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ENGINEERING FACTORS AFFECTING EXTRACTION OF CANOLA OIL

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ABSTRACT

A study was carried out to test and evaluate the effect of pre-thermal treatment, pressing pressure and holding time on mechanical extraction of canola oil using a laboratory scale hydraulic press unit. The experimental parameters included five different levels of crushed seeds heating temperature (30, 75, 100, 125 and 150^{o}C) for 30 minutes, five levels of pressure over the samples mats (163, 204, 244, 285 and 326 bar) and four levels of holding time (20, 40, 60 and 80 min). The experimental measurements included, seed bulk temperature, extracted and remained oil percentages, extraction efficiency and percentage of free fatty acids in the extracted oil. The obtained results showed that, the percentage of remaining oil decreased with the increase of bulk temperature among 30 to 62^{o}C, while it was increased as the bulk temperature exceeded 62 till 90^{o}C. Also, the percentage of remaining oil decreased and the extraction efficiency increased with the increasing of both, the applied pressure and the holding time at all levels of crushed seeds. On the other hands, no effect on the percentage of FFA in the extracted oil was observed at all levels of experimental parameters. The recorded values of the FFA percentage were ranged from 0.32 to 0.38% which was in the safe level for similar type of oils.

INTRODUCTION

In Egypt, about 1, 129, 000 ton of oil is consumed annually but till now production is only about 153,000 ton. This means that production is only about 13.55% of all our needs and the import is about 86.45% (Oilseed situation and outlook, 2002).

The cultivated area of canola crop, yield and production in Egypt during growing season of 2004 were 1627 fed, (0.752 ton/fed) and 1224 ton, respectively (Agricultural ministry pamphlet, 2006).

Canola (Brassica napus, L) is a member of a large family of plants called crucifers. It is one of the world's most important oilseed crops. Canola seed contains approximately 40% oil and the meal consists of 35 to 40% protein (Shahidi, 1990 and Raymer, 2002).

Oil is usually extracted from oil-bearing material by mechanical expression or with the solvent method (Fasina and Ajibola, 1990 and Owolarafe *et al.,* 2003).

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 (Hendawy, 2009).

The general objective of the present work is to test and evaluate the effect of pre-thermal treatment of the crushed canola seeds on the mechanical extraction process using laboratory scale hydraulic press unit under different levels of applied pressure and holding time. The evaluation bases included the percentage of extracted and remained oil, extraction efficiency and percentage of free fatty acids.

MATERIALS AND METHODS

Materials:

Fresh canola seeds (variety serow 4) were used during the experimental work. It was obtained from the Agric Research Station, Gharbiea Governorate, to grantee the purity of the selected variety, the seeds were cleaned to remove impurities, immature kernels and foreign materials. The initial moisture content of seeds was about 8.5 ±1% (d.b). The canola seeds were stored in plastic bags in a freezer adjusted at temperature of -18^{o}C in order to suppress fungal growth and minimize quality changes.

