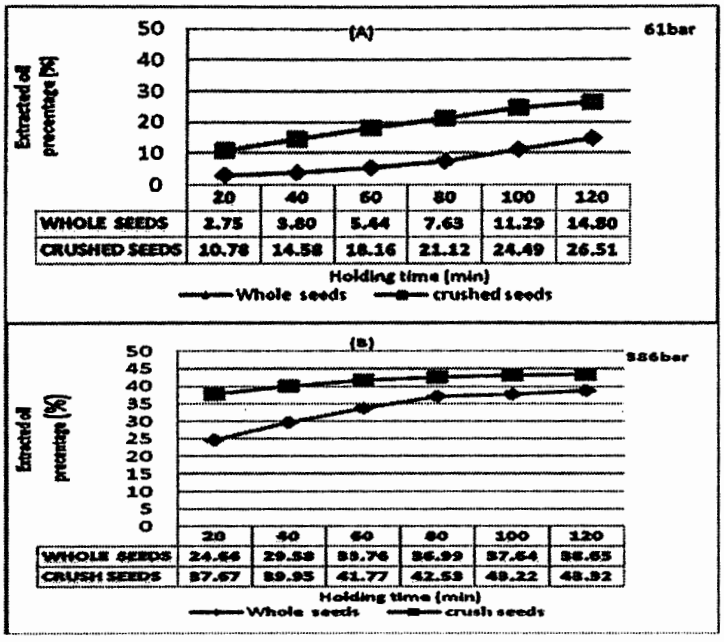


Figure (4) Effect of seeds condition on the percentage of extracted oil.

As shown in the figure, at all levels of applied pressure and holding time, the crushed seeds recorded higher extracted oil percentage in comparison with the whole seeds. At the minimum applied pressure of (61 bar) the increasing percentages of extracted oil for the crushed seeds in comparison with the whole seeds were 8.03, 10.78, 12.72, 13.40, 13.20 and 11.71 % at holding times of 20, 40, 60, 80, 100 and 120 min respectively. However, at the maximum applied pressure of (368 bar) the corresponding increase of oil extraction percentages were 13.01, 10.37, 8.01, 5.54, 5.58 and 4.67 % respectively.

The observed increase of oil extraction percentage for the crushed seeds in comparison with the whole seeds may be attributed to the rupture of oil cells which causes easier releasing of oil from the cells of crushed seeds as mentioned by Hendawy (2009).

4 - The effect of applied pressure and holding time on oil extraction:

a - Effect of applied pressure:

Fig (5) illustrates the effect of different applied pressure at the range of (61 – 368 bar) on the percentage of extracted oil for the whole seeds condition. At

all levels of holding time, the percentage of extracted oil increased with the increasing of applied pressure. As shown in fig (5), at the minimum holding time of 20 min, as the applied pressure increased from 61 to 368, bar the percentage of extracted oil increased from 2.75 to 24.66 %. While, at the maximum holding time of 120 min, the percentage of extracted oil increased from 14.8 to 38.65 % as the applied pressure increased from 61 to 368 bar. Similar trends were found for other levels of holding time.

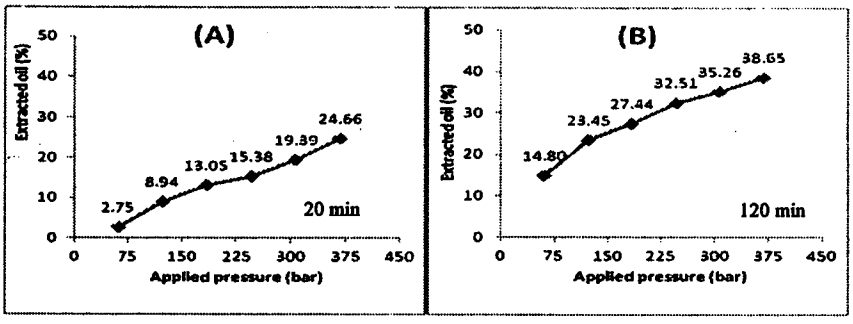


Fig (5) Effect of applied pressure on the percentage of extracted oil of the whole seeds of jojoba at (A: 20 min and B: 120 min holding time)

However, for the crushed seeds, fig (6) illustrates the effect of different applied pressure at the range of 61 – 368 bar on the percentage of extracted oil at different holding times. At the minimum holding time of 20 min, as the applied pressure increased from 61 to 368 bar, the percentage of oil extraction increased from 10.78 to 37.67 %. While, at the maximum holding time of 120 min, the percentage of extracted oil increased from 26.51 to 43.32 %.

