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EFFECT OF RICE BRAN PELLETING AND PELLETS CHARACTERISTICS ON THE EFFICIENCY OF OIL EXTRACTION

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ABSTRACT

A study was carried out to test and evaluate the effect of rice bran pelleting using a single face extruder on the extraction efficiency of rice bran oil. Four different various screw speeds 30, 50, 70, and 90 rpm, three different die hole diameters 6, 8 and 10 mm and four different various pelliting lengths 1, 2, 3 and 4 cm were examined and evaluated. The results show that, moisture content of pellets decreased at all levels of screw speed and die hole diameter. At screw speed of 30 rpm the moisture content decreased from an initial moisture content of 11.9 % (w.b.) to 6.22, 6.43 and 6.71 % (w.b.) with die hole diameters of 6, 8 and 10 mm, respectively. At all levels of screw speed and die hole diameter the bulk density of pellets (0.29 g/cm^3) increased by one and half times of raw bran bulk density and ranged from 0.43 to 0.59 g/cm^3. Penetration rate increased by increasing pellets length and diameter and ranged from 37.44 to 38.96 cm/min. Oil retention ratio decreased by increasing pellets length, while increasing pellets diameter tended to increase oil retention ratio. Residual oil % increased with increasing length and diameter of pellets. Oil extraction efficiency decreased with increasing pellets length and diameter and it was ranged from 84.6% at 4 cm length and 10 mm diameter of pellets to 95.5% at 1 cm length and 6 mm diameter of pellets.

INTRODUCTION

Rice bran is the most valuable by-product of rice processing industry. It forms about 10% of the total grain and is highly nutritious, being rich in lipids, protein, minerals and vitamins. It is a major source of oil, with the oil content varying from 12-25% depending on the quality of bran and the degree of polishing. (Motthew, 2009).

In Egypt, the cultivated area of rice is about 1.534 million feddan which annually produces 6.38 million tons (RRTC, 2006). The bran, which an important as a by-product, is mainly produced during rice milling operation which represented about 10 % of the weight of rice grain. It is rich in protein 13-16%, oil 15-22%, fiber 6.2-14.4%, ash 8-17.75%, vitamins and trace minerals (Daniel et al., 1993).

Bor (1991) reported that, the solvent extraction method can extract 95-99% of the oil in the raw material and is ideal for rice oil extraction. Many organic solvents are suitable for oil extraction, however, n-hexane has become the most popular organic solvent in modern extraction plants because of its efficiency, safety and availability. The mechanical removal of oil from oilseeds can be achieved by extraction, expression or a combination of extraction and expression.

Extraction is the process of separating a liquid from a liquid solid system with the use of solvents. Expression is the process of mechanically removing liquid contained in solids by the use of equipment such as screw presses, hydraulic presses, roll presses and mills (khan and Hannan, 1983).

Abhaysah and Shukla (1983) stated that, particle size is one of the most important variables influencing the rate of extraction of oil-bearing materials. Rice bran is a floury material and any attempt to extract the oil directly poses problems due to so much fines. Hence, bran needs granulation or pelletization to facilitate extraction.

Frank (2005) investigated pelletizing of the bran improves percolation and minimizes fines in the miscella. Pellets are 6–8 mm in diameter. Moistening during palletizing reduces the fines problem. Parboiled bran does not produce the hard pellets found for raw bran possibly because of protein denaturation during parboiling binding of the fines in the pellet is assisted by starch gelatinization during heating of the bran. He also reported that the fines agglomeration, which is due to the starch gelatinization and protein denaturation contained in the bran, helps to increase the percolation rate of the treated material during solvent extraction. Also, the oil extraction rate of extruded rice bran pellets (6 – 8 mm, in diameter) was rapid with 96% of the oil being removed in 5 minutes and only 0.7% residual oil remaining after 1 hour of extraction.

