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EFFECT OF SCREW SPEED AND TEMPERATURE ON THE YIELD AND QUALITY OF BIO-OIL FROM EGYPTIAN CASTOR SEEDS

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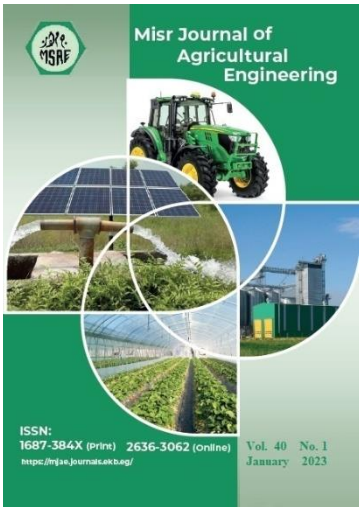


Keywords:
Screw press; Castor Yield; Temperature; Speed; Energy.

ABSTRACT

Energy scarcity and conventional energy problems are the main reason of finding a renewable source of energy which is cheap and environmental friendly, therefore, biodiesel production is one of the most promising solutions of this problem. Also, Egyptian castor is one of the most important crops for oil yield production compared with other commonly used oil crops. The main aim of this study is to enhance the production of bio-oil from Egyptian castor seeds by extraction screw speed and temperature. To achieve that, the effects of extraction screw speed (30, 60 and 90 rpm) and temperature (120, 140, 160 and 200 °C) on oil extraction yield from castor seeds, extraction energy and extraction time were studied. The results indicate that, the highest value of decreasing of oil extraction yield (40.85 %) was found for 200 °C extraction temperature. The extraction energy decreased from 40.1 to 14.9, 42.0 to 15.2, 43.1 to 15.7 and 46.7 to 16.0 W.h when the screw speed increased from 30 to 90 rpm, respectively, for 120, 140, 160 and 200 °C. The highest value of extraction time (5.45 min) was found of 200 °C extraction temperature and 30 rpm screw speed, while, the lowest value of extraction time (1.52 min) was found of 120 °C extraction temperature and 90 rpm screw speed. The Palmitic acid, Stearic acid, Oleic acid, Linolenic acid and α Linolenic acid were 1.14, 1.32, 4.48, 5.40 and 0.61 %, respectively, at 200 °C extraction temperature and 30 rpm screw speed.

1. INTRODUCTION

The energy crisis, high oil prices, and global warming are among the most important problems the world faces. Therefore it is imperative to use biodiesel as an environmentally friendly renewable alternative resource as it features higher biodegradation than fossil fuels, non-toxic, excellent lubrication, and is free of sulfur and aromatics. And reduce the level of pollutants and potential carcinogens. It is an environmentally friendly fuel that can be used in any diesel engine without the need to redesign existing technology. It has better quality exhaust gas emissions because the organic carbon in it is a photo generator. Where it does not contribute to the increase in the level of carbon dioxide in the atmosphere and thus to global warming **(Keera, *et al.*, 2018, Khater *et al.*, 2020 and Osorio-González *et al.*, 2020)**.

Biodiesel is produced from fatty acids (FA) from vegetable oils and animal fats by reacting them with catalyzed alcohols using an acid/base catalyst. The feedstock for vegetable oils may be edible oils (1st generation) or inedible oils (2nd generation). But nonedible oils are the best for biodiesel production to overcome any crisis related to food production. Also, due to its low prices, the cost of biodiesel production depends mainly on the cost of crude oil (about 75% of the cost is paid to obtain the crude oil) **(Palconite *et al.*, 2018)**. Due to the high availability and low cost of crude castor oil in Egypt, Therefore, it is important to production castor oil from castor seeds.

Ricinus communis (castor) seeds are considered as a second generation raw material. Castor bean (*Ricinus Communis L.*) can be grown on marginal lands with low water demand where it is drought tolerant, pest-resistant, requires less industrial care and the biomass can be harvested three times in a year. Castor seeds have an oil content usually of 40-55%, which is very high compared to most other commonly used oil crops (soybean: 15-20%, sunflower: 25-35%, rapeseed: 38-46%, Palm: 30-60%). It is characterized by its high Ricinoleic acid content and is suitable for industrial rather than food applications. It is worth noting that the cost of growing of castor is much lower than other plants such as jatropha, soybean and rapeseed. Therefore, castor seed is an attractive sustainable source for biodiesel production **(Palconite *et al.*, 2018, Attia *et al.*, 2018 and Keera *et al.*, 2018)**.