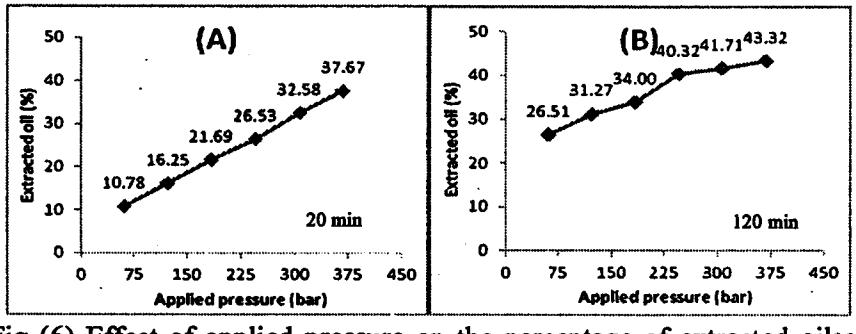
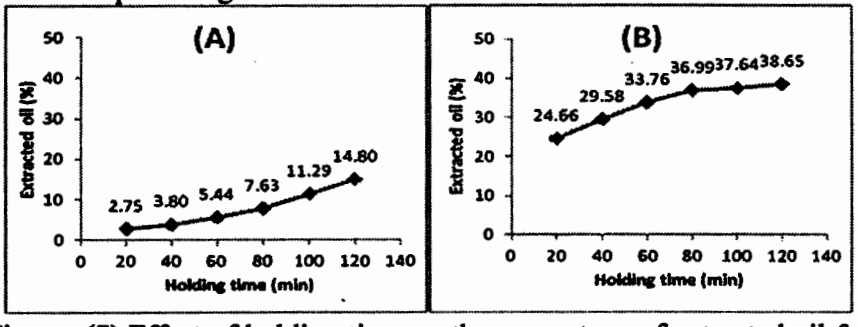


Fig (6) Effect of applied pressure on the percentage of extracted oil of crushed jojoba seeds (A: 20 min and B: 120 min holding time)

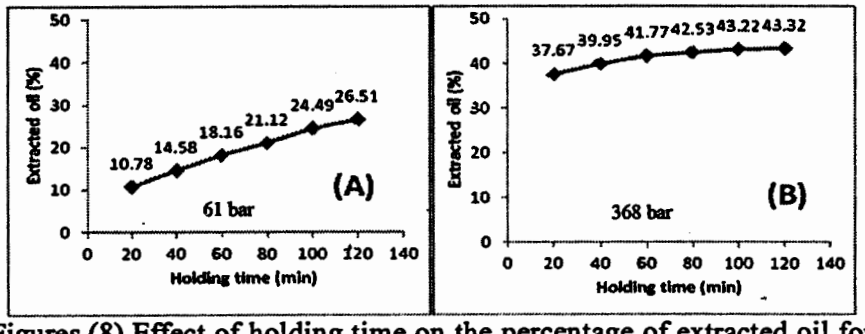
b - Effect of holding time:

Fig. (7)(A & B) illustrates the effect of different holding time on extracted oil percentage for the whole and crushed seeds. For the whole seeds condition, at all levels of applied pressure the oil extraction percentage increased with the increasing of holding time. As shown in the figure, at the minimum applied pressure of (61) bar as the holding time increased from 20 to 120 min the extracted oil percentage increased from 2.75 to 14.80 %. While, at the maximum applied pressure of (368 bar) the extracted oil percentage increased from 24.66 to 38.65 %.



Figures (7) Effect of holding time on the percentage of extracted oil for the whole jojoba seeds.

For the crushed seeds, fig. (8) (A and B) shows that, at the minimum applied pressure of (61 bar) as the holding time increased from 20 to 120 min, the extracted oil percentage increased from 10.78 to 26.51 % respectively. While, at the maximum applied pressure of (368 bar), the extracted oil percentage increased from 37.67 to 43.32 %.



Figures (8) Effect of holding time on the percentage of extracted oil for the crushed jojoba seeds.

To relate the changes in the extracted oil percentage (Eo) with the applied pressure (Pa) and the holding time (Ht). A multiple regression analysis was employed. A generalized relationships for the whole and crushed seeds are presented in table (3).

Table (3) Equations relating the applied pressure and the holding time with the extracted oil percentage for both whole and crushed jojoba seeds

Seeds condition	Regression equations	R^2
Whole seeds	$E_o = 0.000824\ (P_a) + 0.001507\ (H_t) - 0.066097$	0.977154
Crushed seeds	$E_o = 0.000735\ (P_a) + 0.001195\ (H_t) + 0.064848$	0.974949

5 - Extraction efficiency of jojoba seeds:

Fig (9) {A and B} presents the extraction efficiency of jojoba seeds at different applied pressure and holding times for both whole and crushed jojoba seeds. As shown in the figure, the extraction efficiency increased with the increasing of applied pressure at all levels of holding times. Also, the crushed seeds condition showed higher extraction efficiency in comparison with the whole seeds. At the minimum holding time (20 min), as the applied pressure increased from 61 to 368 bar, the extraction efficiency increased from 16.99 to 57.07 % for the whole seeds and from 27.93 to 40.86 % for the crushed seeds. While, at the maximum holding time (120 min), the extraction efficiency increased from (45.65 to 92.23 %) and from 63.29 to 99.17 % for the whole and crushed jojoba seeds, respectively.

In general, the extraction efficiency was affected by all studied parameters and it was ranged from 16.99 to 92.23 % for the whole seeds condition and from 27.93 to 99.17 % for the crushed seeds. Also, it should be mentioned that, the crushing process increased the oil extraction efficiency by about 6.75 to 29.25 %.