Kim et al. (1987) reported that rice bran is essentially a powder, and problems occur in direct solvent extraction of oil. Fines do not permit rapid solvent percolation under gravity flow, and special pressure techniques are required for effective extraction. Also, the flow of solvent through the bran bed is channelized, resulting in a very high bran/solvent ratio. Removal of solvent retained in the extracted meal is an additional problem.

Kaliyan and Morey (2007) indicated that temperatures of around 85°C can occur in conventional ring-die pelleting machines due to frictional heating. When heat sterilization treatment is given in the presence of a moisture level sufficient to cook the material, the additional benefit of fines agglomeration is obtained. These developments of cooking rice bran eliminate the fines and retard the free fatty acids formation, which are the two vexing problems concerning the processing of rice bran, would render rice bran as easily extracted as any other well prepared oil seeds. Cooking also releases the oil similar to the effect of cooking upon other oleaginous materials. The fines agglomeration, which is due to the gelatinization of carbohydrates and denaturation of proteins contained in the bran, helps to increase the percolation rate of the treated material as well as eliminate the problems encountered in the miscella clarifiers and meal desolventizer.

The objective of the present study was to modify, testing and evaluating an expeller machine for forming rice bran pellets to maximize oil extraction rate during solvent extraction operation. The effects of some operating parameters such as screw speed, die hole diameter and length of pellets on oil extraction were also studied and examined.

MATERIALS AND METHODS

Materials:

Rice bran samples of Sakha 101 rice variety, were obtained from a rice mill in Kafr El-Shikh Governrate. The obtained rice bran was filled in plastic bags and stored temporarily in a freezing room adjusted at a temperature of -5^{o}C in order to suppress fungal growth and minimize quality changes of the stored bran.

Equipment:

An expeller machine for flax oil extraction developed by Al-Ashry (1999) and modified by Matouk et al.(2009) was used for the experimental work after modification of the outlet ring die and barrel design. Specifications of the original machine are lised in Table (1) and shown in Fig.(1).

Table (1): Specifications of the original flax oil extraction machine.

Item	Specifications
Main Dimensions:	
- Overall length, cm	136
- Overall width, cm	61.5
- Overall height, cm	155
- Total mass, kg.	513
Screw:	
- Length, cm	56
- Diameter, cm	10
- Pitch (trough width), cm	5
- Peak height (trough depth),cm	1.5
- Flights No.;	10
Hopper:	
- Length, cm	35
- Diameter, cm	30
Power source:	Three phase electric motor,
- Power req., HP (kW)	10 (7.5)

Machine modification for rice bran pelleting:

The die outlet head of the original machine has a chuck like outlet that changed and replaced by an outlet ring die with 16, 14 and 12 mm round holes for forming rice bran pellets at different diameters 6, 8 and 10 mm.

Also, the barrel used for oil extraction process was modified to fit with rice bran pelleting. The clearance between the flat steel bars inside the barrel cage was eliminated and the bars also sloped towards the die hole of the extruder by reducing the bars cross section area` to increase the compression action of the screw towards the die hole of the extruder as shown in Fig.(2).

