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Effect of Extracting Temperature and Screw Speed on the Oil Yield and Energy Consumed from Sesame Seeds

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Abstract

The main aim of the current study was to improve the production of oil from sesame seeds by optimizing the extracting screw speed and extracting temperature. To achieve that, the effect of different extraction temperatures (45, 55, and 65 °C) and different extraction screw speeds (75, 90 and 120 rpm) on the oil extraction yield, extraction efficiency, extraction energy requirements and extraction time were investigated. The results most important indicate that the sesame oil yield increased from 49.6 to 52.4, 49.2 to 52.0 and 48.0 to 51.2 %, when the extracting temperature increased from 45 to 65 ºC, for 75, 90, and 120 rpm screw speeds, Respectively. The highest value of the extraction efficiency (84.52%) was obtained at 65 °C extracting temperature and 75 rpm screw speed. The lowest value of the extraction time (2.203 min) was observed at 65 ℃ extracting temperature and 120 rpm screw speed. The optimal specific energy consumption of 0.215 $kW.h/kg_{oil}$ was obtained at 65 °C extracting temperature and 120 rpm screw speed.

Keywords: Oil extraction, sesame oil, screw press, extraction efficiency, specific energy consumption, time

Introduction

The issue of food security is currently receiving too much attention in most regions of the world, where there is a nutritional gap between the production and consumption of key food products. This nutritional gap could be due to variables such as continued population growth and the inability of agricultural resources to produce these goods sufficiently to meet with the number of citizens and residents who require food to satisfy their needs, as well as food high prices around the world **(Bandura and Fialkovska, 2023)**. This leads to higher prices on the local import markets. Oilseeds are one of the most important ingredients in modern agriculture **(Khobragade et al., 2021)**. That is because they easily provide people and animals with high-quality food. From a nutritional perspective, oils obtained from oilseeds provide calories, vitamins and essential fats **(Ionescu et al., 2013)**.

Oilseeds are considered one of the most important strategic crops in both Egypt and other countries of the world, as they represent an important source of fats as people consume them in various ways. According to **(Mohamed et al., 2023)**, the global production of vegetable oil in 2021/22 was 208.8 million tons and was expected then to increase to 217 million tons in 2022/23 where the total production of vegetable oil of Egypt increased from 230,271 tons in 2010 to 300,726 tons in 2021. Oilseeds growing areas are concentrated in the governorates of Upper Egypt, where temperatures are suitable for growing peanut, sesame and sunflower, as they are summer crops. Other oilseeds are mainly grown in the northern delta, where the climate is cold **(Saber et al., 2015)**.

In Egypt, the total cultivated area with oil crops reached nearly 320000 hectares in 2021**(Mohamed et al., 2023)**. Oil crops occupied 164415.12 hectares with 4.057% of the total area under cultivation in Egypt during 2022. **(Ministry of Agriculture and Land Reclamation, 2022)** Egypt consumes about 2.5 million tons of edible oils annually. About 48.5 thousand tons are produced locally from both local and imported oilseeds **(El-Hamidi et al., 2020** and **Mahran and Elhassaneen, 2023)**. The average oil consumption per person in the edible oils market was amounted by 3.29 kg in 2024. This is based on a projected growth of 0.9% per annum according to the OECD-FAO Agricultural Outlook 2019-2028. **(Rahoveanu et al., 2018)**

Sesame (Sesamum indicum L.), belongs to the Pedaliaceae family and has its origins in African especially in Sudan, Ethiopia and Nigeria **(Hamitri-Guerfi et al., 2020)**, is considered one of the oldest and most important oilseeds known to mankind. In addition, it is characterized by its economic and universal importance distributed worldwide **(Zerihun and Berhe, 2020** and **Wang et al., 2021)**. Sesame oil comes 9th among the first 13 oil crops around the world and its cake, which is a byproduct of the extraction process, is considered a healthful animal feed because it is rich in carbohydrates, proteins, dietary fibers and mineral nutrients **(Basnagoda., 2018** and **Wang et al., 2021).** Sesame oil is rich in vitamins A, D, E and K, which provide the essential fatty acids that human body can't produce them **(Ramezani and Rezaei, 2018)**. Moreover, sesame oil is a good provider of antioxidative materials like sesamin, sesamolin, and tocopherols which provide nutritional benefits **(Li et al., 2023)**. Moreover, 60% of all world production of sesame oil is obtained from Asia. Ethiopia is the third largest exporter of sesame crop around the world **(Zerihun and Berhe, 2020)**.

