

## EFFECT OF WHEAT GERM PRETREATMENT ON OIL EXTRACTION BY EXPELLING MACHINE

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### ABSTRACT

*An atmospheric steam process is used for preheating (in the range of 60-70°C) and increasing the moisture content (m.c.) of the wheat germ to study the effect of such process on machine capacity, percentage of oil recovery, percentage of residual oil, and specific energy consumption (SEC) of a double stage expelling machine for wheat germ oil extraction. Four levels of m.c. (13.2, 15.4, 16.2, and 16.8%), and five screw rotation speeds (25, 35, 45, 55, and 65 rpm) were used. It was found that at 25 rpm of screw speed, increasing m.c. from 13.2% (initial m.c.) to 16.2% (wb.), increased the machine capacity by 23.7%, and increased SEC from 0.043 to 0.482 kWh kg<sup>-1</sup> feed (including the energy consumption needed for steam generation). At 16.2% m.c. and 65 rpm screw speed, the percentage of oil recovery and oil productivity were 53.42% and 1.97 liter/h, respectively. The maximum percentage of oil recovery (62%) was obtained at 16.2% m.c. and 25 rpm screw speed.*

*The economic feasibility data indicated that the total hourly cost was about 11.80 EGP/h, and the total cost of oil extraction was about 49.48 EGP/liter of oil. A net annual profit of 160941.3 EGP can be earned providing a Benefit-Cost-Ratio of 1.07, a Return on Investment (ROI) of 106.5% with a Pay-Back Period of 0.07 yr. In addition, the unit would generate an employment of 480 man-days at rural level.*

*Keywords: Wheat germ – Preheating - Oil extraction - Expelling machine.*

### 1. Introduction

**W**heat germ is a unique source of highly concentrated nutrients. It offers three times as much protein of high biological value, seven times as much fat, fifteen times as much sugar, and six times as much mineral content, when compared with flour from the endosperm.

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In addition, wheat germ is the richest known source of  $\alpha$ -tocopherols (vitamin E) of plant origin and also a rich source of phytosterols, policosanols, thiamine, riboflavin, and niacin (Atwell 2001).

Wheat germ, a nutritious by-product of flour milling industry constituting 2.5–3.0% of the grain can be separated in a fairly pure form by using a germ separator or by suitable adjustments in milling techniques. Wheat germ contains about 10–14%, (w/w) oil (Dunford, 2005).

Tong and Lawrence (2001) mentioned that wheat germ oil is an excellent source of polyunsaturated fatty acids and vitamin E. It is one of the richest natural sources of  $\alpha$ -tocopherol, the type of tocopherol with the greatest vitamin E activity. Wheat germ oil has been attributed to reduced plasma and liver cholesterol in animals, improved physical endurance, and delayed aging.

Hill (1992) reported that mechanical extraction of oil from seed involved methods such as hydraulic pressing and continuous screw pressing. He described a screw as a device which gradually increased the pressure exerted on a material. As the seeds were conveyed along a shaft by the screw flights, the volume between flights decreased, thus increasing pressure and the oil was expressed and removed.

Adeeko and Ajibola (1990) noted that the oil yield will increase within pressure, and the oil in seed is contained in sacs or in fibrous capillaries. When pressure is applied, the volume of the capillaries is reduced, and the oil is expelled. However, the increasing pressure narrows, shears, and eventually seals the capillaries. Therefore, the screw press has a practical limit for its oil recovery.

Xie (2009) mentioned that wheat germ oil extracted by mechanical pressing is completely avoids the use of organic solvents. Thus the final product can be considered natural. However, the efficiency of this method can be 50% or lower, depending on the germ pretreatment and type of press used for extraction.

Singh and Bargalo (2000) designed a screw press with two tapered screws which are mounted adjacently and concentrically. The seeds are

compressed in two stages instead of one compression that is prior to exit. In this design, instead of a single stage compression as in the conventional screw presses, a compression ratio of 5:1 in the primary section and 3:1 in the secondary section is used. As a result, the design configurations avoids the possible damages of choking and jamming occurrences, which causes wear and tear of the machine components and results in energy losses. Also, pressure required to recover the oil with 80% efficiency is decreased to the levels at which choking and jamming cannot occur.

**Xiaojun (2002)** studied that stabilization of wheat germ (WG) by high pressure steam, and the results show that the process is effective. The increase of acid value (AV) and peroxide value (POV) of stabilized WG stored at 38°C was slowed down, reaching 85mgKOH/100g (WG) and 13.4 meq l 2/kg (WG) respectively after 30 days, and with no rancid smell.

**Yan-bo *et al.* (2008)** studied stabilization of wheat germ (WG) by ordinary drying, microwave drying, atmospheric steam and high pressure steam was studied for estimating the effect of deactivated lipase. He stored wheat germ at 38°C for 35d and had carried on the track examination. Take acid value and peroxide value as the characterization parameter and compared optimized results (acid value and peroxide value) for the different method processing raw material. The results showed that lipase deactivated effect: the effect of wet heat processing was obvious better than ordinary dry in processing, the acid value and the peroxide value rise slowly; and atmospheric steam process 20min could achieve the desired effect. Wheat germ oil extracted by supercritical-CO<sub>2</sub> from wheat germ steamed by atmospheric steam was analyzed by gas chromatography, and compared with control group; fatty acid composition and content did not change significantly. The steam is the good heat-carrying agent and the heat transfer medium, can effectively deactivate the lipase, and enhances the stability of wheat germ in storage. The objective of the work presented in this paper was study the effect of preheating and increasing the moisture content of the wheat germ by

using atmospheric steam process on the machine capacity, percentage of oil recovery, percentage of residual oil, and specific energy consumption (SEC) at different screw speeds rotation of double stage expelling machine for wheat germ oil extraction. Economical evaluation will also be made.