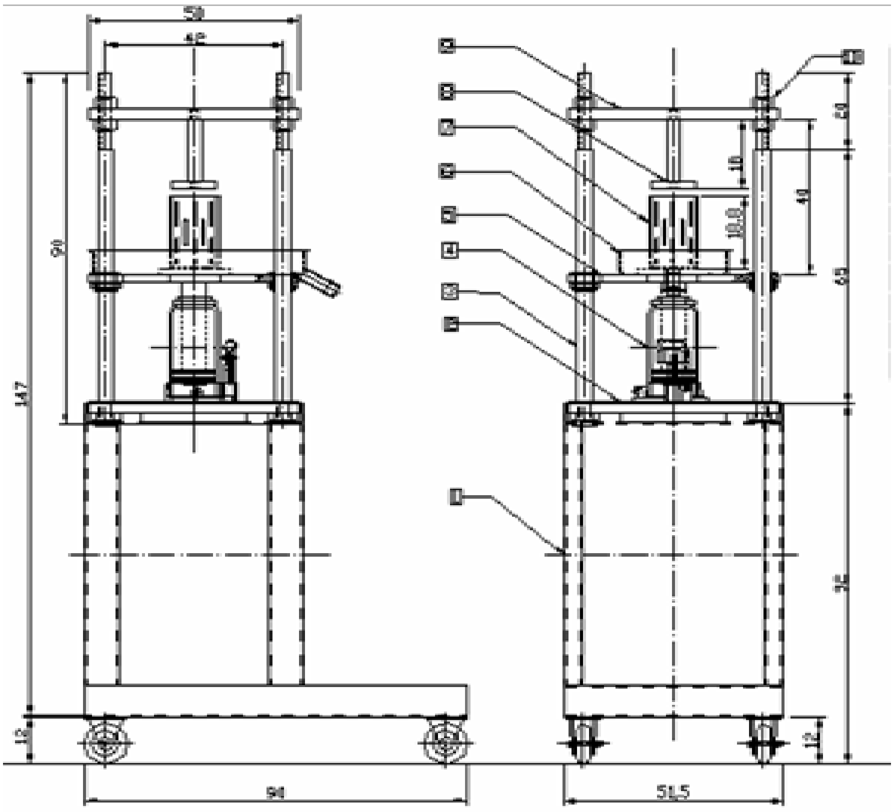
Equipment and testing procedure:

The hydraulic pressing unit:

A 50 tons manual hydraulic piston with pressure gauge (600 bar) and stainless steel perforated cylinder rested over a stainless steel oil receiving tray was used for canola oil extraction. The hydraulic press unit consists of an iron base with dimensions of 90 x 51.5 x 20 cm, welded to a frame with dimensions of 72 x 51.5 x 51.5 cm, and made of an angle iron 7 x 4 cm.

The hydraulic press piston was carried on a 3 cm 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 (3.5 cm diameter and 90 cm high) were welded to the horizontal iron plate and attached with two pressing plates made of steel iron (2.5 cm 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 to the frame using a set of nuts and washers.

To proceed the extraction process, the piston of the hydraulic unit was fixed 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 6.5 cm and discharge hole of 2.5 cm diameter. Schematic diagram of the hydraulic press unit was shown in fig. (1).



(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.

Measuring Instruments:

Mass of samples:

A digital balance model (Sartorius Gmbh Gottinge) made in Germany with maximum capacity of (200 g) and accuracy of (0.01 g) was used to determine the mass of the samples.

Moisture content determination

An electrical drying oven model (binder ED-53) was used to determine the moisture content of the crushed canola seeds and also for heating treatment of the samples. The samples were heated at 130^{o}C for 4 hr as recommended by (ASAE standards, 2003).

Bulk temperature:

Immediately after taking out the heated samples from the oven, it was filled inside an isolated cup to measure the bulk temperature of the crushed seeds before the samples filled into the mats. The temperature measurement was conducted using the digital temperature meter model (A.W.SPERRY DM-8600, Taiwan)

Oil extraction process

Soxhelt 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.

The percentages of total or remaining oil (d.b %) were calculated using the following equations :

$$O_t = [\ W_o / (W_t - W_o)\ ] \times 100 \qquad \text{.........(1)}$$

$$O_r = [\ W_r / (W_t - W_r)\ ] \times 100 \qquad \text{.........(2)}$$

Where:

O_t = Total percentage of oil (d.b %)

O_r = Percentage of remaining oil (d.b %)

W_t = weight of canola sample, g.

W_o = weight of total oil, g.

W_r = weight of remaining oil, g.

Extraction Efficiency

The extraction efficiency was determined using the following equation:

$$E_f = [(O_t - O_r) / O_t] \times 100 \qquad \text{......... (3)}$$

Where:

E_f = Extraction efficiency (%)

O_t = Total percentage of oil (d.b %)

O_r = Percentage of remaining oil (d.b %)

Free Fatty Acids (FFA%)

The FFA% of oil samples were calculated as oleic acid using the corresponding acid value of each sample according to **A.O.A.C. (1991)** as follows:

$$FFA\% = \frac{(282 \times 100 \times A.V)}{(56.1 \times 1000)} \qquad \text{...............(4)}$$

$$FFA\% = \frac{A.V}{1.9894} \qquad \text{...............(5)}$$

Where:

A.V = acid value

The values 282 and 56.1 refer to the equivalent weight of oleic acid and the potassium hydroxide (KOH), respectively.

