EFFECTS OF OPERATING PARAMETERS OF A SCREW PRESS ON SOYA BEAN OIL YIELD

Anebi Joseph Garba
University of Agriculture
Makurdi, **NIGERIA**
anebigarba59@gmail.com

Victor Imolemhe Umogbai
University of Agriculture
Makurdi, **NIGERIA**
victorimolemhe@yahoo.com

Samuel Enyi Obetta
University of Agriculture
Makurdi, **NIGERIA**
obetta.samuel@gmail.com

John Okanagba Awulu
University of Agriculture
Makurdi, **NIGERIA**
jawulu@yahoo.com

ABSTRACT

The effect of operating parameters (screw speed and choke clearance) of a screw press on soya bean oil yield was investigated in this study, using factorial experimental design. Both the screw speed (within the range of 70 to 110 rpm) and choke clearance (within the range of 1 to 3 mm) studied, produced significant differences in soya bean oil yield. Analysis of results showed that the values of the screw press variables for high soya bean oil yield are screw speed of 110 rpm and choke clearance of 1 mm. The result of this study would be useful for rational design and development of soya bean oil screw press.

Keywords: Choke clearance, screw press, screw speed.

INTRODUCTION

The soya bean is well known as a source of oil which is known edible and industrial oil, and soya bean cake which is a useful component of livestock feeds. Separation of oil from oilseeds is an important processing operation. The process employed has a direct effect on the quality and quantity of protein and oil obtained from the oilseeds. Basically, two methods are used for this purpose. One is the solvent extraction method in which a solvent, when brought in contact with the preconditioned oilseed, dissolves the oil present in the seed and the separated mixture is later heated to evaporate the solvent and obtain the oil. The method is most popular in North America, is highly efficient (over 98 % oil recovery) and a single extractor can handle very large capacities (up to 4000 tons per day). The method, however, requires a large infrastructure with high initial cost and there is a fire and pollution hazard as it requires large quantities of highly flammable solvents.

The other method used involves mechanical oil expression. In this process, the preconditioned oilseed is passed through a screw press where a combination of high temperature and shear is used to crush the oilseed to release the oil. The method is relatively less efficient as it recovers only 70.80 % of the available oil, depending on the oilseed and pressure employed. Pretreatments and operating conditions determine the efficiency of the screw press but each pass can handle much smaller quantity of oilseeds (up to 1000 tons per day).

Oilseed pressing involves very low initial and operating costs compared to the solvent method of oil extraction and is relatively free of any polluting or fire hazardous substances. This method is most widely used for oil expression in the developing countries or for high oil content seeds in combination with a solvent system. There is a need to further develop this century old method of oil expression through improving the extraction and energy efficiency of the existing presses and by increasing their handling capacities.

Efficient extraction of oil from oilseeds using the screw press involves a careful establishment of optimal pressing conditions for different oilseeds because the best process parameters are somewhat different for each oil-bearing seed and nut (Deli *et al*., 2011). Mwithiga and Moriasi (2007) stated that the parameters that were used before and during pressing will affect oil pressing processes including particle size, heating temperature, heating time, moisture content, and applied pressure. Bargale (1997) oilseeds variables that affect mechanical oil extraction to include moisture content, roasting or heating temperature, particle size, age, variety, maturity, cleanliness and pretreatments and screw press variables include diameter of screw shaft, rotational speed, worm pitch, helix angle of worm, flight width and flight length.

Vadke and Sasulski (1988) reported the effect of shaft speed, choke opening and seed pre-treatment i.e. moisture conditioning, flaking and preheating of canola seed in a small screw press. With reduction of choke opening and shaft speed, maximum pressure increased and both press throughput and residual oil in the cake decreased. When either the whole seed or flakes were preheated in the range of 40-100 ^{o}C, the pressure and throughput increased and residual oil in the cake decreased. The press throughput and oil output were maximum at 5% seed moisture content while the residual oil showed a continuous rise with increasing seed moisture content.

The effect of screw press design parameters, especially compression clearance and speed has great effect on oil expelling efficiency (OEE) and energy consumption. The most important screw press variables are screw press speed and screw choke gap (Sayasoonthorn *et al*., 2012). A good understanding of the influence of these process variables is important for the design and efficient operation of a soya bean oil screw press. Previous studies on soya bean oil extraction using the screw press are very limited. Those studies investigated the effect of preheating seed moisture content, heating temperature, heating duration, screw press speed, and extraction pressure on soya bean oil yield (Akinoso *et al*., 2009). However, the effect of screw choke gap which mainly controls the extraction pressure has not been investigated.

The aim of this work was to study the effects of screw press factors on extraction of soya bean oil using a locally fabricated screw press. The specific objective of the work was: to investigate the effects of screw press speed and choke clearance on soya bean oil yield.