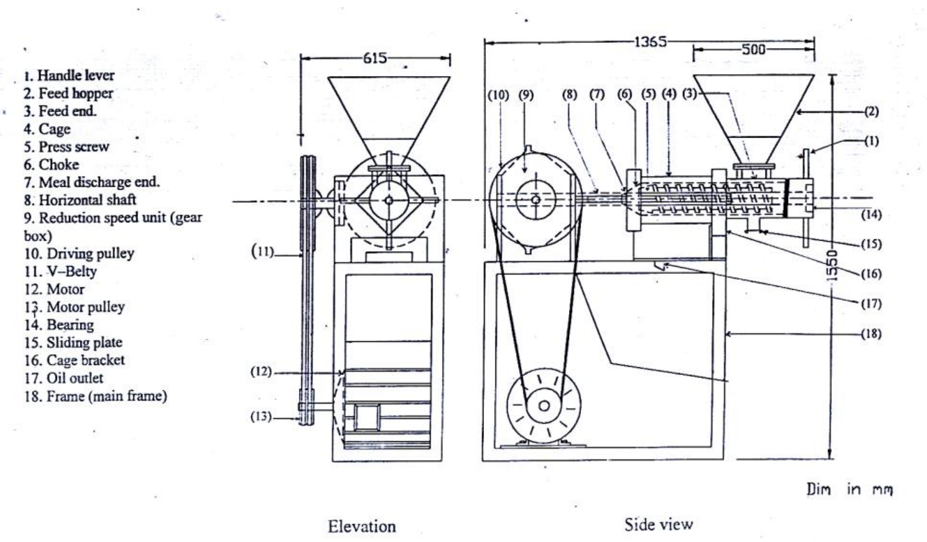

Fig. (1): Schematic diagram of the original expression machine.

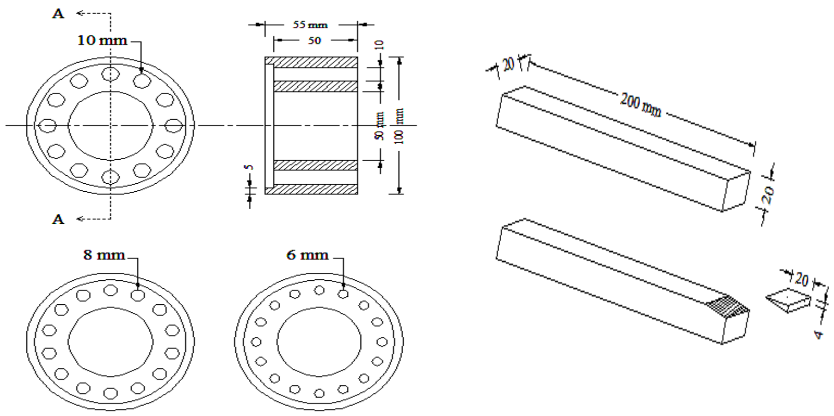

Fig. (2): Cross section of the modified barrel and die holes diameters of the extruder.

Experimental Treatments:

The experimental treatments, included four different levels of screw speed 30, 50, 70 and 90 rpm, three various levels of die hole diameter 6, 8 and 10 mm and four different levels of pellets length 1, 2, 3 and 4 cm.

Test procedure and measurements:

Before each experimental run, rice bran samples were taken out from the freezing room and left under the room temperature until the initial temperature of the rice bran approached the room temperature.

The following steps were proceeded for the experimental work:

1-The tested die was used and the clearance between warm and choke was adjusted to the required level by changing the position of the handle lever.

2-The screw speed was adjusted to the required level by a means of pulleys.

3-The machine was initially operated till reached to the stable conditions and the bran sample was poured inside the machine feeding hopper.

4-The cutting knife was adjusted to get the required pellets length.

Oil extraction from rice bran:

Oil was extracted from rice bran samples (powder and pellets) by a simple extraction system using the commercial n-hexane. 12.5 grams bran samples were rolled inside a filtration paper (12.5 Watman) and installed inside a bottle filled with 50 ml n-hexane for 24 hours at room temperature, then it was allowed to dry in an electric oven at 70^oC for two hours in order to completely evaporate the remaining solvent from the sample. The obtained samples were again weighed and the percentage of remaining oil was calculated.

Determination of remaining oil percentage:

The remaining percentage of oil was determined as follows:

1-The powder and pellets samples of about 30 grams was dried inside the oven at 105^oC for 3 hours.

2-A sub-samples of 5g each was rolled inside a filtration paper (12.5 Watman).

3-Three sub-samples was installed inside a soxhlet unit adjustd at 60^oC for 16 complete circles using petroleum-ether.

4-After oil extraction using the soxhlet unit the sample allowed to dry in an electric oven at 70^oC for two hours in order to completely evaporate the remaining solvent from the sample.