## **2. MATERIAL AND METHODS**

The experiments were carried out at the laboratory of Agricultural Engineering Research Institute (AEnRI), Dokki-Giza in 2010. The experimental work involved two stages as follows:

- Testing the expelling machine for determining the best productivity and power consumption at five screw speeds (25, 35, 45, 55, and 65 rpm) (0.08, 0.11, 0.14, 0.17, and 0.2 m/s), four steaming process (without steaming, 10, 20, and 30 min) (13.2, 15.4, 16.2, and 16.8%) at 0.5mm outlet clearance.
- Determining the economic feasibility of the developed expelling machine.

In order to fulfill the aim of the research through the consecutive stages of the work plan, the following materials; tools and methods were used:

### **2.1. Wheat germ:**

Fresh wheat germ, which was used for all experiments, was taken directly after the milling process from Ibn Al-Khattab Factory in El-Sadat city, and then stored in polyethylene bags at a temperature of - 5° C.

### **2.2. Expelling machine description:**

The manufactured expelling machine (double stage compression screw press) is photographed in **Fig. (1)**, and illustrated schematically in **Fig. (2)**. A complete description will be given in the next sections. An expelling machine consists of:

**2.2.1. The main frame**, it was made of hollow square iron pipe (40×40×4 mm) that was formed an iron stand of size 1100 mm length, 650 mm width, and 1150 mm height in which all the parts of the expelling machine were fixed on it.

**2.2.2. Two hoppers**, they were made from stainless steel. The first hopper is used to carry and canalize the wheat germ into the screw press, and the second hopper is used to take wheat germ cake after the first

compression screw to feed the second screw press. Feeding does not need any energy; gravity is sufficient for feeding.

**2.2.3. Two barrels**, the first barrel is shown in Fig. (3). It consists of 24 flat steel bars parallel to the worm shaft. The cross section of each bar is slightly trapezoidal, the whole set of the bars are functioned as lining bars which are fixed inside the surface of the cage, where the space between bars created drainage gaps. The second barrel is consisted of 8 triangular barrel rings made of steel with 15 mm thickness, and have central circular opening, as shown in Fig. (4) The barrel rings are separated by circular spacers that slide onto the tie bars to form the drained barrel of the press. This arrangement offers greater flexibility to adjust the drainage gaps of the press and forms a very simple assembly that can be easily maintained. The gaps between rings, that are created by PROSBAN material (25mm thickness), allow oil to drain.

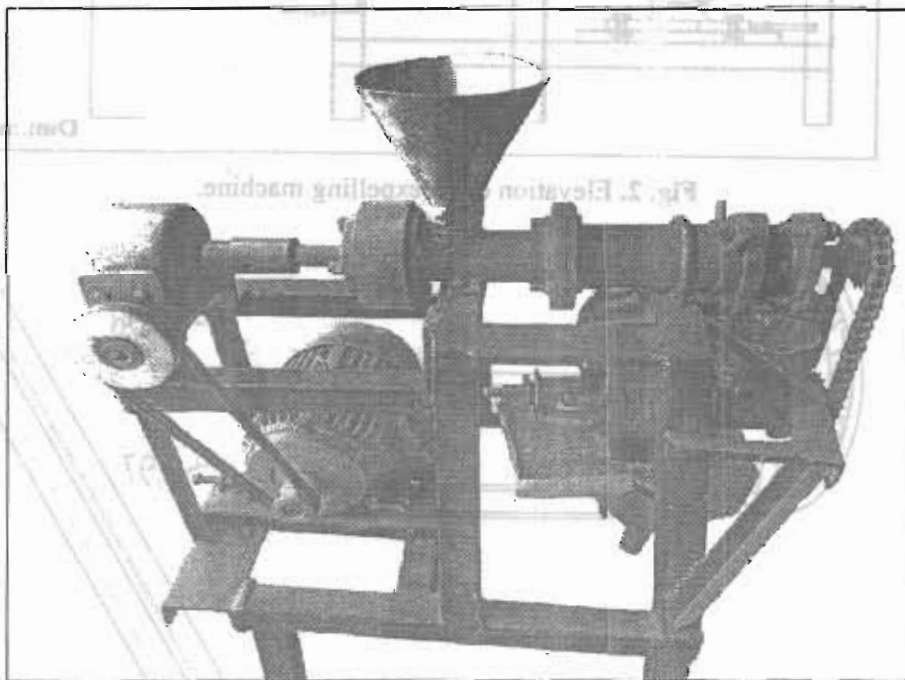


Fig. 1. Photograph of an expelling machine.