Preliminary Experiments

1 - Determination of the proper heating time for the crushed canola seeds

In order to specify the most proper heating time for the crushed seeds to maximize the oil extraction efficiency, five levels of heating time (10, 20, 30, 40 and 50 min) were tested.

The treated samples were pressed at the maximum and minimum piston pressures of (200 and 400 bar) and holding times of (20 and 80 min), then the extraction efficiency was determined to specify the most effective treatment. The experimental results showed that, heating the samples for 30 minutes was the most effective treatment which maximized the extraction efficiency.

2 - 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 follows:

The effective force over the surface area of the piston (F_1)

$$F_1 = P_P . A_1 \quad \text{.................. (6)}$$

Where :

P_P = The piston pressure, bar

A_1 = the area of piston, mm^2

Also, the extraction force over the surface area of mats (F_2)

$$F_2 = P_e . A_2 \quad \text{.............. (7)}$$

Where :

P_e = the extraction pressure, bar

A_2 = the surface area of mats, mm^2

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

$F_1 = F_2$ or $P_p.A_1 = P_e.A_2$

$$\text{So} \quad P_e = (P_p.A_1)/A_2 \quad \text{............. (8)}$$

For the presented pressing unit:

$A_1 = 7048.625\ mm^2$

$A_2 = 8654.625\ mm^2$

When P_p , A_1 and A_2 are known , the extraction pressure or the pressure over the surface area of canola mats could be calculated and presented in Table (1).

Table (1) : The extraction pressure over the surface area of canola mats

Piston pressure (bar)	Extraction pressure (bar)
200	163
250	204
300	244
350	285
400	326

Experimental procedures

Canola seeds were crushed using the laboratory crusher model (Moulinex) for 20 seconds and then sieved using the 14 mesh sieve to obtain a particle sizes less than 1.2 mm. Then, a thermal treatment was carried out at five different heating temperatures (30, 75, 100, 125 and 150^{o}C) for 30 min in the drying oven. The treated samples at each heating temperature were pressed using the hydraulic pressing unit at five different levels of applied pressure (163, 204, 244, 285 and 326 bar) and four different holding times (20, 40, 60 and 80 min).

For each experimental run, samples of crushed canola seeds were dispersed inside cotton mats for the hydraulic pressing unit as follows:

(1) Sample of 210 g of crushed canola seeds were heated at the required heating temperature for heating time of 30 min, then distributed into three mats.
(2) The mats were vertically placed inside a perforated stainless steel cylinder.
(3) The pressing unit was manually operated to increase the pressure load gradually over the mats surface until reaching the required pressure level.
(4) After reaching the required pressure level, the applied pressure was kept constant all over the experimental run.
(5) A stop watch was used to determine the holding time for each treatment.
(6) The extracted oil from canola samples was received in the stainless steel tray and the canola mats were removed by changing the position of pressing plate down.
(7) The extracted oil sample was filled in a glass bottle to determine the percentage of free fatty acids (FFA%).
(8) The canola cake was taken out from the mats to determine the moisture content and remaining oil percentage using the soxhelt apparatus, then the extraction efficiency was calculated.

RESULTS AND DISCUSSION

Bulk temperature of the heat-treated crushed seeds

Bulk temperatures of the heat-treated crushed seeds at heating temperatures of 30, 75, 100, 125 and 150^oC were 30, 48, 62, 78 and 90^oC respectively. Fig. (2) showed the relationship between the studied levels of heating temperature and the bulk temperature of the heat-treated crushed seeds sample.

