American Journal of Science and Technology
2014; 1(5): 238-242
Published online September 30, 2014 (http://www.aascit.org/journal/ajst)

American Association for Science and Technology

Performance evaluation of continuous screw press for extraction soybean oil

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Citation
Davies Rotimi Moses. Performance Evaluation of Continuous Screw Press for Extraction Soybean Oil. *American Journal of Science and Technology.* Vol. 1, No. 5, 2014, pp. 238-242.

Keywords
Screw Press Expeller,
Materials Variables,
Extraction,
Kneading Temperature,
Flow Rate

Received: August 30, 2014
Revised: September 18, 2014
Accepted: September 19, 2014

Abstract
The recent upsurge of interest in the demand for oils from soybean has prompted the development of more efficient mechanical screw press. The performance evaluation test was conducted to investigate the expelling efficiency of the machine, the effect of kneading temperature on the oil yield and the extraction losses of the machine. The literature put soybean oil content as between 18-20% of the whole soybean. The moisture content of the soybean used for the experiment was 10.7% (w.b). The mean oil yield, expelling efficiency and extraction losses ranged between 6.61 and 14.22%, 32.26±0.39% (50 ^{o}C) and 68.13±2.27% (90 ^{o}C), and 5.39% and 9.90% respectively. The optimum kneading temperature that corresponded to the highest expelling efficiency was (69.13±2.27%) at 90 ^{o}C. The differences among the mass flow rate values of the paste at the different temperature levels were statistically different ($P<0.05$). The machine competed favourably with other expelling machines. The operation of the machine is simple, minimize the drudgery and labour intensities that are involved in the traditional manual operation.

1. Introduction

Soybean otherwise known as *Glycine max merilli* is regarded as a cheap source of protein and edible oil and industrial purposes, and the protein-rich (>50%) meal for production of animal feed. Presently, soybean is viewed as one of the best answers to the shortage of protein and calories deficient in the diet of many millions of people in various parts of the world. There has been increasing interest in utilization of soy meal as a protein source for human foods. Lacks of appropriate and efficient technology on extraction of oil from soybean have been identified as a major bottleneck to its utilization. Soybean is considered as one of most important cereal grains in Nigeria.It contains about 40% protein and 18-20% cholesterol-free oil [1, 2].

Roselle (*Hibiscus sabdariffa L.*) seeds, palm kernel *(Elaeis guinensis J*), soybean (*Glycine merilli*), Melon (*C. lanatus*), peanut (*Arachis hypogaea L.*), cotton (*Gossypium L.*), rapeseeds (*Brassica napus* L.), sunflower (*Helianthus annus* L.) and jatropha (*Jatropha curcas* L.) have considerable high oil content [2, 3, 4, 5, 6, 7, 8]. They are considered to be important oilseed crops due to large quantity of oil they possessed. Which can be used for various purposes such as biodiesel production [4, 7, 8]. The oils extracted from these oilseeds crops can be used for different purposes such as vegetable oil for cooking, manufacturing of margarine, paints, toilet soap and cosmetics. The pharmaceutical and medical industries (pomade, drugs, medical ointment). Recently, they have found their uses in energy and automotive industries as biodiesel and engineering industry as cooling fluid in machining process and lubricants for machine components [9].The deoiled meal is a source of protein in the livestock feed. In recent years, however, more interest has been directed toward using soy meal as a protein source for human consumption [10].

There are two main types of processes for extracting oil from oilseeds crops: physical and chemical. The physical process, involves the use of manual squeezing of ground sample by hand or on a hard smooth wooden platform and mechanical power to remove oil from the seed, such as batch hydraulic pressing, continuous mechanical screw presses and extrusion cooker [5]. The manual process is time consuming, drudgery-prone, involves heat hazards, and grossly inefficient. Apart from this, the oil extracted by this method is of poor quality and is, in most cases, not used for human consumption. The mechanical oil extraction technique for separation of oil from soybean is the most popular method but less efficient in oil extractability (< 70% oil extraction). Among the mechanical processes for the extraction of oils, the continuous mechanical pressing emerges as the best technology to serve small farmers [5]. This type of equipment associates with both small scale and low cost when compared to the other methods. Another important advantage is the possibility of using cake resulting from the pressing as fertilizer or animal feed, since it is free of toxic solvents. It can be easily adaptable to wide variety of oilseed crops. The major limitation is relatively high temperature and pressure to operate. However, it is less injurious and hazardous compared to solvent extraction due to its chemical nature.