Nde and Foncha (2020) classified oil extraction methods into three main techniques: chemical, biochemical, and mechanical. They also mentioned that oil extraction methods have been developed from traditional methods like solvent and mechanical extraction to nonconventional methods such as supercritical fluid extraction and extraction assisted by ultrasound and microwave.

The methods of oil extraction are mechanical, chemical and enzymatic. It has been found that the most efficient method of oil extraction with the highest productivity is to use organic solvents such as hexane, toluene or ether, but this has environmental effects where highly volatile organic compounds are emitted that have negative effects on human health due to the handling of hazardous and flammable chemicals and increase the specific energy consumption. Thus, the cost of the process increases the final cost of oil production. Mechanical extraction was the best method from a practical point of view. Since it can be purchased at low cost, it has a relatively lower oil yield than chemical extraction, but it is simpler, safer and has fewer steps than solvent extraction. The mechanical extraction method uses either a manual piston or a motor-driven screw piston. More oil can be extracted with a motorized screw piston (68 - 80%) than an engine-driven ram piston (60 - 65%). **(Osorio-González et al., 2020)**.

Lertbuaban and Muangrat, (2023) studied the effect of extracting temperature on sesame oil yield, three extracting temperatures (45, 55 and 65 °C) were applied. The highest value of oil yield (47.73%) were obtained at extracting temperature of 65 °C. it was mentioned that oil yield is propotional to extracting temperature. That was due to increasing extractiing temperature leads to a decrease in oil viscosity which allows oil to flow out of sesame seeds.

Using the traditional methods of oil extraction results in low oil yield, low extraction efficiency, high energy consumption and low quality of oil extracted, therefore, the main aim of the present investigation is to study the effects of extraction screw speed and temperature as main factors affecting the oil extraction yield from sesame seeds, extraction energy consumed and time.

Materials and Methods

The experiment was conducted in a private factory, Qalioubya governorate, Egypt. During summer season, 2024.

2.1. Sesame seeds

Sesame seeds were collected from a private farm in Beni Suef governorate. A lipid analysis was performed at Agricultural Analysis and Consulting Center (AACC), Faculty of Agriculture, Benha University, to determine the percentage of oil in sesame seeds. The average oil content of sesame seeds was 62%. Sesame seeds have been purified and cleaned of impurities manually, and then physical characterization of sesame seeds using digital vernier was achieved, before extraction process. Sesame oil was extracted from seeds using a screw press. The schematic diagram in Fig. (1) Shows the sequence of oil extraction process, by screw press, from sesame seeds.