The oil extraction methods are mechanical, chemical and enzymatic extractions. It is found that the most effective way to extract castor oil with the highest productivity is through organic solvents such as hexane, toluene or ether, but it has environmental effects where high volatile organic compounds are emitted that have negative effects on human health due to dealing with dangerous and flammable chemicals and increasing specific energy consumption. So, the cost of the process increases the final cost of biodiesel. The mechanical extraction has been the best method from a practical point of view **(Osorio-González *et al.*, 2020)**. As it can be obtained at low cost, it has a relatively lower oil yield unlike chemical extraction but is simpler, safer and contains fewer steps compared to solvent extraction. Mechanical extraction method, a manual piston or an engine-driven screw piston is used. More oil can be extracted by an engine-driven screw piston (68 - 80%) than by an engine-driven ram piston (60 - 65%). Pretreatment of crops such as frying was found to increase the oil yield of the screw press by up to 89% after intermittent passage and 91% after double-pass **(Bibin *et al.*, 2020 and Osorio-González *et al.*, 2020)**.

The previous studies to improve the oil yield production from Egyptian castor seeds are very poor; also, the Egyptian castor seeds which is very high oil content and good properties. The main aim of this study is the effects of extraction screw speed and temperature on oil extraction yield from castor seeds, extraction energy and extraction time.

2. MATERIALS AND METHODS

The main experiment was carried out in National Research Centre, Giza, Egypt. During summer season of 2021.

2.1. Egyptian castor seeds.

Egyptian castor seeds were obtained from a privet farm in Sinai Governorate. A lipid analysis was performed showing the percentage of oil in the seeds. The bio-oil was extracted from the Egyptian castor seeds by a screw press without pre-treatments and pre-treatments were accomplished using Microwave and Ultrasonic to enhance the production of bio-oil from castor seeds. The schematic diagram in Figure 1 shows the sequence of oil extraction by screw press from castor seeds.