MATERIALS AND METHODS

Determination of Seed Moisture Content

A known weight of soya bean seeds was manually cleaned to remove foreign matter, dust, dirt, broken and immature seeds. The initial moisture content of the samples was determined before processing by oven drying at 105 °C for 72 h (Baryeh, 2002). Equation 1 was used to calculate the moisture content.

$$MC_{db} = \frac{w_1 - w_2}{w_2 - w_o} \times 100\% \qquad (1)$$

Where; MC_{db} = Moisture content - dry basis (%), w_o = weight of container (g), w_1 = Weight of fresh sample and container (g), w_2 = Weight of dry sample and container (g).

Determination of Seed Oil Content

The fat extraction was carried out by soxhlet extraction method (AOAC, 2005). The initial weight of the soya bean sample was taken and was dried in an oven at about 105 ^{o}C for about 8 to 10 hours until constant weight was reached and the sample was grind in an electric grinder. The ground sample was put into a labelled thimble. A dry boiling flask was correspondingly weighed and labelled. 300 cm^3 of petroleum ether (boiling point 40 – 60 °C) was measured into the boiling flask and the extraction thimble was plugged lightly with cotton wool. The soxhlet apparatus was assembled and allowed to reflux for about 6 hours. The thimble was removed with care and the petroleum ether on the top of the container of the set-up was collected and drained into a container for reuse. The flask was removed and dried at (105-110 °C) for one hour when it is almost free of petroleum ether. The flask and its content were finally transferred into a desiccator, allowed to cool and then weighed. The fat content was calculated from equation 2 (AOAC, 2005).

$$\text{Fat content } (\%) = \frac{W_2 - W_1}{W} \times 100 \qquad (2)$$

Where; W_1 = Weight of empty flask (g), W_2 = Weight of flask and fat (g), W = Weight of soya bean sample (g).

Determination of Experimental Parameters

A quartz stopwatch was used for measurement of time during the performance evaluation of the machine. A digital tachometer (DT 2235B) was used to determine the peripheral speed of the screw shaft and electronic balance of sensitivity of 0.01 kilograms was used in weight measurements. The commonest variety of soya beans seeds (*Glycine max*) in Nigerian market was used for the evaluation.

A. Determination of rotational speed of screw shaft

The shaft rotational speed of 70, 90 and 110 rpm (Ezeoha and Akubuo, 2017) were used for the experiments and were attained with help of set of driver pulley of 30 mm and driven pulleys of different sizes of 400, 487 and 626 mm (Plate 3). The shaft rotational speeds of the oil extractor during its evaluation were determined using a digital tachometer (DT 2235B) which has a sensitivity of 1.0 rpm.

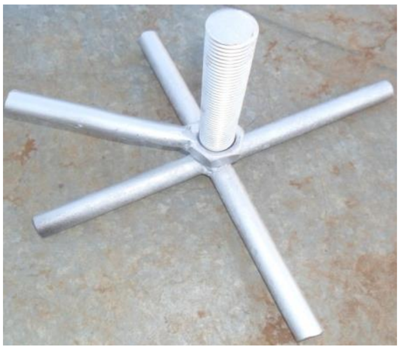

Plate 2: Photograph of Choke Regulator Lever used to vary the Choke Clearance

A = 400 mm B = 487 mm C= 626 mm

Plate 3: Photograph of Three Pulleys Used to Vary the Machine Speed

B. Choke clearance

The extractor was evaluated at three levels of choke clearance (space between barrel wall and conical choke) of 1.0, 2.0 and 3.0 mm (Akerele and Ejiko, 2015). The adjustment of the choke was done with the aid of the choke regulator. Choke clearance was changeable from zero to 10 mm by the lever handle (Plate 3).

Experimental Procedure

A. Selection, preparation and pre-treatment of test materials

For this research, the commonest variety of soya bean seeds (*Glycine max*) was obtained from the market in Makurdi for the performance evaluation of the constructed machine. The sample was sorted, dehulled and heated to 100-105 °C for approximately 20 minutes. This process coagulates the proteins and disrupts the cell membranes thus allowing leakage out of oil.

B. Machine evaluation procedure

The constructed soya bean oil extractor was tested to evaluate its performance in the extraction process. Materials required include weighing balance, measuring cylinder, water, prepared soya bean seeds, cake receiving container and oil receiving container. The expeller powered by an electric motor (5 hp) was set into operation and a known weight (6000 g) of each prepared sample was fed into the machine through the feeding hopper. The continuous helical screw shaft conveyed, crushed, squeezed and pressed the material in order to extract the oil. The oil phase was separated from the solid phase (press cake) by the screen. The oil extracted and the press cake were collected and weighed separately. Clarification was done by decantation and heating to separate the oil from its entrapped impurities. The decanted oil was heated at 80 °C to remove moisture and was allowed to cool and then filtered using sieves to obtain refined soya bean oil. From the values obtained, the yield of oil extraction was calculated using equation 3 (Adesoji *et al*., 2012).

$$O_Y = \frac{100\, W_{OE}}{W_{OE}+W_{RC}} \qquad (4)$$

Where; O_Y = Oil yield (%), W_{OE} = Weight of oil extracted (kg), W_{RC} = Weight of residual cake (kg).