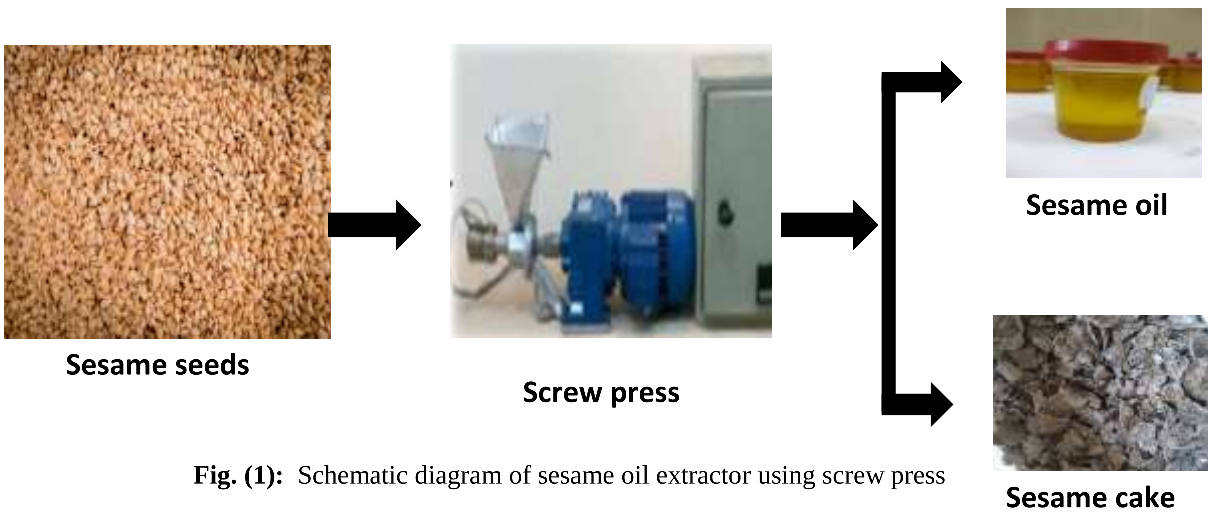
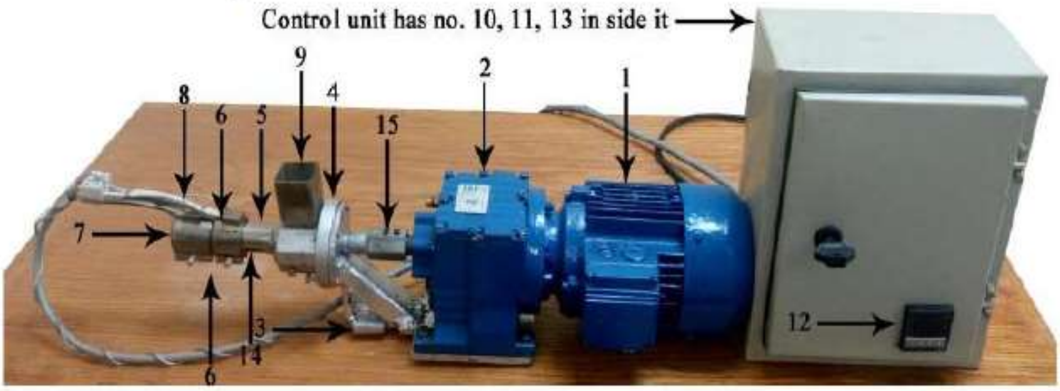


Fig. (1): Schematic diagram of sesame oil extractor using screw press

2.3. Mechanical extraction of sesame oil method

The oil extraction process was performed using mechanical screw press. The screw press specifications are mentioned and its parts are explained according with **(Ibrahim et al., 2017)**. A photograph of the screw press and its specifications are depicted in Fig. (2).



1	Electric Motor	2	Gear box	3	Screw press base A
4	Screw press base B	5	Housing	6	Heaters
7	Screw	8	Temperature sensor	9	Feeding hopper
10	Inverter	11	Motor direction switch	12	Temperature thermostat
13	Relay	14	Oil collector	15	Coupling

Fig. (2): Photograph of the screw press

Sesame seeds were first pressed at temperatures of 45, 55 and 65 °C and screw speeds were tested at 75, 90 and 120 rpm.

2.4. Measuring and Instruments

The oil yield and cake masses were recorded. Specific energy consumption was estimated for each treatment, and the time required for pressing for each treatment was monitored. The effects of motor rotational speed and extracting temperature, on the oil yield and specific energy consumption were studied. Three replicates were conducted for each treatment.

2.4.1. Oil yield

Oil yield is the mass of extracted oil. Moreover, oil yield can be expressed as a ratio between the mass of extracted oil and the mass of seeds sample.

2.4.2. Oil extracting efficiency

Oil extracting efficiency is calculated as the ratio between the mass of extracted oil and the mass of oil existing in seeds before extraction.

2.4.3. Oil extracting time

Time was monitored using a stopwatch for every treatment. Every treatment was replicated three times and the mean value was determined.