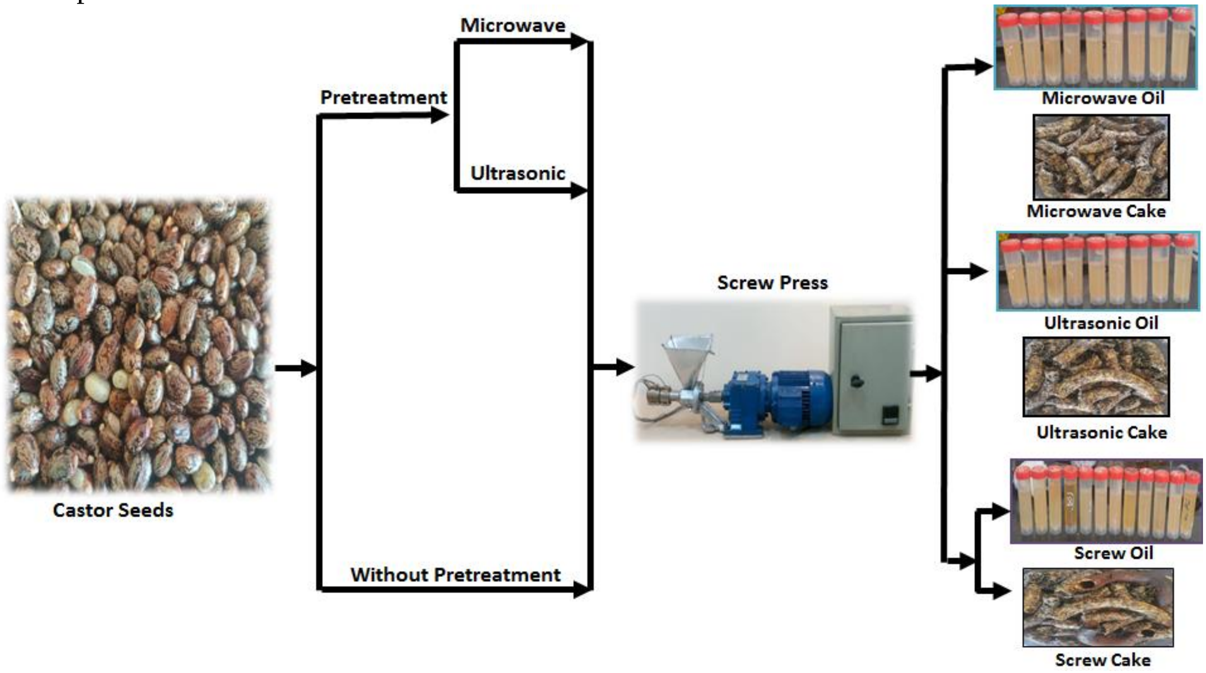
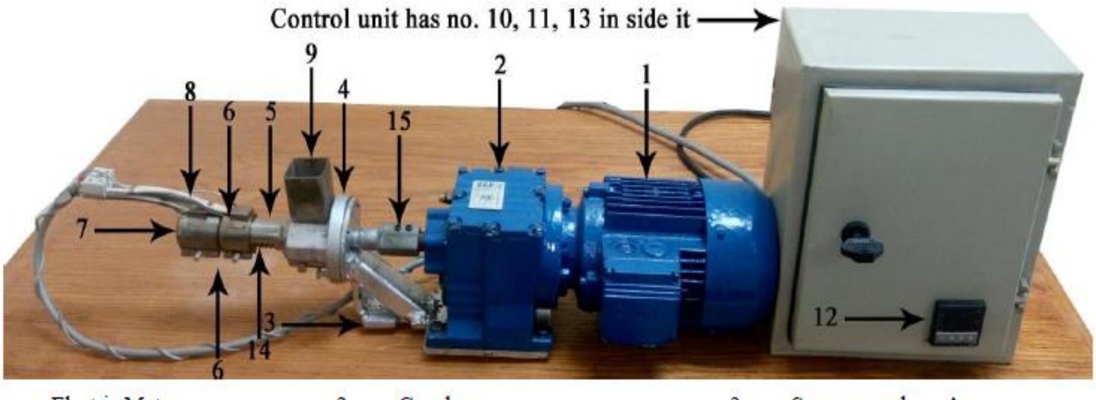


Figure 1. Schematic diagram of oil extraction by screw press from Egyptian castor seeds.

2.2. Mechanical screw pressing extraction method.

The oil extraction was performed using a specially designed laboratory scale mechanical screw press in the National Research Center was used and whose specifications are mentioned its parts explained in this reference **(Ibrahim *et al.*, 2017).** A photograph of the screw press and its are shown in Figure 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

Figure 2. Photograph of the screw press.

The screw press was used in oil extraction as studies have proven its success and efficiency in extraction. Castor seeds were pressed at low temperatures of 50 to 100 °C and speed of 40, 80 and 120 rpm, so the temperatures were raised and the parameters and conditions were chosen to suit the nature and characteristics of the castor seed. Therefore, the experiments were conducted in factorial arrangement, with three speeds of 40, 60 and 80 rpm, at extraction temperatures of 100, 150, 200 and 250 °C where three replicates were made for an experiment. The yield oil weight and cake weight were measured. Power and energy were measured for each treatment by energy meter machine, and the time required for pressing for each treatment was recorded. It is important to mention that the preheating temperature is limited to 200 °C in order not to increase the undesirable fatty acids in the oil. The effect of motor rotational speed and extraction temperature on the oil extraction yield was studied

2.3. Measurements.

The gas chromatography (GC) test is a technique used to measure the fatty acid composition in an oil sample which allows separation of mixtures based on their boiling point **(Ibrahim *et al.*, 2020)**. The fatty acid composition was determined by the transmethylation of the fatty chains to fatty acid methyl esters (FAMEs) according to the modified method by **Zahran and Tawfeuk (2019)**. The FAMEs were separated with an HP 6890 plus gas chromatography (Hewlett Packard, USA), using a capillary column Supelco™ SP-2380 (60 m×0.25 mm×0.20 μm), (Sigma-Aldrich, USA), Detector (FID) and the injector and detector temperature was 250°C. The column temperature was 140°C (held for 5 min) and rose to 240°C, at rate of 4°C/min, and held at 240°C for 10 min. The carrier gas was helium at flow rate 1.2 mL min^{-1}. Sample volume was 1µL (in *n*-hexane) and injected through a split injector at splitting ratio of 100:20. FAMEs were identified by comparing their relative and absolute retention times to those authentic standards of FAMEs (Supelco™ 37component FAME mix). The fatty acid composition was reported as a relative percentage of the total peak area **(Zahran and Tawfeuk, 2019)**. Saponification number, Acid value and Moleculer weight of oil were determined according to **AOCS (2017)**.