5-The obtained samples were again weighed and the percentage of remaining oil was calculated using the following equation:

Remaining oil % = $(w_r / w_t) \times 100$ .... (1)

Where:

w_r = Weight of the remaining oil, g.

w_t = Weight of the bran sample, g.

Extraction efficiency:

The extraction efficiency was determined using the following equation:

Extraction efficiency = $O_t – O_r / O_t$ ……….......................................…....…… (2)

Where:

O_r = Remained oil, %;

O_t = Total oil in the sample, %.

Moisture content of rice bran:

Five samples were taken from bran powder and pellets, and the moisture content of bran were determined according to AOAC (2003) using standard air oven method at 135ºC for 3 hours.

Penetration rate cm/min:

Solvent penetration rate through beds of bran powder and pellets during extraction was determined as average cm/min travel for the tested particular depth beds.

Retention ratio:

After free draining, the miscella retention ratio was calculated by determining the oil and n-hexane remained in the bed of whole bran. Data reported was taken as average of three replications.

RESULTS AND DISCUSSION

Effect of screw speed and die hole diameter on moisture content of bran pellets:

The effect of screw speed and die hole diameter on moisture content of the extruded bran is plotted in Fig.(3). It evidently shows that, moisture content decreased at all screw speeds and die hole diameters. At screw speed of 30 rpm moisture content of bran pellets decreased from an initial moisture content of 11.9 % (w.b.) to 6.22, 6.43 and 6.71 % (w.b.) for die hole diameters of 6, 8 and 10 mm, respectively. While, at screw speed 90 rpm it was decreased to 6.78, 7 and 7.38 % (w.b.) for the same die hole diameters, respectively.

Fig.(3): Effect of screw speed and die hole diameter on bran moisture content.

Effect of screw speed and die hole diameter on bulk density of bran:

As shown in Fig.(4) the bulk density of the extruded bran. Also, as shown in the figure, bulk density of bran pellets decreased from 0.29 g/ cm^3 for the raw bran to different values depending upon the die hole diameter and screw speeds. It also shows the effect of screw speed and die hole diameter on bulk density of the extruded bran. At 6 mm die hole diameter, the recorded bulk density of the bran pellets were 0.59, 0.56, 0.52 and 0.51 g/cm^3 for the screw speeds 30, 50, 70 and 90 rpm, respectively. However, at 10 mm die hole diameter the corresponding values were 0.48, 0.46, 0.44 and 0.43 g/cm^3 for the same screw speeds respectively.

When the die hole diameter increased with all screw speeds, same trend was observed. The recorded bulk density of pellets were 0.59, 0.54 and 0.48 g/cm^3 at 30 rpm screw speed and die hole diameters of 6, 8 and 10 mm, respectively. While at the maximum screw speed of 90 rpm the corresponding values of pellets bulk density were 0.51, 0.47 and 0.43 g/cm^3, respectively. Therefore, the screw speed was found to be inversely proportional to bulk density.

The above mentioned results reveals that, the bulk density of bran pellets nearly increased one and half times in comparison with raw bran. This obtained results is in agreement with that published by kim et al.(1987).

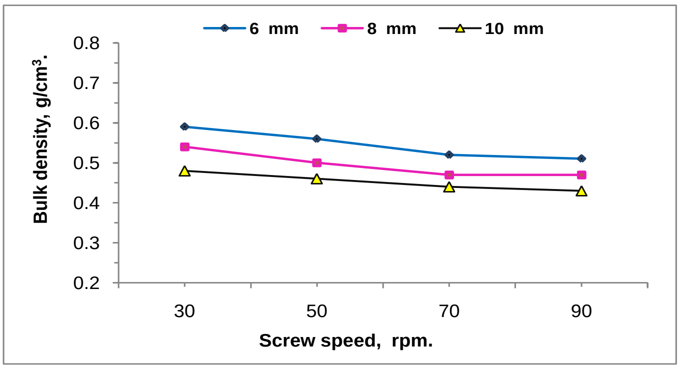

Fig. (4): Effect of screw speed and die hole diameter on bulk density of bran pellets.