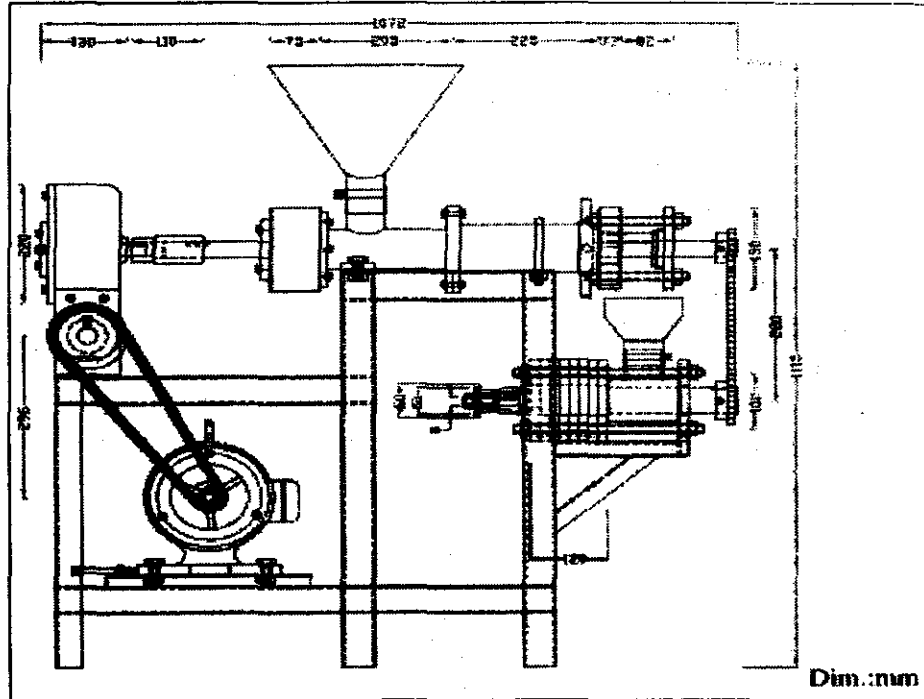


Fig. 2. Elevation of an expelling machine.

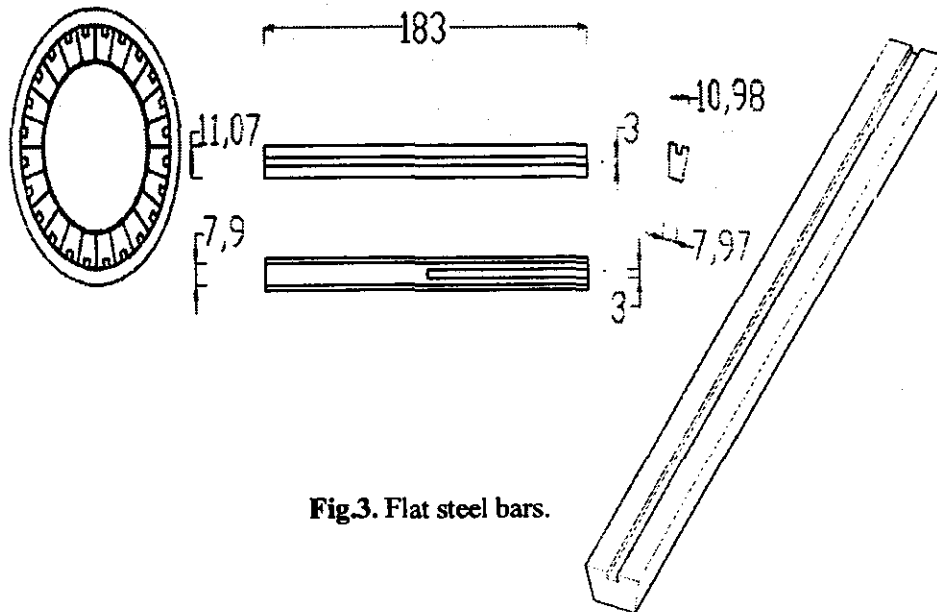


Fig.3. Flat steel bars.