3. RESULTS AND DISCUSSION

3.1. Effect of extraction screw speed and temperature on oil extraction yield:

Figure 3 shows the effect of extraction screw speed (30, 60 and 90 rpm) and temperature (120, 140, 160 and 200 °C) on oil extraction yield from castor seeds. The results indicate that the oil extraction yield decreases with increasing screw speed and decreasing temperature. It could be seen that the oil yield decreased from 37.66 to 31.13, 32.17 to 31.88, 39.24 to 32.59 and 40.85 to 33.20 % when the screw speed increased from 30 to 90 rpm, respectively, for 120, 140, 160 and 200 °C. The results also indicate that the highest value of decreasing of oil extraction yield (40.85 %) was found for 200 °C extraction temperature. This is due to the oil viscosity decreases with increasing extraction temperature, therefore, the oil exit from the cell easy **(Ibrahim *et al.*, 2020)**.

Also, the high temperature causes evaporate the oil from the cell, which leads to a decrease of oil yield. These results agreed with those obtained by **Ibrahim *et al.* (2017)** whose found the lowest value of oil yield extraction was found the highest value of extraction temperature. The results indicate that the maximum oil production is about 40.84% by the screw press which is equivalent to 83.41% by mass fraction of oil in seeds in comparison percentage oil 48.96% in seeds obtained at an engine speed of 30 rpm and preheating temperature of 200 °C. These results agreed with those obtained by **Raja *et al.* (2011)**. However, in these extraction conditions, much time is consumed with higher energy. The maximum yield of oil (40.84 %) was obtained at temperatures in the range of 200 °C at speed of 30 rpm, the yield is slightly lower but the energy is much lower than are much less as will. The oil yield decreases with increasing screw speed due to the extraction time was decreased with increasing screw speed.

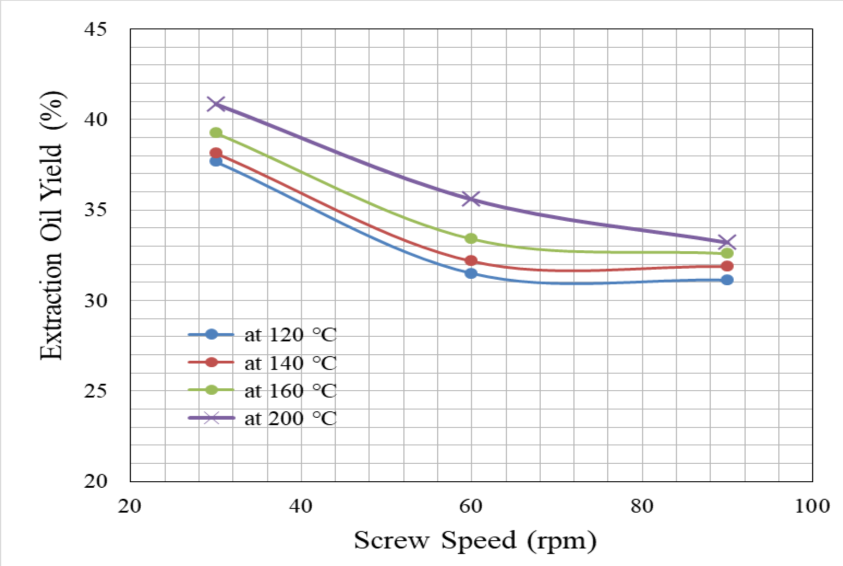


Figure 3: Effect of extraction screw speed and temperature on oil extraction yield of castor.