Effect of pellets characteristics on oil extraction process:

The effect of pellets length and diameter on solvent penetration rate for the pellets produced at screw speed of 30 rpm. during the experimental work is plotted in Fig.(5). It evidently reveals that, solvent penetration rate increased by increasing pellets length and diameter. It was increased from 37.44, 37.90 and 38.50 cm/min to 37.84, 38.48 and 38.96 cm/min by increasing pellets length from 1 to 4 cm at pellets diameters of 6, 8 and 10 mm respectively. While solvent penetration rate was 4.5 cm/min for raw bran sample. However, the difference in penetration rate at all length of pellets was not significant.

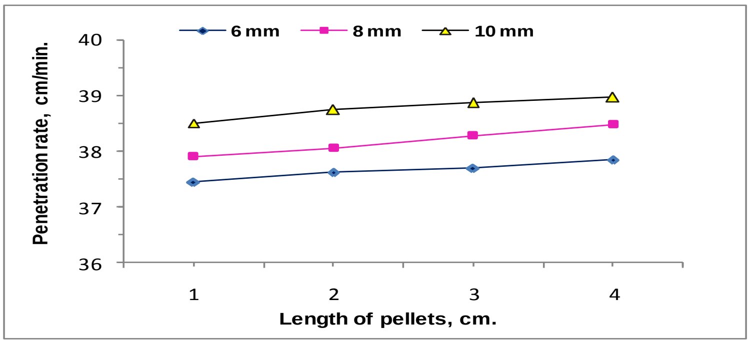

Fig. (5) : Effect of length and diameter of pellets on solvent penetrationrate, cm/min at screw speed of 30 rpm.

Effect of pellets length and diameter on oil retention ratio:

Fig. 6 shows the effect of pellets length and diameter on oil retention ratio for the pellets produced at screw speed of 30 rpm. It shows that, oil retention ratio decreased by increasing pellets length at all pellets diameters. The oil retention ratio decreased by 16.4, 14.1 and 10.8% with increasing pellets length from 1 to 4 cm at 6, 8 and 10 mm pellets diameter respectively. On the other hand, it was increased by 10.4, 10.9, 13.3 and 17.8% with increasing pellets diameter from 6 to 10 mm at 1, 2, 3 and 4 cm pellets length, respectively. While, retention ratio was 1.3 g miscella/g inert. for raw bran samples.

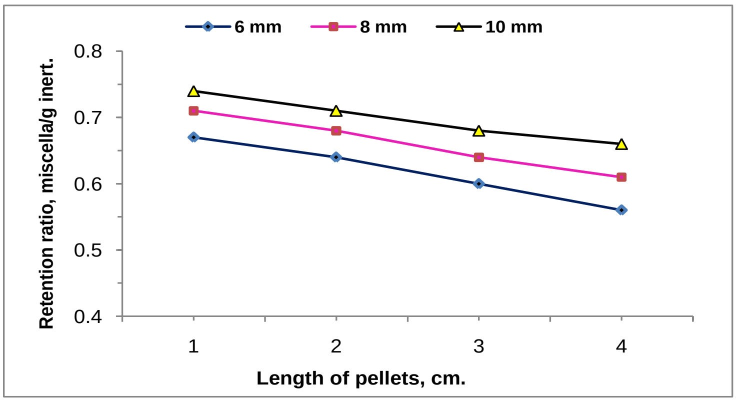

Fig. (6): Effect of length and diameter of pellets on oil retention ratio, miscella/g inert. at screw speed of 30 rpm.

Effect of pelletslength and diameter on residual oil,%:

The effect of pellets length and diameter on residual oil % for pellets during the experimental period is plotted in Fig.(7). As shown in the figure, residual oil % increased with increasing length and diameter of pellets. It was increased from 1.1, 1.3 and 1.7% to 2.1, 2.6 and 3.2% with increasing pellets length from 1 to 4 cm at 6, 8 and 10 mm pellets diameter, respectively. Also, it was increased from 1.1, 1.4, 1.7 and 2.1% to 1.7, 2.3, 2.8 and 3.2% with increasing pellets diameter from 6 to 10 mm at 1, 2, 3 and 4 cm pellets length, respectively.