The chemical extraction method is technically more effective and efficient for oil extraction from soybean. It involves use of chemical or solvent and this is otherwise known as solvent extraction. It had oil extraction efficiency up to 98% [11]. Solvent extraction can be combined in commercial operation, that is continuous mechanical pressing with continuous solvent extraction, and batch hydraulic pressing followed by solvent extraction [5, 10, 11, 12] for improve oil extraction efficiency. New technologies are emerging, related to the production of vegetable oils, such as supercritical-fluid extraction [13].

The operating principle of continuous mechanical pressing equipment consists a helical screw which moves the material, compressing it, and at the same time, eliminating the oil and producing the cake. Effects of processing parameters on the oil yield of finely and coarsely ground oilseeds using continuous mechanical pressing were studied; the optimum parameters, such as compressive stress, feeding rate and speed of shaft screw press temperature pressure applied during pressing, heating time, applied pressure, duration of pressing, heating temperature of the grains, pressing time and heating time particle size of the materials and moisture content of grain, or adjustments on the press, in order to reach optimum yields of oil [5, 11, 14, 15].

Akinoso et al. [14] and Anna et al. [11] described the working principle of the continuous mechanical pressing, forced the oilseed mass through the barrel by the action of the revolving worms. The volume of the mass is being reduced as the transition takes place through the barrel, causing compression of the cake and the resulting output of oil by the perforation of the lining bars of the barrel while the deoiled cake is discharged through the annular orifice. Screw presses can be powered with electric motors, diesel or even be operated manually [16].

Some researchers have developed different types of mechanical oil expression machines. Olaniyan, [17], developed a manually-operated for groundnut oil extraction, Alonge et al. [18] 2004 developed a small scale screw press for groundnut oil extraction. Olaniyan and Oje [19] manufactured mechanical expression rig oil for shea butter. Olaniyan et al. [20], developed screw press expeller for palm kernel (Elaeis guinensis J) and soybean (Glycine Merilli) oil extraction. Khan and Hanna [21] and Bamgboye and Adejumo [5] developed a screw press for sunflower oil expeller. Mpagalile et al. [22] reported application of photovoltaic cells to power screw presses.

2. Materials and Methods

The moisture content of the crushed soybean was determined by the oven-drying method prior to oil extraction processes [23]. The initial weight of the sample was determined, and placed in an oven set at 103ºC for 24 hours. The samples was removed and cooled in a dessicator, reweighed (W_2). Moisture content of the sample was calculated from this equation:

$$\mathrm{Mc.\,(w.b)} = \frac{\text{Loss of weight x 100}}{\text{Weight of sample}}$$

Fig. 1. *Mechanical screw press*

This mechanical screw press consists of two major units, steaming and extraction units Fig. 1. The heating chamber comprises of hopper 250kg capacity of crushed soybean, mechanical stirrer, in-built thermometer and underneath is a compartments of heating using diesel as a source of fuel. The other unit called expelling unit consists screw press, two outlets points (one for oil and the other for cake).The screw press was powered by electric motor of 5HP. Soybean was obtained from International Institute of Tropical Agriculture (I.I.T.A), Ibadan, Nigeria. The seeds were cleaned manually to ensure that the seeds were free of dirt and other foreign materials. Cleaned seeds were weighed and crushed to particle sizes distribution ranging from <0.25 to 4.75 mm using hammer mill. The particle size distribution was achieved by using particle size analysis equipment consisting of sieve shaker and Tyler sieves of various diameter or particles size openings (Table 1).