2.4.4. Power and specific energy consumption

The power requirement (kW) was estimated by using the clamp meter to measure the line current strength (I) and the potential difference value (V).

The total electric power requirement under machine working load (P) was calculated according to **Kurt (1979)** by the following equation as:

$$P = \frac{I \times V \times \cos\theta}{1000}$$

Where:
P is the power requirement to automatic feeder, kW
I is the line current strength, Amperes
V is the potential difference, Voltage
Cos θ is the power factor, equal 0.8

The specific energy consumption (SEC) in kW.h/kg $_{oil}$ was calculated by using the following equation:

$$EC = \frac{P \times t}{60 \times Yield} \qquad (2)$$

Where:

SEC is the specific energy consumption, kW.h/kg $_{oil}$
t is the extracting time, min

Results and Discussion

1. Effect of extracting temperature and screw speed on the oil extraction yield

Fig. (3) Shows the effect of the different extracting temperatures (45, 55, and 65 ºC) and different screw speeds (75, 90, and 120 rpm) on oil extraction yield. The results indicate that the oil yield increases with increasing extracting temperature and decreasing screw speed. It could be seen that, the total sesame oil yield was increased from 49.6 to 52.4, 49.2 to 52.0 and 0.48 to 51.2 %, when the extracting temperature increased from 45 to 65 ºC, respectively, for 75, 90, and 120 rpm screw speed.

The results also indicate that the highest value of the oil extraction yield (52.4 %) was obtained at extracting temperature 45ºC and screw speed 120 rpm. On the other hand, the lowest value of the oil extraction yield (48.0 %) was obtained at extracting temperature 65ºC and screw speed 75 rpm. This can be explained that high temperature decreases oil viscosity which in turn allows oil to flow from sesame seeds. On the other side, increasing screw speed decreasing extraction time so that oil don't have enough time to get out of cells.

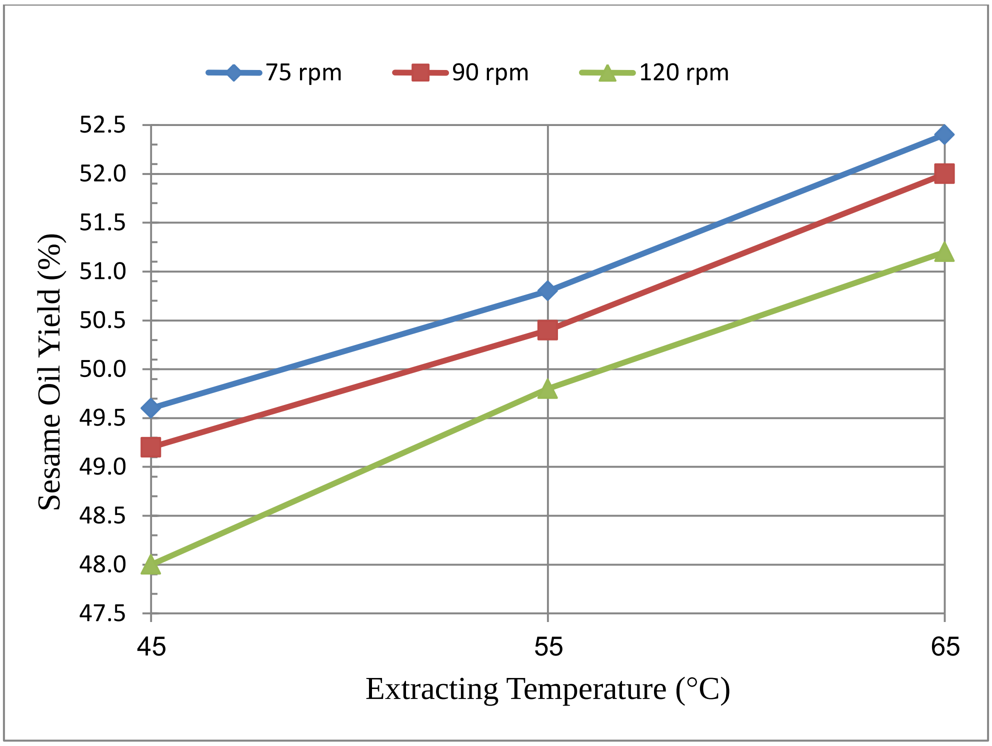


Fig. (3): Effect of extracting temperature and screw speed on sesame oil extraction yield