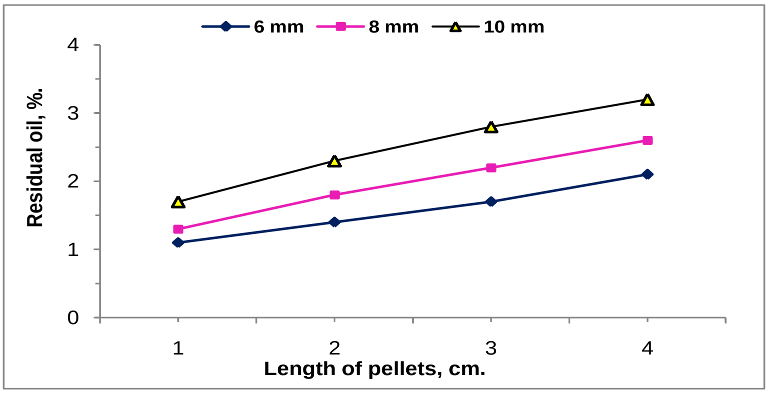

Fig. (7): Effect of length and diameter of pellets on residual oil, % at screw speed of 30 rpm.

Effect of pelletslength and diameter on oil extraction efficiency,%:

The effect of pellets length and diameter on extraction efficiency (%) at screw speed of 30 rpm was studied and examined during the experimental period. The obtained results are plotted in Fig.(8). As shown in the figure, extraction efficiency decreased with increasing pellets lengths at all pellets diameter. At pellets diameter 6 mm the recorded values of oil extraction efficiency were 95.5, 93.5, 92 and 90.2 % at pellets lengths 1, 2, 3 and 4 cm, respectively. While at 10 mm pellets diameter the recorded values of oil extraction efficiency were 92.1, 89.3, 86.8 and 84.6 % at the same pellets lengths, respectively. The same trend was obtained with increasing pellets diameter at all pellets length. It was decreased from 95.5, 93. 5, 92 and 90.2 % to 92.1, 89.3, 86.8 and 84.6 % with increasing pellets diameter from 6 to 10 mm at pellets lengths 1, 2, 3 and 4 cm, respectively.

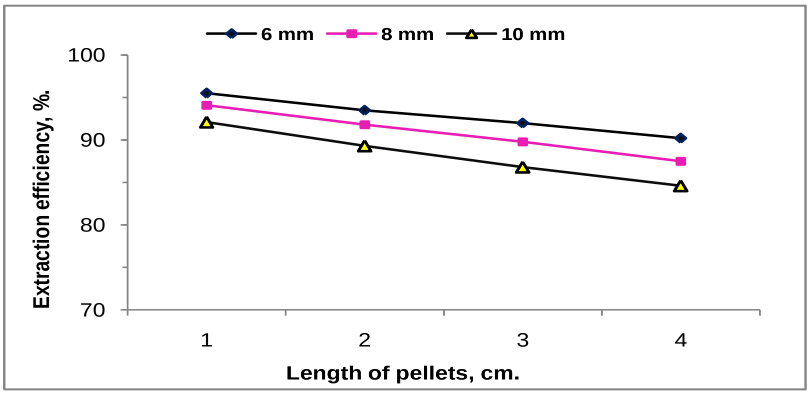

Fig. (8) : Effect of length and diameter of pellets on extraction efficiency at screw speed of 30 rpm.

CONCLUSION

Based on the obtained results from this research work, the following conclusions can be drown:

1- Bran pellets moisture content decreased at all screw speeds and die hole diameters.

2- Bulk density of bran pellets was higher in comparison with raw bran which was 0.29 g/ cm^3 where it was increased by about one and half times of raw bran bulk density at all levels of screw speed and die hole diameter.