Table 1. *Feedstock particle size distribution for production of briquettes*

Sieve size (mm)	Percentage of material retained on the sieve (%)
4.75	1
3.0	3
2.0	3
1.0	17
0.5	22
0.25	28
<0.25	25

The known weight of crushed soybean was fed into the machine through the feeding hopper and heated to desire temperature. The worm shaft conveyed, compressed and pressed the seeds in order to expel the oil. The oil expelled and the soybean cake were collected and weighed separately. From the values obtained, oil yield, extraction efficiency and extraction loss were calculated according to Olaniyan and Oje [19] and Olaniyan and Oje [24] as:

$$\text{Extraction Efficiency}(E_E) = \frac{W_{OE} \times 100}{XW_T}$$

$$\text{Percent oil extracted}(P_{OE}) = \frac{W_{OE} \times 100}{W_{OE} + W_{RC}}$$

$$\text{Extraction loss} = \frac{100\{W_{FS} - (W_{OE} + W_{RC})\}}{W_{FS}}$$

$E_P = XW_F$

$D_F = E_P - E_A$

W_{OE} = Weight of oil extracted after each kneading operation, (kg)

W_{RC}= Weight of soybean residual cake after kneaded operation, (kg)

W_{FS}= Weight of soybean used for the each operation before kneaded operation, (kg)

X= Oil content of soybean seed used for the experiment in decimal.

E_P= Expected oil yield

E_A= Actual oil yield

D_O= Deficit oil yield

3. Results and Discussion

The literature put soybean oil content as between 18- 20% of the whole soybean. The initial moisture content of the soybean was 10.7% (w.b). The summary of the result of performance evaluation of continuous mechanical screw press at different kneading temperature (50, 60, 70, 80, 90, 100, 110 °C) revealed in Table 2. The interaction between kneading temperature and expelling efficiency of the machine for oil extraction from soybean was studied. The values ranged between 32.26 ±0.39% (50%) and 69.13±2.27% (90 °C).The maximum oil extraction efficiency of the machine corresponded to optimum kneading temperature of 90 °C. ANOVA showed that there was significant difference among the values of expelling efficiency at the different kneading temperature levels. The result revealed that the higher the kneading temperature of crushed soybean the higher the expelling efficiency of the machine, but beyond 90°C the oil expelling efficiency reduced. It was observed at 100 °C, the extracted was very thick and brownish with a lot of sediment. Moreso, the cake was not binded together unlike cake from lower temperature. The maximum percentage of oil extracted by the machine was 12.44% while the minimum was 5.56%. The mechanical oil expeller is less efficient in oil extraction and the cake is left with residue of oil 5-7%. The obtained values conformed to the literature [25]. Gunstone [26] reported that cooking and drying are the factors which most affect the performance of the screw press. Heating before pressing increases oil yield due to the breakdown of oil cells, coagulation of protein, adjustment of moisture content to the optimal value for pressing, and decreased oil viscosity, which allows the oil to flow more quickly.

The expected oil yield ranged from 6.30% for 50 °C to 7.56% for 100 °C.Percentage actual oil yield varied between 2.03% for 50 °C to 4.93% for 100 °C, expelling efficiency of the machine ranged from 32.26 to 69.13%. Bamgboye and Adejumo [5] reported the expelling efficiency of 73.08% for sunflower oil expeller. Chalkrauenty [27] reported screw press having expelling efficiencyranged between 60 – 70%. According to Pathak et al. [28] improved the efficiency of mechanical expeller machine from 73% to 80% for rapeseed and groundnut and from 60% to 65% for cotton seedsfor oil recovery. To improve oil yield production from oilseeds and extraction efficiency of the machine there must be modification in the design of the worm shaft of the mechanical screw press and optimization of material process variables is highly necessary [5, 19, 24]. The performance evaluation revealed that the mechanical screw press was able to extract some of the oil from the seeds but there is still plenty of scope for improvement. The effect of kneading temperature was equally determined on extraction loss. The extraction loss ranged between 5.39% and 9.90%.