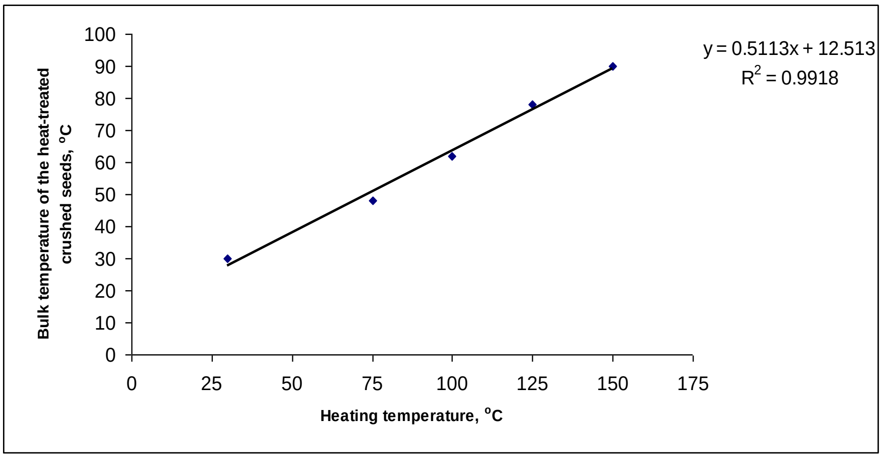


Fig. (2): Relationship between bulk temperature and heating temperature

Moisture content of the heat-treated crushed seeds

The moisture contents of the heat-treated crushed seeds at heating temperatures of 30, 75, 100, 125 and 150 °C were 8.5, 7.1, 6.2, 5.1, and 4.2% (d.b.) respectively. Fig. (3) shows the relationship between the heating temperature and the moisture content of the heat-treated crushed seeds.

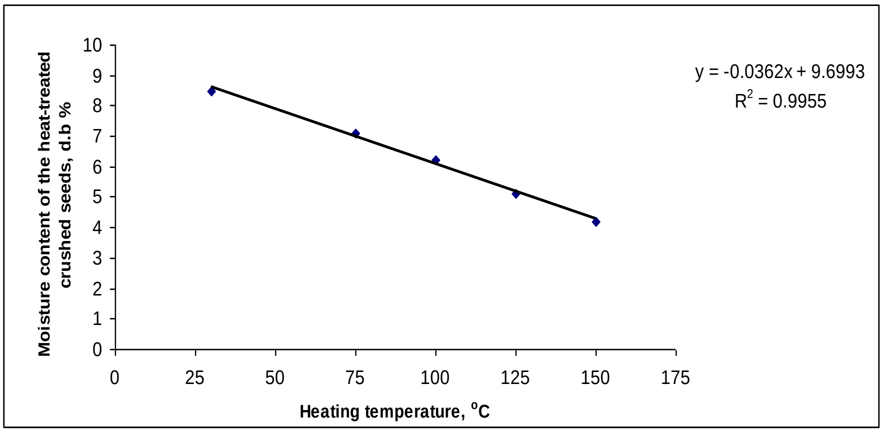


Fig. (3): Moisture content of crushed seeds as a function of heating temperature.

Effect of experimental parameters on the percentage of remaining oil

Fig. (4) illustrates the effect of different studied parameters on the percentage of remaining oil. The percentage of remaining oil decreased with the increasing of bulk temperature among 30 to 62°C, then it was increased with the increasing of seeds bulk temperature from 62 to 90°C at all levels of applied pressure. This resulted behavior could be attributed to the decreasing of moisture content of the crushed canola seeds which related to the increasing of heating temperature as reported by several researchers (Sirisomboon and Kitchaiya, 2008; Olaniyan, 2010 and Adejumo *et al*., 2013). Fig. (4) also shows that the percentage of remaining oil decreased with the increasing of applied pressure at all levels of crushed seeds bulk temperature. For instance, the remaining oil percentage at the minimum holding time of 20 min were decreased from 34.21 to 23.68 %, 26.79 to 17.75 %, 24.17 to 15.16 %, 31.85 to 21.82 % and 39.16 to 28.80 % with the increasing of applied pressure from 163 to 326 bar at bulk temperature of 30, 48, 62, 78 and 90°C, respectively. Same results were obtained at other levels of the holding time. This result was agreeable with the results of El-Kholy et al., 2009and Matouk *et al.,* 2012.