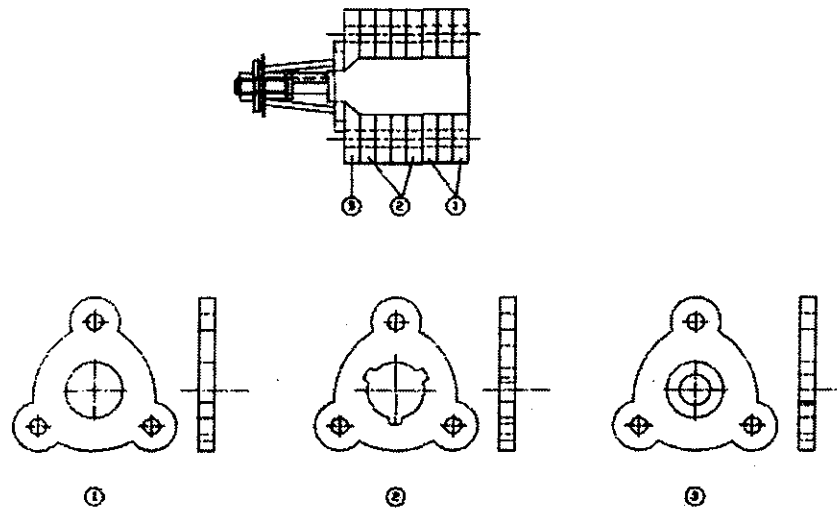


Fig. 4. Barrel ring with circular spacers

**2.2.4. Two tapered screws, the first screw with tapered outside diameter (60mm) is designed. The pitch is constant (59 mm), where the annular area is decreasing along the length of the screw shaft (370 mm) and takes its minimum value at the end of the screw. The swept volume by the screw thread in each turn is the multiplication of the annular area and the pitch distance. During this stage, the increase of pressure rate is higher at the end of screw shaft, which is depended on the taper angle ( $1.5^\circ$ ) of the shaft. The wheat germ cake, which is produced from the first stage press, will be fed into the second stage of the compression screw press. The power is transmitted from the first screw shaft to the second shaft by means of two sprockets, and chain. The second screw shaft as shown in Fig. (5) is also, a tapered shaft and the outside diameter (50 mm) are constant whereas the root diameter is inclined through the screw. The pitch, also, is constant (49 mm), the length of the screw (235 mm) and takes its minimum value at the end of the screw, and the taper angle is  $2.4^\circ$ . A small clearance is found between the barrel and the screw shaft (2mm), it is necessary for avoiding escaping the wheat germs between the outside diameter of the screw shaft**

and the inside surface of the barrel. In such a case, friction force between the screw shaft and barrel increases, and required torque becomes higher. The wheat germ is continuously fed through the feeder, the material in the primary section (first screw) moves forward and drops into secondary section (second screw) through the second hoper. In second stage, the compression is more effective since the clearance between the barrel and screw is reduced considerably with the help of the end cone clearance. To accomplish that, the end part of the worm is of conical form. The backward movement of the worm (i.e. movement towards the feed hopper) increases the clearance and thereby reduces the pressure on wheat germ present inside while its forward movement does it otherwise. The clearance between the worm (cone end) and choke is controlled by means of a handle lever fitted on a threaded rod and fixed with the worm. By changing the hand lever position the press head clearance can be changed.

**2.2.5. Power transmission.** The power unit that utilized to drive the expelling machine is an electric motor (1440 rpm; 4.1 kW). The power is transmitted by means of a set of pulleys, V-belt, sprockets, chain, and speed reducer (gear box 24:1).

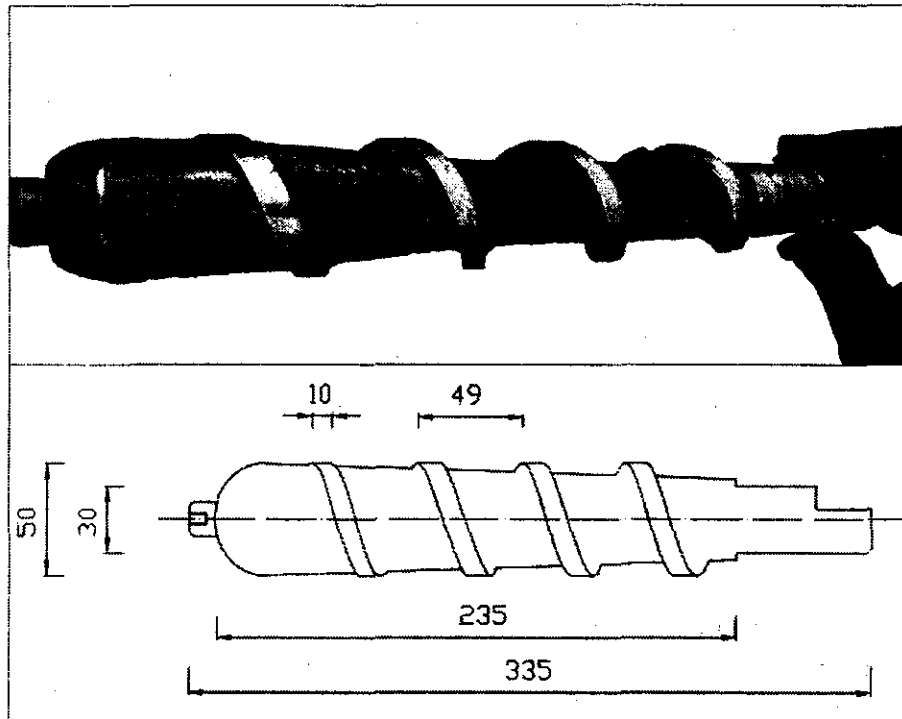
### **3. TEST PROCEDURE**

Many parameters and factors were affecting the machine performance, some of them are related to the wheat germ (moisture content), and some others are related to the expelling machine (screw speed and outlet clearance).

Before each experiment, the following procedures were donning:

1. The clearance between conic and choke was adjusting at 0.5mm.
2. The screw speed was adjusted to required level by a means of pulleys
3. The expelling machine was operating up to the stable condition and the wheat germ sample was pouring inside the hoper.
4. As the liquid phase separated from the raw material, the resulted wheat germ cake of each sample was taking for determination of remaining oil percentage.