Table 2. *Summary of mean performance of the Soybean oil expeller*

Temperature (ºC)	Quantity (Kg)	Expected oil yield (Kg)	Actual oil yield (Kg)	Cake yield (Kg)	Deficit oil yield (Kg)	Oil yield (%)	Extraction losses (%)	Efficiency of the machine (%)
50	35	6.30	2.03	30.00	4.27	6.61	8.49	32.26a
60	31	5.58	2.67	22.35	2.91	9.51	9.90	47.89b
70	47	8.46	4.18	35.38	3.28	10.0	7.15	49.37b
80	41	7.20	4.31	30.49	2.89	12.08	5.63	59.89c
90	38	3.27	4.73	27.95	1.46	14.22	5.39	69.13d
100	42	7.56	4.93	32.28	2.63	12.52	5.86	65.26e
110	33	5.94	3.05	24.98	1.89	10.13	6.90	51.32b

Fig. 2 revealed the effect of kneading temperature and mass flow rate of continuous screw press for oil extraction from soybean. The effect of kneading temperature was determined on mass flow rate of the material through the continuous screw press oil expeller for soybean oil extraction. The obtained values varied from0.89 ±0.05 kg/min to 1.32± 0.08 kg/min (Fig. 2). The differences among the mass flow rate values of the paste at the different temperature levels were statistically different (P<0.05).

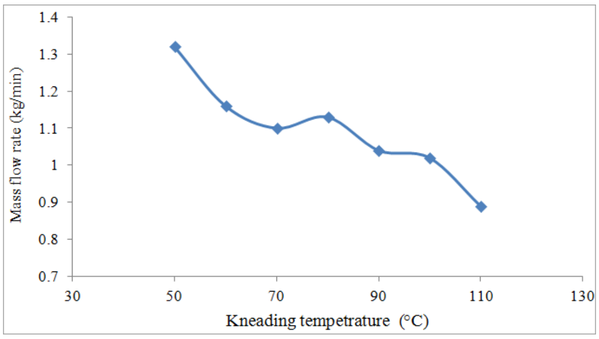

Fig 2. *Interaction between mass flow rate and kneading temperature*

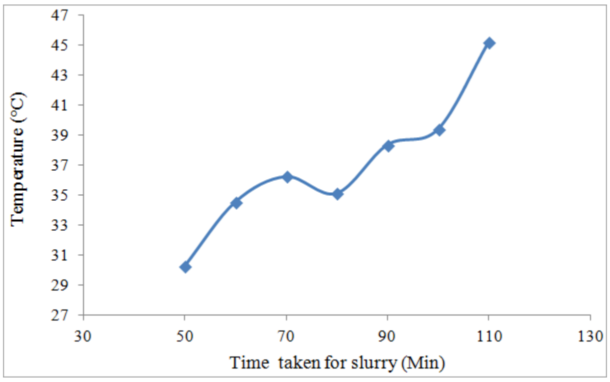

Fig. 3. *Effect of kneading temperature on the time taken for expulsion of oil*

The relationship between kneading temperature and the kneading time for processing of soybean paste varied from 30.24±2.01 min for 50°C to 39.37±2.12 min 110 °C (Fig. 3). The kneading time increased with increased kneading temperature. The result of analysis of variance showed significant difference (P<0.05) for the mean values of kneading time of paste at the different kneading temperature. The corresponding report of average kneading time of 7.72, 11.25 and 10.17 min for processing 4.4, 66, and 8.8 kg of groundnut paste at 100rpm were obtained as against 20, 25 and 30 min (kneaded by three operator exchanging hands) recorded for manual rotary tool [29]. For all the speed levels, the time variation showed a savings in kneading time of between 45-76% for the paste quantities ranging from 4.4 to 8.8 kg [29].

4. Conclusion

Based on the various results obtained from this study, the following conclusions have been made: The interaction between kneading temperature and expelling efficiency of the machine for oil extraction from soybean was studied. The values ranged between 32.26±0.39% (50%) and 69.13±2.27% (90 ºC).The maximum oil extraction efficiency of the machine corresponded to optimum kneading temperature of 90 °C. ANOVA showed that there was significant difference among the values of expelling efficiency at the different kneading temperature levels. The result revealed that the higher the kneading temperature of crushed soybean the higher the expelling efficiency of the machine, but beyond 90^0C the oil expelling efficiency reduced The effect of kneading temperature was determined on mass flow rate of the material through the continuous screw press oil expeller for soybean oil extraction The differences among the mass flow rate values of the paste at the different temperature levels were statistically different (P<0.05). The kneading time increased with increased kneading temperature. The result of analysis of variance showed significant difference (P<0.05) for the mean values of kneading time of paste at the different kneading temperature. The operation of the machine is simple, minimize the drudgery and labour intensities that are involved in the traditional manual operation.

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