It also shows that the percentage of remaining oil decreased with the increasing of holding time at all levels of applied pressure. The values of remaining oil percentage at applied pressure of 163 bar decreased from 34.21 to 28.72 %, 26.79 to 22.76 %, 24.17 to 19.22 %, 31.85 to 25.85 % and 39.16 to 35.33 % with the increasing of holding time from 20 to 80 min at bulk temperature of 30, 48, 62, 78 and 90°C, respectively.

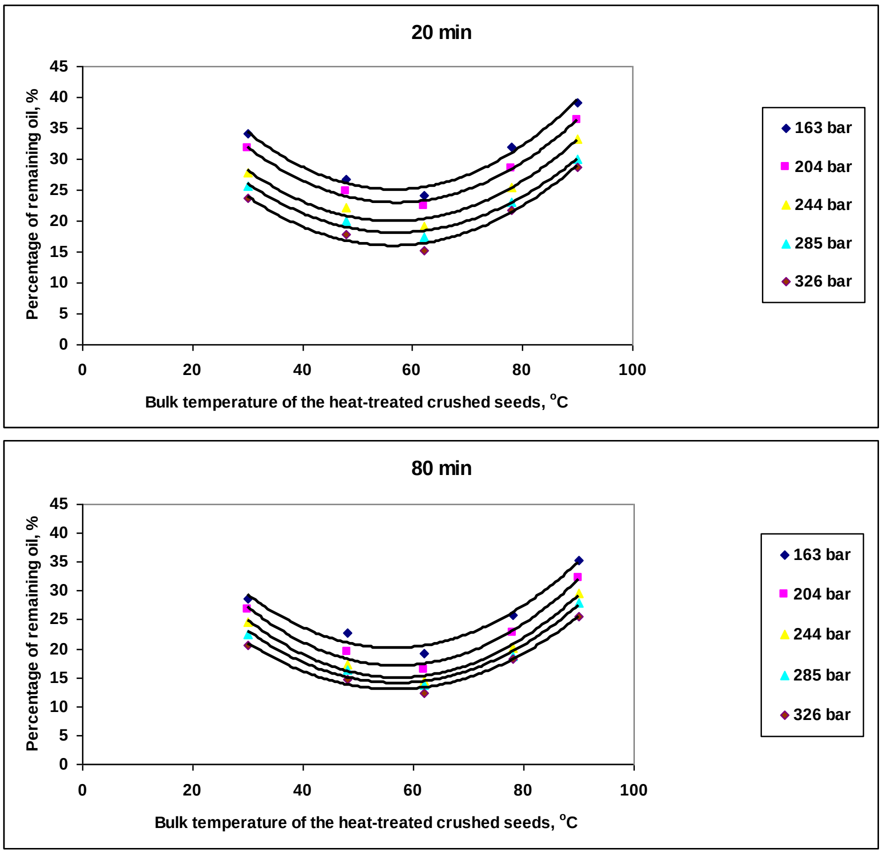


Fig. (4): The effect of bulk temperature of the heat treated crushed seeds on the remaining oil percentage under different levels of applied pressures

In order to describe mathematically the effect of bulk temperature of heat-treated crushed seeds (T), applied pressure (P_a) and holding time (H_t) on the remaining oil percentage (O_r), a multiple regression analysis was employed as shown in equation (9):

$$O_r = 0.231575\,(T) + 0.026657\,(P_a) + 0.0387\,(H_t) \qquad \text{......... (9)}$$

(R^2 = 0.89775; S.E = 7.987079)

Effect of experimental parameters on the extraction efficiency of canola oil

Fig. (5) illustrates the effect of experimental parameters on the extraction efficiency of canola oil. As shown in the figure, the extraction efficiency increased with the increasing of bulk temperature up to a level of 62 °C. Then it was decreased with the increasing of bulk temperature over the above mentioned level.