The results agreed with those obtained by **Piravi-Vanak et al. (2024)** who found that sesame oil yield increased from 38 to 51% by increasing extracting temperature 60 to 120 ºC . In terms of screw speed, the results agreed with those obtained by **Asafi et al. (2020)** who studied effect of the different screw speeds (20, 50 and 80 rpm) on the sesame oil extraction yield. They found the highest oil yield was obtained at 50 rpm screw speed. The results also agreed with those obtained by **Khater et al. (2024)** who studied the effect of different screw speeds (60, 90, and 120 rpm) and different extracting temperatures (60, 80, 100 and 120 °C) on the process of extracting Jatropha oil and mentioned the highest value of the oil yield (25.1%) was obtained at 60 rpm screw speed and 120 °C extraction temperature.

2. Effect of extracting temperature and screw speed on extraction efficiency

Fig. (4) Shows the effect of different extracting temperatures (45, 55, and 65 ºC and different screw speeds (75, 90, and 120 rpm) on sesame oil extraction efficiency. The results indicated that the sesame oil extraction efficiency increases with increasing extracting temperature and decreasing screw speed. It was clear that the sesame oil extraction efficiency increased from 77.42 to 82.58, 79.35 to 84.52, and 80.00 to 84.52% when extracting temperature increased from 45 to 65 ºC, and screw speed decreased from 120 to 75 rpm, respectively. The results also indicated that the highest value of the sesame oil extraction efficiency (84.52%) was found at 65 ºC extracting temperature and 75 rpm screw speed. That can be explained that increasing extracting temperature decreases oil viscosity which makes it easier for oil to flow out of cells. In addition, decreasing the screw speed prolongs the duration of the seeds inside the extractor which expose seeds to a longer press period, resulting in the most oil coming out of the cells.

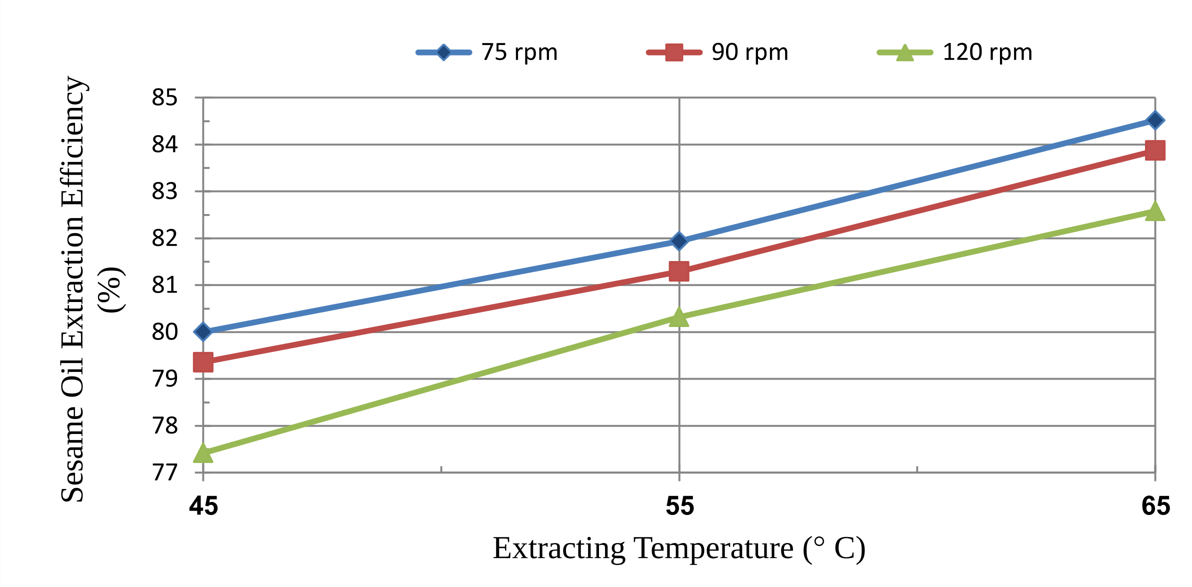


Fig. (4): Effect of extracting temperature and screw speed on extraction efficiency