3- Oil penetration rate increases by increasing pellets length and diameter. While, oil retention ratio decreased by increasing pellets length and diameter.

4- Residual oil % increased with increasing length and diameter of pellets. While, oil extraction efficiency decreased with increasing pellets length and diameter.

5- Pelleting process at 30 rpm screw speed, 6 mm diameter and pellets length of 1 cm is recommended to increase oil extraction efficiency.

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RRTC (2006) التوصيات الفنية لمحصول الأرز - برنامج الأرز - مركز البحوث و التدريب فى الأرز مركز البحوث الزراعية.

تأثير عملية التصبيع وخصائص مصبعات رجيع الأرز على كفاءة استخلاص الزيت

ياسر طلبة هنداوى، عبدالفتاح عبدالرؤف القويعى و أحمد عزت خاطر
معهد الدقي – الجيزة

يعتبر رجيع الأرز أهم منتج ثانوي لعملية ضرب الأرز وتنتج مصر منه حوالي ٦٣٨٠٠٠ طن سنويا (Matouk et al. (2009. ورجيع الأرز يكون فى صورة مسحوق ناعم كثافته منخفضة مما يقلل من كفاءته التخزينية ويجعل عمليات تداوله بصورة حرة غير اقتصادية، حيث يسبب غبار كثيف وانسداد خطوط الإنتاج أثناء التداول، وكذلك انخفاض كفاءة تشغيل معدات التداول، بالإضافة إلى صعوبة استخلاص الزيت منه بالمذيبات حيث تنخفض كفاءة الاستخلاص إلى ٥٠%. ولتعظيم الاستفادة من رجيع الأرز يفضل تحويله إلى مصبعات حيث يسهل تخزينه وتداوله، هذا فضلاً عن رفع كفاءة استخلاص الزيت منه باستخدام المذيبات. ولذلك تم تعديل آلة لعصر بذور الزيت محلية الصنع لإنتاج مصبعات رجيع الأرز، وكذلك دراسة تأثير خصائص تلك المصبعات على عوامل استخلاص الزيت المختلفة.

وقد أمكن تلخيص النتائج المتحصل عليها فيما يلى:

١-انخفض المحتوى الرطوبى للرجيع عند كل مستويات سرعة دوران بريمة الكبس وكذلك لكل أقطار فتحات تشكيل المصبعات.

٢-زادت كثافة الرجيع عند كل مستويات سرعة دوران البريمة وأقطار المصبعات، حيث تراوحت من ٠.٤١ إلى ٠.٥٨ جم/سم٣ مقارنة ب ٠.٢٩ جم/سم٣ للرجيع الحر.

٣-زاد معدل نفاذية المذيب بزيادة كل من قطر وطول المصبعات حيث كان أعلى معدل نفاذية ٣٨.٨٠ سم/دقيقة عند قطر ١٠ مم وطول ٤ سم مقابل ٤.٥ سم/دقيقة للرجيع الحر.

٤-انخفضت نسبة استبقاء المذيب بزيادة طول المصبعات فى حين زادت هذه النسبة بزيادة قطر المصبعات، وتراوحت نسبة استبقاء المذيب من ٠.٥٧ إلى ٠.٦٧ جم ميسلا/جم رجيع عند قطر ٦ مم، بينما تراوحت من ٠.٦٦ إلى ٠.٧٣ جم ميسلا/جم رجيع عند قطر ١٠ مم وذلك مقارنة ب ١.٣ جم ميسلا/جم للرجيع الحر.

٥-كانت هناك علاقة عكسية بين كفاءة استخلاص الزيت وكلا من قطر وطول المصبعات، وكانت أعلى كفاءة استخلاص تعادل ٩٥.٥٣ عند قطر ٦ مم وطول ١سم.

٦-يوصى بإجراء عملية التصبيع لرجيع الارز عند سرعة ٣٠ لفة /دقيقة للبريمة و قطر ٦ مم للداى وطول قطع للمصبعات ١سم.