Plate 1: Photograph of the Soya Bean Oil Extractor

Effect of Screw Speed and Choke Clearance on Soya Bean Oil Yield

For the experiments to determine the effect of screw speed and choke clearance on soya bean oil yield, soya bean seeds at average moisture content of 7.4 % (d.b.) were used. A 3^2 factorial experimental design was employed with 3 replications each. The dependent variable was actual soya bean oil yield measured in percentage (%). The independent variables and their levels were screw choke clearance (1, 2, and 3 mm) and screw press speed (70, 90 and 110 rpm). A total of 27 samples were used and each sample weighed 6000 g.

Statistical Analysis

All data collected were subjected to analysis of variance (ANOVA) to test for significant effects at 95 % confidence limit using the procedure recommended by Steel and Torrie (1980). When significant difference is observed, treatment means were separated using the F-LSD.

Excel and Statistical Package for Social Science (SPSS) version 23 for windows was used to analyze the data generated from the study.

RESULTS AND DISCUSSION

The study of the effects of screw shaft speed and choke clearance on oil yield (Table 1) shows that oil yield increased with increasing screw shaft speeds but oil yield increases with decreasing choke clearances. The best oil yield of 14.1 % was obtained for the conditions of 110 rpm screw shaft speed and 1 mm choke clearance. The lowest oil yield of 11.1 % was obtained for the conditions of 70 rpm screw shaft speed and 3 mm choke clearance. However, the screw speed of 110 rpm and choke clearance of 1 mm were considered to be the optimum pressing condition for soya bean oil extraction. This is in agreement with the statement of Bamgboye and Adejumo (2011) who reported that a reduction in speed of rotation of the shaft, for example, could reduce the oil yield, increasing the oil content in the cake and solids in the oil. Akinoso *et al*. (2009) while evaluating the effects of compressive stress, feeding rate and speed of shaft screw press on palm kernel oil yield observed same trend of increase in oil yield with increased speed. The observation may be due to the fact as the screw shaft speed increased from 70 to 110 rpm, there was an increase in barrel temperature which invariably led to the heating and rupturing of the oil cell and thus a decrease in oil viscosity and moisture content and hence an increase in oil recovery.

From the results obtained, it was discovered that oil yield from the soya bean seed was dependent on the clearance between the conical choke and the extracting chamber. The oil yield increased with decreasing choke clearance. This statement was supported by Ezeoha and Akubuo (2017) while investigating the effects of speed of shaft screw press and choke gap on palm kernel oil yield observed same trend of increase in oil yield with decreased choke gap. The reason for this is the fact that when there is a large clearance there is not enough pressure to mill the cake to remove the oil. Hence there is loss of oil as the cake comes out containing some quantity of oil. Smaller size of choke might add pressure to the seed which thus promote heat to be produced by the result of the collision between the shaft screws and the seeds and also between the seeds themselves. From the test results, it can also be deduced that at smaller choke clearance, there will be much residence time for the seed material to undergo enough cell rupturing which eventually led to an increase in oil recovery.

The effects of different shaft speeds (21, 54, 65, and 98 rpm), nozzle sizes (6, 10, and 12 mm), and diameters of the shaft (8 and 11 mm) on *Nigella sativa L* seeds were examined by Deli *et al*. (2011) using a cylinder press. In this type of press the press cake is extruded through a nozzle attached to the end of the cylinder. Nozzle diameter is one of the factors affecting the pressure level in the expeller. Pressure increases with decreasing nozzle size. The highest oil yield was obtained under the following conditions: 21 rpm shaft speed, shaft diameter of 8 mm, and nozzle size of 6 mm. Because of the wear of the flight in operation, flight clearance increases with the use, therefore the effect of it is of interest. The pressure decreases with increasing radial flight clearance, the cause of which is the leakage of the material across the flight. In normal operations a lower discharge pressure represents a lower pressure drop across the die and directly leads to a reduction in the production rate (Deli *et al*., 2011). To compensate for this loss the rate of the screw rotation has to be increased.

The Analysis of variance (ANOVA) at $p \leq 0.05$ of the effect of screw shaft speed and choke clearance on oil extraction yield (%) is presented in Table 2. There was a significant difference in the choke clearances and screw shaft speeds but no significant difference in their interactions on the oil yield from the ANOVA. The means separation at 5 % level of significance shows that the oil yield was significantly different at all the choke clearances for all the screw shaft speeds investigated (Table 1). This implies that these process parameters must be controlled to effectively extract oil from soya bean seeds.