3.2. Effect of extraction screw speed and temperature on extraction energy.

Figure 4 shows the effect of extraction screw speed (30, 60 and 90 rpm) and temperature (120, 140, 160 and 200 °C) on oil extraction energy from castor seeds. The results indicate that the extraction energy decreases with increasing screw speed and decreasing temperature. It could be seen that the extraction energy decreased from 40.1 to 14.9, 42.0 to 15.2, 43.1 to 15.7 and 46.7 to 16.0 W.h when the screw speed increased from 30 to 90 rpm, respectively, for 120, 140, 160 and 200 °C.

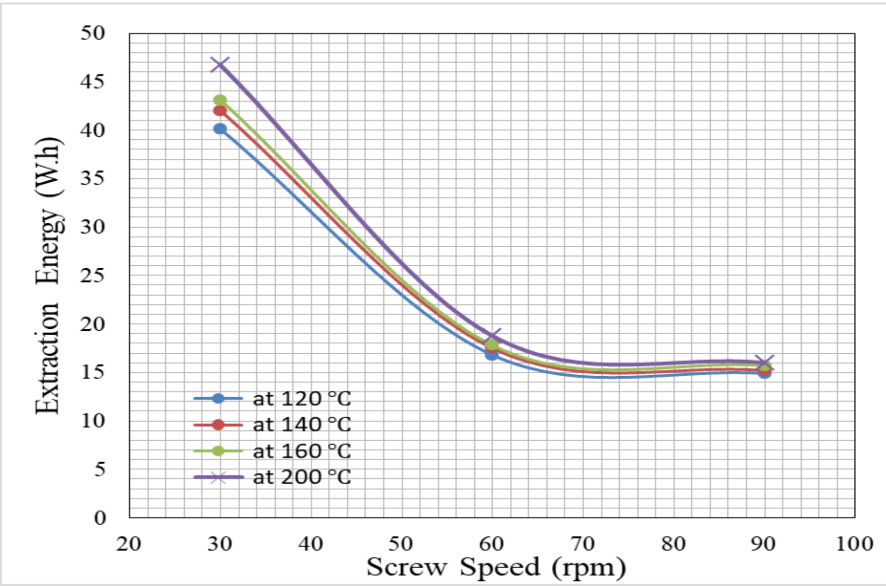


Figure 4: Effect of extraction screw speed and temperature on extraction energy.

The results also indicate that the highest value of extraction energy (46.7 W.h) was found of 200 °C extraction temperature and 30 rpm screw speed, while, the lowest value of extraction energy (14.9 W.h) was found of 120 °C extraction temperature and 90 rpm screw speed. These results agreed with those obtained by **Ofori-Boateng *et al.* (2012)**.

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

Figure 5 shows the effect of extraction screw speed (30, 60 and 90 rpm) and temperature (120, 140, 160 and 200 °C) on oil extraction time from castor seeds. The results indicate that the extraction time decreases with increasing screw speed and decreasing temperature. It could be seen that the extraction time 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, for 120, 140, 160 and 200 °C. The results also indicate that the highest value of extraction time (5.45 min) was found of 200 °C extraction temperature and 30 rpm screw speed, while, the lowest value of extraction time (1.52 min) was found of 120 °C extraction temperature and 90 rpm screw speed. These results agreed with those obtained by **Ofori-Boateng *et al.* (2012)**.