The results agreed with those obtained by **Moses (2014)** who studied the effect of extracting temperature (50, 60, 70, 80, 90, 100, and 110ºC) on soybean extraction efficiency using single screw extruder. It was found that extraction efficiency increased from 32.26 to 69.13%, when the extraction temperature increased from 50 to 90 ºC, respectively. Also, he found the extraction efficiency increased with increasing the extracting temperature. In terms of screw speed, the results agreed with those obtained by **Abd Allah et al. (2023)** whose found that increasing screw speed leads to a lower oil yield which in turn leads to lower oil extraction efficiency.

3.3. Effect of extracting temperature and screw speed on oil extraction time

Fig. (5) shows the effect of different extraction temperatures (45, 55, and 65 ºC) and different screw speeds (75, 90 and 120 rpm) on sesame oil extraction time. The results indicate that the extraction time decreases with increasing extraction temperature and increasing screw speed. It was noticed that the extraction time was decreased from 4.62 to 3.107, 4.11 to 2.69, and 3.85 to 2.203 min, respectively, when extraction temperature increased from 45 to 65 ℃, and screw speed increased from 75 to 120 rpm. It was also indicated that the highest value of the extraction time (4.62 min) was obtained at extraction temperature 45 ºC and screw speed 75 rpm, while, the lowest value of the extraction time (2.203 min) was found at 65 ºC extraction temperature and 120 rpm screw speed. These results agreed with those obtained by **Abd Allah et al. (2023)** whose found extraction time of Egyptian castor seeds decreased from 4.00 to 1.52, 4.25 to 1.65, 4.76 to 1.73 and 5.45 to 1.85 min, when the screw speed increased from 30 to 90 rpm, respectively, at 60, 80, 100 and 120 °C of extraction temperature.