Table 1: Effects of Screw Speed and Choke Clearance on the Mean Oil Yield (%)

Screw speed, N (rpm)	Choke clearance, C (mm)		
	1.0	2.0	3.0
70	12.6	11.8	11.1
90	13.4	12.7	11.3
110	14.1	13.3	11.9

$F\text{-}LSD_{0.05} = 0.529$

Table 2: Analysis of Variance (ANOVA) of the Effects of Screw Speed and Choke Clearance on Oil Yield (%)

Sources	DF	SS	MS	F-cal	F-tab
Screw speed, N (rpm)	2	7.22	3.610	37.93*	3.55
Choke clearance, C (mm)	2	17.63	8.816	92.62*	3.55
Interaction (N × C)	4	0.57	0.143	1.50^{ns}	2.93
Error	18	1.71	0.095		
Total	26	27.1363			

* - Significant at $P \leq 0.05$ ^{ns} - Not significant at $P \leq 0.05$

CONCLUSIONS

The effects of screw speed and choke clearance on soya bean oil yield was studied in this work. The following conclusions could be drawn from the results of the study:

i. The screw choke clearance and screw press speed had effect on soya bean oil yield; soya bean oil yield increased as the screw press speed increased from 70 rpm to 110 rpm and as screw choke clearance decreased from 3 mm to 1 mm.
ii. The screw choke clearance should be equal to or smaller than 1 mm to achieve high soya bean oil extraction efficiency.
iii. The optimal screw press speed was found to be 110 rpm for the screw press.
iv. The results of this study are considered useful for design and development of screw press for soya bean oil extraction.

REFERENCES

Adesoji, M.O., Kamaldeen, A.Y., Adebayo, L.W. and Kunle, O.A. (2012). Design, Development and Testing of a Screw Press Expeller for Palm Kernel and Soybean Oil Extraction. Post Harvest, Food and Process Engineering. International Conference of Agricultural Engineering-CIGR-Ag. Eng. 2012: Agriculture and Engineering for a Healthier Life, Valencia, Spain, 8-12 July 2012. 1748 pp.

Akerele, O.V. and Ejiko, S.O. (2015). Design and Construction of Groundnut Oil Expeller. *International Journal of Engineering and Computer Science*, 4(6): 12529-12538.

Akinoso, R., Raji, A.O. and Igbeka, J.C. (2009). Effects of Compressive Stress, Feeding Rate and Speed of Rotation on Palm Kernel Oil Yield. *Journal of Food Engineering*, 93: 427-430.

AOAC (2005). Official Methods of Analysis of the Association of Analytical Chemists International, 18th edition, Gathersburg, MD U.S.A Official methods. 2200 pp.

Bamgboye, A.I. and Adejumo, O.I. (2011). Effects of Processing Parameters of Roselle Seed on its Oil Yield. *International Journal of Agricultural and Biological Engineering*, 4(1): 82-86.

Bargale, P.C. (1997). Mechanical Oil Expression from Selected Oilseeds under Uniaxial Compression. PhD Thesis, Department of Agricultural and Bioresource Engineering, University of Saskatchewan, Canada. 337 pp.

Baryeh, A.E. (2002). Physical properties of millet. *Journal of Food Engineering*, Elsevier Science Limited, 5: 139-146.

Deli, S., Farah Masturah, M., Tajul Aris, Y. and Wan Nadiah, W.A. (2011). The Effects of Physical Parameters of the Screw Press Oil Expeller on Oil Yield from *Nigella sativa* L. seeds. *International Food Research Journal*, 18(4): 1367-1373.

Ezeoha, S.L. and Akubuo, C.O. (2017). Investigating the Effect of Choke Gap and Speed of a Screw Press on Palm Kernel Oil Yield. American Society of Agricultural and Biological Engineers (ASABE), 2017 Annual International Meeting Presentation, Spokane, Washington, July 16-19, 2017, pp 1-7.

Mwithiga, G. and Moriasi, L. (2007). A study of Yield Characteristics during Mechanical Oil Extraction of Preheated and Ground Soybeans. *Journal of Applied Sciences Research*, 3(10): 1146-1151.

Sayasoonthorn, S., Kaewrueng, S. and Patharasathapornkul, P. (2012). Rice Bran Oil Extraction by Screw Press Method: Optimum Operating Settings, Oil Extraction Level and Press Cake Appearance: *Rice Science*, 19(1): 75-78.

Steel, R.G.D. and Torrie, J.H. (1980). Principles and Procedures of Statistics. A Biometrical Approach. 2nd Edition. New York: McGraw-Hill Book Company Limited, USA. 633 pp.

Vadke, V.S. and Sasulski, F.W. (1988). Mechanics of Oil Expression from Canola. *Journal of American Oil Chemists' Society*, 65: 1169-1176.