It also shows that the extraction efficiency increased with the increasing of applied pressure at all levels of crushed seeds bulk temperature. The values of extraction efficiency at holding time of 20 min were increased from

45.54 to 62.32 %, 57.36 to 71.75 %, 61.53 to 75.87 %, 49.31 to 65.27 % and 37.68 to 54.17 % with the increasing of applied pressure from 163 to 326 bar at bulk temperatures of 30, 48, 62, 78 and 90°C, respectively.

Fig. (5) also shows that the extraction efficiency increased with the increasing of holding time at all levels of applied pressure. The values of extraction efficiency at applied pressure of 163 bar were increased from 45.54 to 54.28 %, 57.36 to 63.78 %, 61.53 to 69.41 %, 49.31 to 58.86 % and 37.68 to 43.77 % with the increasing of holding time from 20 to 80 min at bulk temperature of 30, 48, 62, 78 and 90°C, respectively.

In order to describe the effect of bulk temperature of the heat-treated crushed seeds (T), applied pressure (P_a) and holding time (H_t) on the extraction efficiency (E_f), a multiple regression analysis was employed as presented in Equation (10) :

$$E_f = 0.051849\ (T) + 0.185065\ (P_a) + 0.246788\ (H_t) \qquad \ldots\ldots (10)$$

(R^2 = 0.970521; S.E = 10.96186)

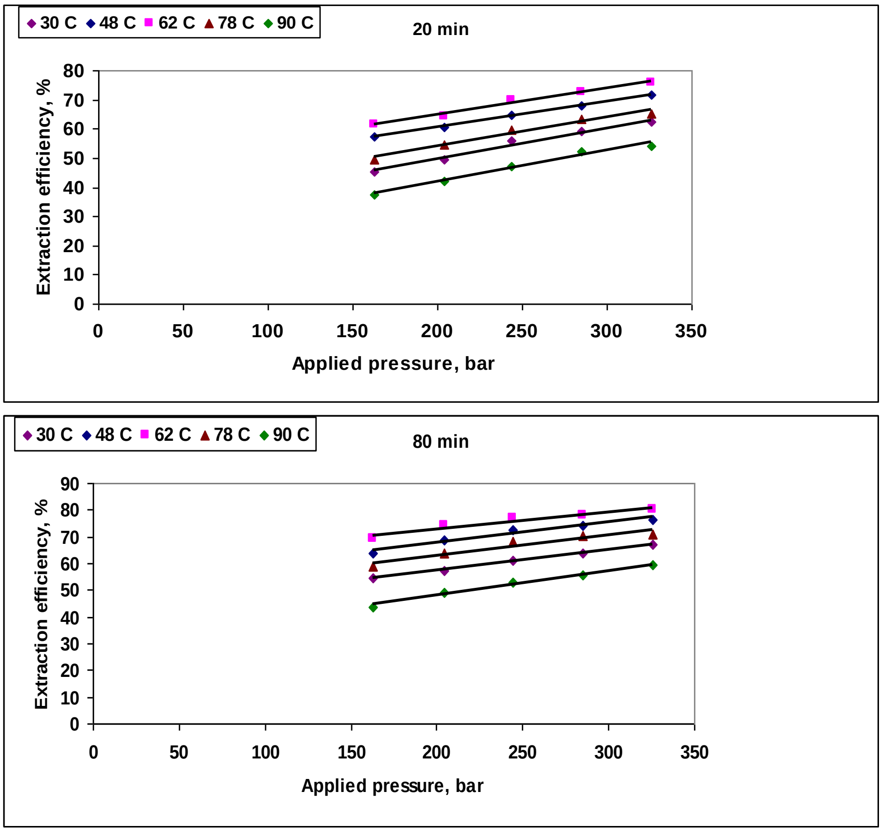


Fig. (5): Effect of applied pressure and holding time on the extraction efficiency of canola seeds heated at different levels of heating temperature.

Effect of the experimental treatments on FFA% of the extracted canola oil

The effect of the studied parameters (crushed seeds bulk temperature, applied pressure and holding time) on the percentage of free fatty acids of the extracted canola oil is presented in Table (2).