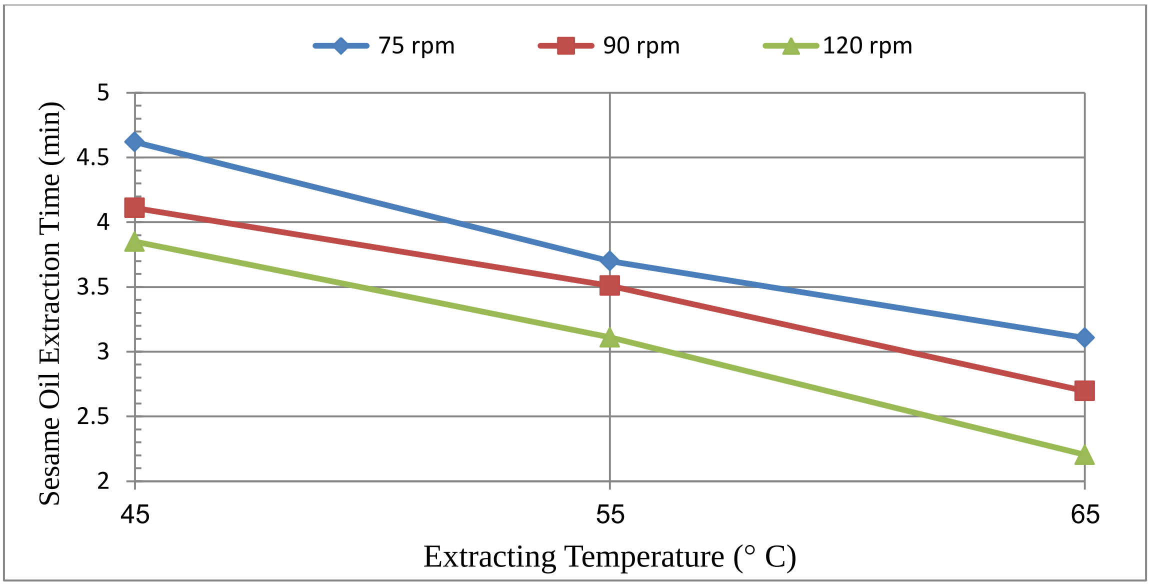


Fig. (5): Effect of extracting temperature and screw speed on extracting time

3.4. Effect of extracting temperature and screw speed on specific energy consumption

Fig. (6) Shows the effect of different extracting temperatures (45, 55, and 65°C) and different screw speeds (75, 90, and 120 rpm) on sesame oil specific energy consumption. The results indicate SEC decreases with increasing extracting temperature and screw speed. It could be seen that SEC was decreased from 0.466 to 0.296, 0.417 to 0.260, and 0.402 to 0.215 kW.h/kg $_{oil}$, when the extracting temperature increased from 45 to 65℃ at 75, 90 and 120 rpm of screw speeds. The results also indicate that the highest value of SEC (0.466 kW.h/ kg $_{oil}$) at 45°C of extracting temperature and 75 rpm of screw speed, while, the lowest value of SEC (0.215 kW.h/ kg $_{oil}$) at 65 °C of extracting temperature and 120 rpm of screw speed. The optimal SEC of 0.215 KW.h/ kg $_{oil}$ was obtained at 65°C extracting temperature and 120 rpm. These results agreed with those obtained by **(Khater et al., 2023)** who found that the energy consumption decreases with increasing screw speed. The main reason of decreasing the energy consumption is decreasing the extracting time which in turn means a decrease in motor working duration.

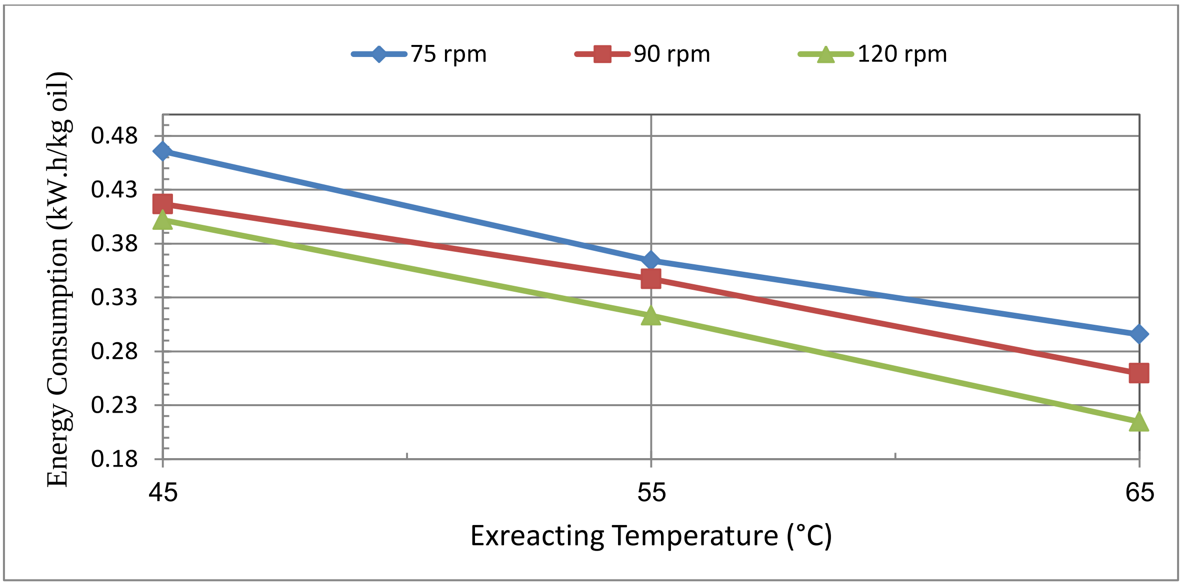


Fig. (6): Effect of extracting temperature and screw speed on extraction energy

Conclusions

The experiment was conducted to study the effect of different extracting temperatures (45, 55, and 65 °C) and different screw speeds (75, 90, and 120 rpm) on sesame oil yield, extraction efficiency, extracting time, and specific energy consumption. The results can be summarized as follows:

- The highest value of the oil extraction yield (52.4 %) was obtained at extracting temperature 45℃ and screw speed 120 rpm. While, the lowest value of the oil extraction yield (48.0) was obtained at extracting temperature 65℃ and screw speed 75 rpm.
- The sesame oil extraction efficiency increased from 77.42 to 82.58, 79.35 to 84.52, and 80.00 to 84.52% when extracting temperature increased from 45 to 65 ºC and screw speed decreased from 120 to 75 rpm, respectively.
- The extracting time was decreased from 4.62 to 3.107, 4.11 to 2.69, and 3.85 to 2.203 min, respectively, when extracting temperature increased from 45 to 65 ℃, and screw speed increased from 75 to 120 rpm.
- The highest value of specific energy consumption (0.466 $kW.h/kg_{oil}$) at 45°C of extracting temperature and 75 rpm of screw speed, while, the lowest value of specific energy consumption (0.215 $kW.h/kg_{oil}$) at 65 °C extracting temperature and 120 rpm of screw speed.

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تاثير درجة حرارة الإستخلاص وسرعة المكبس اللولبي علي انتاجية الزيت والطاقة النوعية المستهلكة من بذور السمسم

أحمد السيد عبدالصادق*، هبة رجب سيد أحمد، عادل حامد بهنساوي*****

***طالب دراسات عليا- كلية الزراعة بمشتهر- جامعة بنها**

****مدرس الهندسة الزراعية- كلية الزراعة بمشتهر- جامعة بنها**

*****أستاذ الهندسة الزراعية - كلية الزراعة بمشتهر- جامعة بنها**

إن الهدف من هذه الدراسة هو تحسين إنتاجية الزيت من بذور السمسم وذلك من خلال دراسة تأثير كلا من السرعة الدورانية للمكبس اللولبي، ودرجة حرارة الاستخلاص. ولتحقيق ذلك، تمت دراسة تأثير ثلاث درجات حرارة مختلفة لعملية الاستخلاص مختلفة (٤٥و٥٥ و٦٥ °م) وثلاث سرعات الاستخلاص مختلفة (٧٥ و٩٠ و١٢٠ لفة في الدقيقة) على كمية الزيت المستخلص، وكفاءة الاستخلاص، ومتطلبات الطاقة النوعية للاستخلاص، وزمن الاستخلاص. وكانت اهم النتائج المتحصل عليها كما يلى: زادت كمية زيت السمسم المستخلص من ٦.٤٩ إلى 52.4 ومن ٤٩.٢إلى ٥٢.٠ ومن 48.0إلى 51.2 %، بزيادة درجة حرارة الاستخلاص من 45 إلى 65 °م، على الترتيب، لسرعات المكبس اللولبي 75 و90 و120 لفة في الدقيقة. كانت أعلى قيمة لكفاءة الاستخلاص (84.52%) عند درجة حرارة استخلاص 65 °م وسرعة دورانية 75 لفة في الدقيقة. بينما كانت أقل قيمة لزمن الاستخلاص (2.203 دقيقة) عند درجة حرارة استخلاص 65 درجة مئوية وسرعة دورانية 120 لفة في الدقيقة. كان الاستهلاك النوعي الأمثل للطاقة هو 0.215 كيلو واط.ساعة/كجم زيت عند درجة حرارة استخلاص 65 °م وسرعة دورانية 120 لفة في الدقيقة.

الكلمات المفتاحية: استخلاص الزيت، زيت السمسم، المكبس اللولبي، كفاءة الاستخلاص، زمن الاستخلاص، استهلاك الطاقة النوعي.