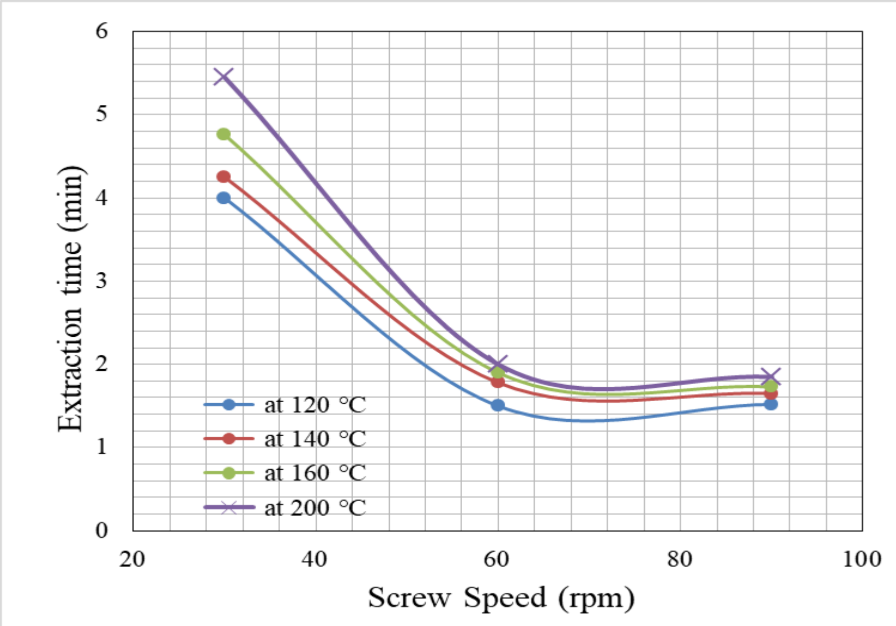


Figure 5: Effect of extraction screw speed and temperature on Extraction time

The results indicate that the optimum condition of Screw press for extracted caster seeds were 200 °C extraction temperature and 30 rpm screw speed. It could be seen that the extraction oil yield, extraction energy and extraction time were 33.20 %, 16.00 and 1.85 min, respectively.

3.4. Gas chromatography analysis

Table 1 shows the gas chromatography analysis at the optimum condition of Screw press for extracted caster seeds were 200 °C extraction temperature and 30 rpm screw speed. The results indicate that, the Palmitic acid, Stearic acid, Oleic acid, Linolenic acid and α Linolenic acid were 1.14, 1.32, 4.48, 5.40 and 0.61 %, respectively, at 200 °C extraction temperature and 30 rpm screw speed. These results agreed with those obtained by **Ogunniyi, (2006) and Conceicao *et al,* (2007)** whose found that the castor oil is presents in minor amount that includes Linoleic acid (4.2%), Oleic acid (3.0%), Stearic acid (1%), Palmitic acid (1%), Dihydroxystearic acid (0.7%), Linolenic acid (0.3%) and Eicosanoic acid (0.3%). Various vegetable oils are potential feedstocks for the production of a fatty acid methyl ester or biodiesel, but the quality of the fuel will be affected by the oil composition. The vegetable oil should have lower saturation and lower polyunsaturation. Vegetable oils which are rich in polyunsaturated fatty acids such as linoleic and linolenic acids give biodiesel with poor oxidation stability. Vegetable oils with a higher degree of unsaturation tend to have higher freezing point and poor flow characteristics at lower temperatures, and need preheating before combustion **(Ibrahim *et al.*, 2020)**.

The results also indicate that the Ricinoleic acid, Saponification Number, acid value and Molecular weight (MW) of oil were 86.87%, 179.2, 1.54% and 943.72, respectively, at 200 °C extraction temperature and 30 rpm screw speed.

Low saponification value implies high molecular weight and high saponification value indicates low molecular weight of the triglyceride high saponification value indicates low molecular weight of the triglyceride. Low saponification value in oil samples proposes their non-suitability for industrial use, hence the high saponification value of castor oil confirms its useful application for the manufacture of soaps and other cosmetic products **(Attia *et al.*, 2021 and Yeboah *et al.*, 2021)**. Also, the physicochemical properties of oil such as low acid value and free fatty acid percentage, high saponification value acid indicate that castor oil has good oil quality.

Table 1: Effect of extraction screw speed and temperature on the gas chromatography analysis

Item	Value
Palmitic acid, %	1.14
Stearic acid, %	1.32
Oleic acid, %	4.48
Linolenic acid, %	5.40
α, Linolenic acid, %	0.61
Ricinoleic acid, %	86.87
Saponification No.	179.2
Acid Value, %	1.54
Molecular weight (MW) of oil	943.72

4. CONCLUSIONS

The experiment was carried out to study the effect of extraction screw speed (30, 60 and 90 rpm) and temperature (120, 140, 160 and 200 °C) on oil extraction yield from castor seeds, extraction energy and extraction time. The obtained results can be summarized as follows:

- The highest value of decreasing of oil extraction yield (40.85 %) was found for 200 °C extraction temperature.
- The extraction energy decreased from 40.1 to 14.9, 42.0 to 15.2, 43.1 to 15.7 and 46.7 to 16.0 W.h when the screw speed increased from 30 to 90 rpm, respectively, for 120, 140, 160 and 200 °C.