**Fig.5. Second screw**

### **3.1. Atmospheric steam process:**

A small scale steaming unit was used at atmospheric pressure for heating the raw material and increases its moisture content. A sample of 3kg raw wheat germ was spread (thickness of 25 mm) on wire mesh (40  $\mu\text{m}$ ) circular aluminum container (500 mm of diameter) that covered the steaming unit. The water height inside the container was 200 mm from the bottom to accommodate the wheat germ during the atmospheric steam process. The heating process of the water was conducted through a natural gas heating source and the gas consumption was determined by gas meter. The samples were exposed to the water steam for different steaming periods to change the initial moisture content of raw material (13.2%) to different levels (15.4, 16.2, and 16.8%). The sample temperatures were in the range of (60-70°C), then the samples were taken immediately to extraction process. *Srivastava et al (2007)*

**3.2. Determination of moisture content:**

Wheat germ sample was dried in an electrical oven at 130° C for 3 h (Srivastava *et al.* 2007). Samples weighted before and after drying to calculated moisture content of wheat germ on wet basis using the following equation:

$$M.C.\%(w.b) = \frac{W_T - W_D}{W_T} \times 100 \dots\dots\dots (1)$$

Where:  $W_T$  = weight of sample before drying, g;

$W_D$  = weight of sample after drying, g

**3.3. Machine capacity (kg feed/h):**

It was calculated by the following equation:

$$P_m = W/t \dots\dots\dots (2)$$

Where:  $P_m$  = Machine capacity, kg/h.

$W$  = Machine feeding, kg.

$t$  = Machine operating time, h.

**3.4. Determination the percentage of oil recovery:**

Percentage of oil recovery (OR) was defined as the ratio of oil weight in the product oil to original weight in the wheat germ that was pressed (Beerens, 2007). It was computed as following:

$$OR = \left(1 - \frac{W_c O_c}{W_m O_m}\right) \times 100\% \dots\dots\dots$$

(3)

Where:  $W_c$  = Mass of cake, g,

$O_c$  = Oil content of cake, g;

$W_m$  = Mass of sample, g, and

$O_m$  = Initial oil content of sample, g.

**3.5. Determination the percentage of remaining oil:**

The percentage of remaining oil of wheat germ cake was determined by using Soxhlet apparatus technique and redistilled n-hexane according to the method of (AOCS, 1996). It was calculated using the following equation:

$$\text{Percentage of remaining oil} = (O_c/O_m) \times 100 \dots\dots\dots (4)$$

**3.6. Specific Energy Consumption (SEC):**

The power requirement for expelling machine was calculated by using the clamp meter to measure the line current strength and the potential

difference value. The total electric power requirement under expelling machine working load was calculated according to (Chancellor, 1981) and (Ibrahim, 1982) by the following equation:

$$P = (I \times V \times \cos \theta) / 1000 \dots\dots\dots (5)$$

Where: P = The power requirement for extracting oil, kW.

I = Line current strength, Amperes.

V = Potential difference, Voltage.

Cos  $\theta$  = Power factor, equal 0.85.

SEC<sub>1</sub> (kWh kg<sup>-1</sup>) is the specific energy consumption of expelling machine; it was calculated by the following equation.

$$SEC_1 = (P / P_m) \dots\dots\dots (6)$$

SEC<sub>2</sub> (kWh kg<sup>-1</sup>) is the specific energy consumption needed for steam generation in the steaming unit, it was calculated by the following equation.

$$SEC_2 = \frac{C_{gas} \times 11.11}{W_s} \dots\dots\dots (7)$$

Where:

C<sub>gas</sub> = Natural gas consumption by m<sup>3</sup>.

11.11 = Conversion factor (1 m<sup>3</sup> of natural gas = 11.11 kWh), where converting the m<sup>3</sup> of natural gas to kWh is done by (MacLeay *et al.* 2011)

W<sub>s</sub> = Weight of sample, kg.

$$SEC = SEC_1 + SEC_2 \dots\dots\dots (8)$$

SEC is the total specific energy consumption of wheat germ oil extraction.

### 3.7. Oil productivity, L/h:

It was calculated by the following equation:

$$\text{Oil productivity} = \frac{P_m \times 0.11 \times OR}{\rho_{oil}} \dots\dots\dots (9)$$

Where:

$\rho_{oil}$  = Density of wheat germ oil, g/cm<sup>3</sup> (It is between 0.925 – 0.933 g/cm<sup>3</sup> at 25°C, Firestone, 1999).

0.11 = Oil contain in raw wheat germ.

### 3.8. Cost analysis:

The cost per hour of operation of the developed expelling machine for a small scale mechanical oil extraction of wheat germ was estimated by using the equation that developed by (Awady, 1978) and presented by (Elnono, 2005) as the following:

$$T_c = C/h ( 1/L + i/2 + t + r ) + (\text{Energy cost}) + (m/144) \dots\dots (10)$$

Where:

$T_c$  = Total hourly cost, EGP/h.

$C$  = Initial price of the machine, EGP.

$h$  = Working hours per year.

$L$  = The estimated life-expectancy of machine in years..

$i$  = Annual interest rate, (0.1 of initial cost).

$t$  = Annual taxes and overheads, (0.01 of initial cost).

$r$  = Annual repairs and maintains rate, (0.1 of initial cost).

Energy cost =  $\{ \{SEC_1 \times S_1\} + \{ (C_{gas}/W_s) \times S_2 \} \} \times P_m$

$S_1$  = Price of electricity, EGP/kWh.

$S_2$  = Price of natural gas, EGP/m<sup>3</sup>.

$P_m$  = Machine capacity kg/h.

$m$  = The operator monthly salary, EGP/month.

144 = The estimated working hours / month.