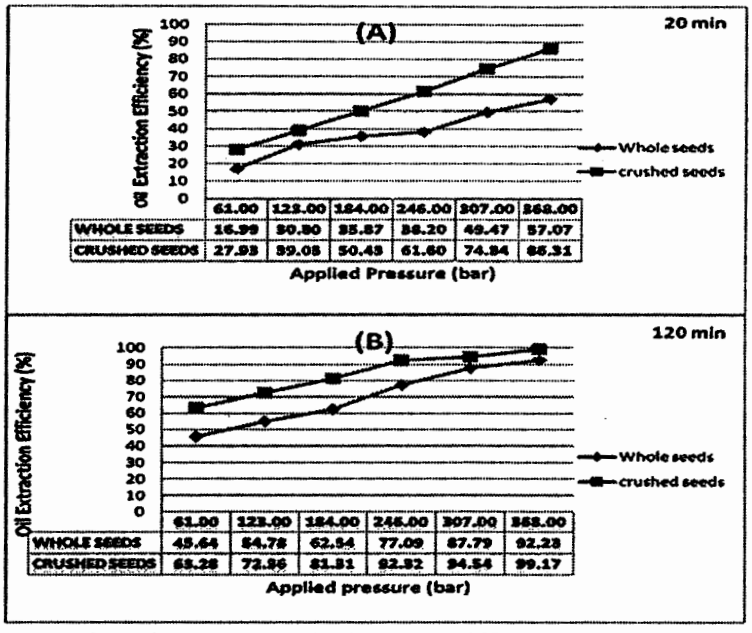


Figure (9): The oil extraction efficiency at different applied pressures for whole and crushed seeds condition.

CONCLUSIONS

1 - The maximum percentage of extracted oil was obtained at heating temperature of 60 °C and holding time of 30 min for both whole and crushed seeds.

2 - At all levels of the applied pressure, the oil extraction percentage increased with the increase of holding time, for both whole and crushed seeds conditions.

3 - At all levels of applied pressure and holding time, the crushed seeds recorded higher extracted oil percentage in comparison with the whole seeds.

4- The extraction efficiency increased with increase of applied pressure at all levels of holding times. Also, the crushed seeds condition showed higher extraction efficiency in comparison with the whole seeds.

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الملخص العربى

الإستخلاص الميكانيكى لزيت الجوجوبا

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تهدف هذه الدراسة إلى تحديد أفضل المعاملات المبدئية لبذور الجوجوبا المناسبه لإستخلاص الزيت بإستخدام وحده كبس هيدروليكى واختيار افضل الضغوط و زمن المكوث المناسب لإنتاج أكبر كميه من الزيت وشملت المعاملات التجريبية نوعين مختلفين من البذور (بذور كامله ومجروشه) تحت ٦ ضغوط مختلفه وهى (٦١، ١٢٣، ١٨٤، ٢٤٦، ٣٠٧ و ٣٦٨ بار) و٦ ازمنه مكوث وهى (٢٠، ٤٠، ٦٠، ٨٠، ١٠٠ و ١٢٠، دقيقة).

أظهرت نتائج الدراسة أنه يمكن الحصول على أعلى نسبه استخلاص للزيت بعد تعريض البذور للمعاملة الحرارية عند درجة حرارة ٦٠ درجة منوية لمده ٣٠ دقيقه قبل عمليه الإستخلاص كما كانت افضل أقطار حبيبات للبذور المجروشه (٢ إلى ٢,٣٦ مم) حيث أنتجت أعلى نسبة استخلاص للزيت. من ناحية اخرى عند جميع مستويات ضغوط الإستخلاص زادت نسبه الزيت المستخلص بزيادة زمن الإستخلاص و ذلك لكل من الحبوب الكاملة و المجروشة ، حيث زادت نسبة الإستخلاص للحبوب الكاملة عند أقل ضغط استخلاص (٦١ بار) من (٢,٧٥ إلى ١٤,٨٠ %) بزياده زمن المكوث من (٢٠ إلى ١٢٠ دقيقة) بينما عند أقصى ضغط إستخلاص (٣٦٨ بار) زادت نسبة الإستخلاص من ٢٤,٦٦ إلى ٣٨,٦٥ % . أما بالنسبة للحبوب المجروشة فقد زادت نسبة الإستخلاص من ١٠,٧٨ الى ٢٦,٥١ % عند اقل ضغط استخلاص (٦١بار) و من ٣٧,٦٧ إلى ٤٣.٣٢ % عند أقصى ضغط إستخلاص (٣٦٨ بار).

كما اظهرت النتائج أيضا انه عند جميع مستويات ضغوط الإستخلاص و أزمنه المكوث سجلت الحبوب المجروشه أعلى نسبه إستخلاص للزيت مقارنه بالحبوب الكاملة . و تراوحت كفاءة الإستخلاص من (١٦,٩٩ الى ٩٢,٢٣ %) للحبوب الكاملة و من (٢٧,٩٣ الى ٩٩,١٧ %) للحبوب المجروشه.

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