Table (2): Percentage of FFA in the extracted canola oil.

Holding time (min)	Applied pressure (bar)			
	163		326	
	bulk temperature (°C)			
	30	90	30	90
20	0.3262	0.3246	0.3262	0.3250
80	0.3821	0.3262	0.3816	0.3271

In general there was no effect of the studied parameters (crushed seeds bulk temperature, applied pressure and holding time) on the percentage of FFA in the extracted canola oil. As shown in Table (2), the recorded percentage of FFA ranged from 0.32 to 0.38. These values were lower than the recommended value of (1.5 – 2%) as reported by Kricka *et al*. (2007).

CONCLUSIONS

The obtained results of this experimental work can be summarized and concluded as follows:

1) The bulk temperature of the heat-treated crushed seeds increased with the increasing of heating temperature while the moisture content decreased.
2) The percentage of remaining oil decreased with the increasing of bulk temperature up to a level of 62 °C. While, it was increased as the bulk temperature exceeded 62 °C at all levels of applied pressure and holding time.
3) The percentage of remaining oil decreased and the extraction efficiency increased with the increasing of applied pressure and holding time at all levels of crushed seeds bulk temperature.
4) The studied range of experimental parameters showed no effect on the percentage of FFA in the extracted canola oil.

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التقرير الصادر عن قطاع الشئون الاقتصادية بوزارة الزراعة واستصلاح الأراضى (2002) عن موقف البذور الزيتية ومستقبلها . (Oilseed situation and outlook, 2002)

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العوامل الهندسية المؤثرة على استخلاص زيت الكانولا

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أجريت تلك الدراسة بهدف اختبار وتقييم تأثير المعاملة الحرارية المبدئية لبذور الكانولا المجروشة على عملية الاستخلاص الميكانيكى لزيت الكانولا باستخدام وحدة كبس هيدروليكى تحت تأثير مستويات مختلفة من الضغط وزمن المكوث. وقد شملت المعاملات التجريبية خمسة مستويات من درجة حرارة التسخين وهى (30 ، 75 ، 100 ، 125 ، 150 درجة مئوية) عند زمن تسخين ثابت (30 دقيقة) ، خمسة مستويات من ضغط الاستخلاص وهى (163 ، 204 ، 244 ، 285 ، 326 بار) ، أربع مستويات من زمن المكوث وهى (20 ، 40 ، 60 ، 80 دقيقة).

وقد شملت القياسات المعملية درجة حرارة بذور الكانولا المجروشة المعاملة حراريا فور خروجها من الفرن الكهربائى ، النسبة المئوية الكلية للزيت فى بذور الكانولا المجروشة المستخدمة ، النسبة المئوية للزيت المتبقى فى كسب الكانولا ، كفاءة استخلاص زيت الكانولا ، نسبة الأحماض الدهنية الحرة (FFA) لزيت الكانولا المستخلص بواسطة الكبس الهيدروليكى.

أظهرت نتائج الدراسة أن نسبة الزيت المتبقى انخفضت بزيادة درجة حرارة بذور الكانولا المجروشة الى 62 درجة مئوية ثم بعد ذلك زادت نسبة الزيت المتبقى بزيادة درجة حرارة البذور المجروشة الى ما بعد 62 درجة مئوية . كما أظهرت النتائج أيضا انخفاض نسبة الزيت المتبقى وزيادة كفاءة الاستخلاص بزيادة الضغط وزمن المكوث وذلك عند كل مستويات درجة حرارة البذور المجروشة . ولم يكن هناك أيضا تأثيرا ملحوظا للمستويات المختلفة من المعاملات التجريبية على نسبة الأحماض الدهنية الحرة لزيت الكانولا المستخلص حيث تراوحت نسبة الأحماض الدهنية الحرة لزيت الكانولا المستخلص من (0,32 الى 0,38 %) حيث تعتبر تلك النسبة فى المدى المسموح به للزيوت المماثلة.