The cost per hour of operation will be estimated by using equation (9) then,

$$\text{Total cost (EGP/kg)} = (T_c/P_m) + \text{price of raw material, EGP/kg} \dots\dots\dots (11)$$

The average total cost of extracting 1 litter of oil:

$$= \text{Total cost} \div [(0.11 \times OR) / \rho_{oil}] \dots\dots\dots (12)$$

## 4. RESULT AND DISCUSSION

### 4.1. Machine capacity (kg<sub>feed</sub>/h):

Fig. (6) showed that, the machine capacity increased with the increase of screw speed and moisture content. It was increased by 39.8% by increasing screw speed from 25 to 65 rpm at 16.2% of moisture content, also it was increased by 23.7% by increasing moisture content from 13.2 to 16.2% at 25rpm of screw speed. However, machine capacity decreased with increasing the moisture content from 16.2 to 16.8%. It decreased by

an average of 15.3% by increasing moisture content from 16.2 to 16.8% at 65 of screw speed. This may be due to the plasticizing effect of water in wheat germ which decreases the frictional coefficient of the feeding material also the cake tends become pulpy, **Singh and Bargale (2000)**. The minimum machine capacity of  $15.18 \text{ kgh}^{-1}$  was obtained at 13.2% of moisture content and 25rpm of screw speed, Meanwhile, the maximum machine capacity of  $31.2 \text{ kgh}^{-1}$  was obtained with 16.2% of moisture content and 65rpm of screw speed.

#### **4.2. The percentage of oil recovery:**

The maximum oil recovery was obtained at a moisture content of 16.2% and 25rpm screw speed when a total of 62% of the available oil in the sample is recovered. **Fig. (7)** showed that at 25rpm screw speed, the oil recovery increased by 23.5 % by increasing the moisture content from 13.2% to 16.2%. While at 16.8% of moisture content, it was decreased by 12.3%, this may be, also, due to the plasticizing reason and tending to become pulpy **Singh and Bargale (2000)**. Also, **Fig. (7)** indicated that the percentage of oil recovery decreased with increasing the screw speed. At 15.4% moisture content the oil recovery decreased from 59.7 to 51.12 % with increasing screw speed from 25 to 65 rpm, while at 16.2% moisture, it was decreased from 62 to 53.42 % and from 46.2 to 37.42% at 16.8% moisture content, with increasing screw speed from 25 to 65 rpm, respectively.

#### **4.3. The percentage of residual oil:**

**Fig. (8)** cleared that the residual oil decreased with the increase of the moisture content and the decrease of the screw speed. The minimum residual oil (38%) was obtained at 16.2% moisture content and 25 rpm of screw speed. At 15.4 % moisture content it was decreased from 48.88 to 40.3 %, and at 13.2% moisture content it was decreased from 58.38 to 49.8% with decreasing screw speed from 65 to 25 rpm, respectively. The highest value of the residual oil percentage, at any screw speed was obtained at moisture content of 16.8% when the percentage of oil recovery was mini as mentioned in the previous section.

#### 4.4. Total specific energy consumption (SEC) (kWh/kg<sub>feed</sub>):

Results illustrated in Fig. (9), show that SEC increased with the increase of wheat germ moisture content. It increased from 0.043 to 0.482 kWhkg<sup>-1</sup><sub>feed</sub> with increasing the moisture content from 13.2 to 16.8% at screw speed of 25rpm. This increase was due to the addition of SEC<sub>2</sub> "of the atmospheric steam process" to the specific energy consumption (SEC<sub>1</sub>). While, it had a little increase with increasing the screw speed from 25 to 65rpm at the same moisture content, this may be due to the decrease in the internal friction between wheat germ particles. The SEC decreased from 0.315 to 0.311 kWhkg<sup>-1</sup><sub>feed</sub> with the increase of the screw speed from 25 to 65rpm, respectively at 16.2% moisture content. But at 16.8% moisture content the SEC decreased from 0.482 to 0.461 kWhkg<sup>-1</sup><sub>feed</sub>, this may be due to some choking and jamming during operation and the cake tends to become pulpy at this moisture level.

#### 4.5. Oil productivity, L/h:

Fig. (10) indicates that the oil productivity increased with the increase of the moisture content and screw speed. It increased by 23.5 % by increasing the moisture content from 13.2 to 16.2%, and increased by 30 % by increasing the screw speed content from 25 to 65rpm at 16.2% m.c. The maximum oil productivity 1.97L/h was obtained at 16.2% m.c. and 65 rpm of screw speed.

#### 4.6. Oil extraction operation costs:

The operation cost was estimated according to equation (10), at screw speed of 25rpm and moisture content of 16.2% as the following:

$$T_c = C/h (1/L + i/2 + t + r) + ((\{SEC_1 \times S_1\} + \{(C_{gas}/W_s) \times S_2\}) \times P_m) + (m/144)$$

"C"= 1200 EGP for expelling machine; "h"= 1728 h/year; "L"=10years;

"i"= 10%; "t" = 1%; "r" = 10%; "SEC<sub>1</sub>"=0.026 kWh/kg<sub>feed</sub>;

"S<sub>1</sub>" = 0.48EGP/ kWh; "C<sub>gas</sub>"= 0.078 m<sup>3</sup>of natural gas; "W<sub>s</sub>" = 3kg;

"S<sub>2</sub>"=0.55 EGP/m<sup>3</sup>; "P<sub>m</sub>" = 18.78 kg<sub>feed</sub>/h; and "m" = 1600 EGP of two labors.