- The highest value of extraction time (5.45 min) was found of 200 °C extraction temperature and 30 rpm screw speed, while, the lowest value of extraction time (1.52 min) was found of 120 °C extraction temperature and 90 rpm screw speed.
- The optimum condition of Screw press for extracted caster seeds were 200 °C extraction temperature and 30 rpm screw speed. It could be seen that the extraction oil yield, extraction energy and extraction time were 33.20 %, 16.00 and 1.85 min, respectively.
- The Palmitic acid, Stearic acid, Oleic acid, Linolenic acid and α Linolenic acid were 1.14, 1.32, 4.48, 5.40 and 0.61 %, respectively, at 200 °C extraction temperature and 30 rpm screw speed.

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تأثير سرعة مكبس الاستخلاص ودرجة الحرارة على انتاجية وجودة الزيت الحيوى من بذور الخروع المصرية

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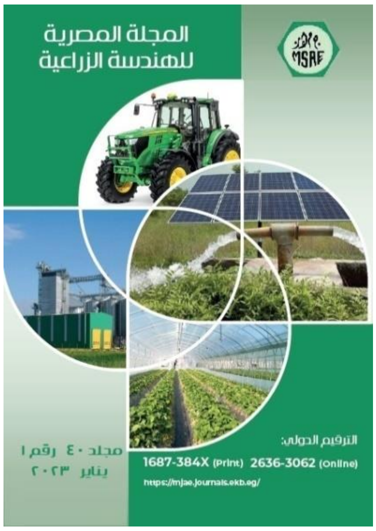

الكلمات المفتاحية:

الخروع؛ الإنتاجية؛ درجة الحرارة؛ الطاقة؛ وقت الاستخلاص.

المخلص العربى

الهدف الرئيسي من هذه الدراسة هو الحصول على السرعة المثلى ودرجة حرارة التسخين المثلى للمكبس اللولبي للحصول على أعلى عائد إنتاج للزيت في ظل اقل وقت استخلاص واقل استهلاك من الطاقة ولتحقيق ذلك تم دراسة تأثير سرعة لولب الاستخلاص (٣٠ ، ٦٠ ، ٩٠ لفة في الدقيقة) ودرجة الحرارة (١٢٠ ، ١٤٠ ، ١٦٠ و ٢٠٠ درجة مئوية) على محصول الزيت من بذور الخروع ، وطاقة الاستخلاص ووقت الاستخلاص. أشارت النتائج إلى أن أعلى قيمة لانخفاض محصول الزيت (٤٠,٨٥٪) وجدت في درجة حرارة الاستخلاص ٢٠٠ درجة مئوية. انخفضت طاقة الاستخراج من ٤٠,١ إلى ١٤,٩ ، ومن ٤٢,٠ إلى ١٥,٢ ، ومن ٤٣,١ إلى ١٥,٧ ومن ٤٦,٧ إلى ١٦,٠ واط في الساعة عندما زادت سرعة اللولب من ٣٠ إلى ٩٠ لفة في الدقيقة ، على التوالي ، لـ ١٢٠ و ١٤٠ و ١٦٠ و ٢٠٠ درجة مئوية. تم العثور على أعلى قيمة لوقت الاستخراج (٥,٤٥ دقيقة) عند درجة حرارة الاستخراج ٢٠٠ درجة مئوية وسرعة المسمار ٣٠ لفة في الدقيقة ، بينما تم العثور على أقل قيمة لوقت الاسستخلاص (١,٥٢ دقيقة) عند درجة حرارة الاستخراج ١٢٠ درجة مئوية وسرعة المسمار ٩٠ لفة في الدقيقة. كان حمض البالمتيك وحمض دهني وحمض الأوليك وحمض لينولينيك وحمض ألفا لينولينيك ١,١٤ و ١,٣٢ و ٤,٤٨ و ٥,٤٠ و ٠,٦١٪ على التوالي عند درجة حرارة استخلاص ٢٠٠ درجة مئوية وسرعة لولبية ٣٠ لفة في الدقيقة.