According the previous data, the total hourly cost =11.80EGP/h, and the average total cost for oil extracting of wheat germ = 49.48 EGP/litter of oil, when the price of wheat germ as 3 EGP/kg and 62% of oil recovery.

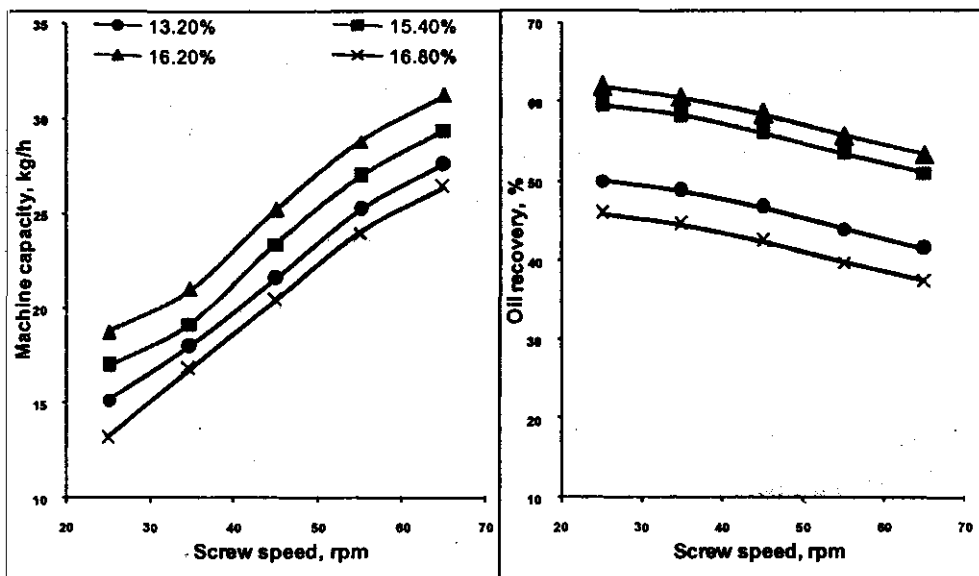


Fig.6: Effect of screw speed and moisture content on machine capacity  $\text{kg h}^{-1}$ .

Fig.7: Effect of screw speed and moisture content on the percentage of oil recovery.

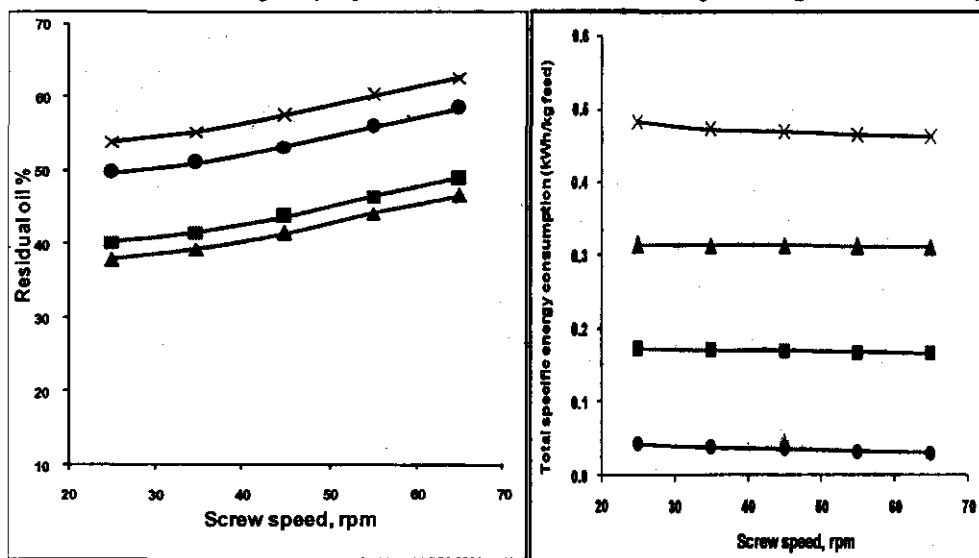


Fig.8: Effect of screw speed and moisture content on the percentage of residual oil in wheat germ cake.

Fig.9: Effect of screw speed and moisture content on specific energy consumption ( $\text{kWh kg}^{-1}_{\text{feed}}$ )

Economic feasibility analysis data were analyzed by following the standard formula and procedure for calculating the Benefit-Cost-Ratio [Benefit/Cost], Pay-Back Period [Total cost/ Annual cash inflows] and Return-On-Investment [(Gain from investment- Cost of investment)/ Cost of investment] (Srivastava, 1981; Kachru, *et al.*, 1986; Chouhan, 1991). It indicated that a net annual profit of 160941.3 EGP can be earned providing a Benefit-Cost-Ratio of 1.07, a Return on Investment of 106.5% with a Pay-Back Period [of 0.07 year. In addition, the unit would generate an employment of 480 man-days at rural level. Hence, installation of such an enterprise could be a profitable proposition for young investors.

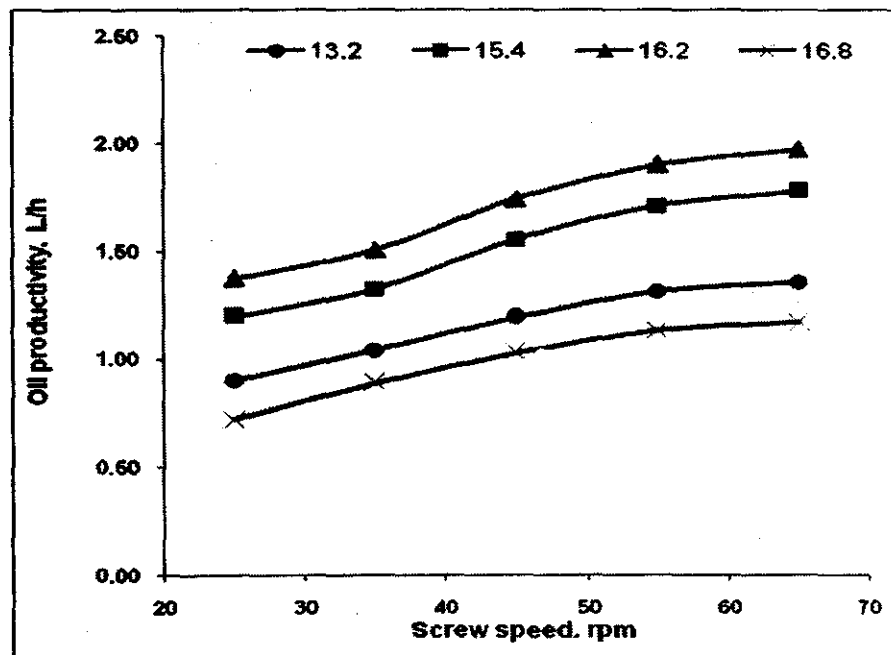


Fig.10: Effect of screw speed and moisture content on oil productivity, L/h.



## **5. CONCLUSIONS AND RECOMMENDATION**

An expelling machine was tested and found capable of expressing oil from small quantities of the oil-seed (wheat germ) using atmospheric steam process. The results showed that,

- The maximum machine capacity (31.2 kg feed/h) was obtained at 16.2% moisture content, and 65 rpm of screw speed.
- The maximum oil recovery (62%) was obtained at 16.2% moisture content, and 25 rpm of screw speed.
- The SEC increased with the increase of wheat germ moisture content. It increased from 0.043 to 0.482 kWhkg<sup>-1</sup><sub>feed</sub> with increasing the m.c. from 13.2 to 16.8% at screw speed of 25rpm.
- The total cost of oil extraction operation = 49.48 EGP/litter of oil..

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#### الملخص العربي

#### تأثير المعاملات الاولية لجنين القمح علي عملية استخلاص الزيت

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تم دراسة تأثير استخدام بخار الماء (عند ضغط جوى) للتسخين الحراري الاولي لجنين القمح الخام (في مدى ٦٠-٧٠م°) ولزيادة المحتوي الرطوبي له من ١٣.٢% الي ١٥.٤، ١٦.٢، و ١٦.٨% (اساس رطب) وذلك لتحديد افضل سعة ميكانيكية، نسبة الزيت المستخلص، نسبة الزيت المتبقي، الطاقة النوعي المستهلكة، انتاجية الالة من الزيت، وتكاليف التشغيل الاقتصادية لوحدة استخلاص زيت جنين القمح ميكانيكياً. عند خمسة مستويات مختلفة من سرعة البريمة هي ٢٥، ٣٥، ٤٥، ٥٥، و ٦٥ لفة/دقيقة.

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وقد توصلت الدراسة إلى النتائج الآتية:

- ١) أعطت الآلة أقصى سعة ميكانيكية (٣١.٢ كج/س) عند ١٦.٢% محتوى رطوبي لجنين القمح وسرعة البريمة ٦٥ لفة/دقيقة.
- ٢) أفضل كفاءة استخلاص (٦٢%) عند ١٦.٢% محتوى رطوبي وسرعة البريمة ٢٥ لفة/دقيقة.
- ٣) الطاقة النوعية المستهلكة في الاستخلاص تزداد من ٠.٠٤٣ إلى ٠.٤٨٢ ك.وات. ساعة/كجم تغذية مع زيادة المحتوى الرطوبي لجنين القمح من ١٣.٢ إلى ١٦.٨% عند ٦٥ لفة/دقيقة سرعة للبريمة.
- ٤) أقصى إنتاجية للاله ١.٩٧ لتر/س عند ١٦.٢% محتوى رطوبي و٦٥ لفة/دقيقة سرعة للبريمة.
- ٥) أشارت تحليل بيانات التكاليف إلى أن تكاليف عملية التشغيل للاله ١١.٨٠ جنية/ ساعة وتكلفة عملية استخلاص ١ لتر زيت جنين قمح بواسطة الآلة ٤٩.٤٨ جنية. والأرباح السنوية كانت ١٦٠.٩٤١ جنية مصري، نسبة الربح للتكلفة ١.٠٧، والعائد على الاستثمار ١٠.٦٥%، وفترة استرداد رأس المال ٠.٧ سنة. بالإضافة إلى ذلك كانت كمية العمل ٤٨٠ أيام-عمل على مستوى الريف المصري.