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ORIGINAL RESEARCH ARTICLE

DEVELOPMENT OF MULTI SEEDS OIL EXPELLER

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ABSTRACT

Multi seeds oil expeller was designed fabricated and evaluated using screw press principle. It was designed and fabricated based on the data obtained on the properties of the oilseeds. The performance of the machine was carried out using a 3 x 3 x 3 factorial experimental design with the following type of seeds (palm kernel, soya bean and groundnut seed), worm shaft speed of 47.6, 87and 92 rpm, and moisture content of 5, 10, and 15 % w.b as factors. Data collected include oil yield, volumetric flow rate of oil, throughput capacity and efficiency of the machine. The results showed that increase in moisture content as stated has direct effect on oil yield and efficiency of the expeller, but has an inverse effect on volumetric flow rate for the three oil seeds. Increase in worm shaft speed as stated increased oil recovery for palm kernel from 19.1 to 23.0%, soya beans from 0.0 to 16.0% and groundnut from 7.3 to 31.7%. Increase in worm shaft speed as stated increased the oil yield, throughput capacity as well as the efficiency of the machine for all the oil seeds. The efficiency increased from 39.4 to 52.1%; 0.0 to 82.1% and 53.1 to 72.0% for palm kernel; soya bean and groundnut, respectively. These results were found to be significant ($p<0.05$) when tested using one way analysis of variance (ANOVA) and Duncan's multiple range test. The study concluded that, the developed multi-seed expeller performed well within the conditions of operation and could have a potential for improving the production of vegetable oil if adopted by small and medium scale processors.

1.0 Introduction

Edible vegetable oil is oil produced from any of the edible oil-bearing seeds that exist in nature. Many of these seeds are produced in large quantities in Nigeria and have a lot of uses. Amongst them are groundnut seed, oil palm fruit and kernel, soybean, cotton seed, sesame seed and melon seeds (Bello, 2013). Hydraulic system (hydraulic press) is one of the most effective methods of oilseed extraction because higher pressure may be attained. However, care should be taken to ensure that poisonous hydraulic fluid does not come in contact with the oil or raw material. Apart from this, there is frequent breakdown of the hydraulic system and hence maintenance cost could be high. Additionally, oil extraction can also be achieved through solvent extraction. This involves the use of organic chemicals to dissolve out the oil from the seed. The seed must have been ground and placed in a semi permeable membrane before placing in the solvent extractor. Solvent extraction is about the most efficient method of oil recovery from oil bearing materials. Extraction of oil from oil bearing material with low oil content (such as soya bean, rice bran and mango kernel) is best carried out using solvent extraction. (Shukla et al., 1992). However, the resulting cake from the extraction process is usually contaminated and may not be suitable for animal feeds. Oil expression is a mechanical method for removing oil from oil-bearing materials. The raw materials are pressed under high pressure. When used for the extraction of food oils, typical raw materials are nuts, seeds and algae, which are supplied to the press in a continuous feed. As the raw material is pressed, friction causes it to heat up; in the case of harder nuts (which require higher pressures) the material can exceed temperatures of 120 °F (49 °C). An expeller press is a screw-type machine that presses oil seeds pass through a caged barrel-like cavity. Raw materials enter one side of the press and waste products exit the other side. The machine uses friction and continuous pressure from the screw drives to move and compress the seed material. The oil extracted from the seeds passes through small openings that do not allow seed fiber solids to pass through. Consequently, the fiber from the pressed seeds are formed into a hardened cake, which is removed from the machine (Agbogun, 2011). Pressure involved in expeller pressing creates heat in the range of 140–210 °F (60–99 °C). Some companies claim that they use a cooling apparatus to reduce this temperature to protect certain properties of the oils being extracted (Olatunde et al., 2014).

There is an increasing demand for edible oil in Nigeria and the world as a whole. Statistics show that the demand for vegetable oil keeps on increasing on yearly basis (Kojima et al., 2016). The large scale plants (which though have high extraction efficiency) utilize sophisticated equipment which are expensive and are always imported. Most of the existing oil expeller machines for small and medium scale processors were designed for a particular seed. The development of a multi-seed oilseeds expeller will provide an opportunity for farmers and processors to have plant that can handle many oilseeds. This will reduce the cost of production and enhance the productivity of the processors. In this study, a multi-seeds oil expeller was designed and fabricated to expel all the oil bearing seeds for purposes of small and the medium scale processors.

2. Materials and Methods

2.1 Design of the Components of the Oil Expeller

This machine was designed to expel oil from hard and soft seeds. The hard seeds selected are palm kernel and soya seed while groundnut was chosen as soft seed. The expeller consists of hopper, pressing chamber, differential unit, the discharge outlets (oil and cake outlets) power unit and frame as shown in Figure 1. The material flows from hopper to the pressing chamber which consists of a worm shaft beveled at the end. The expelled oil flows out of the oil outlet after the frictional effect which causes heat in pressing chamber while the cake comes out of the cake outlet.

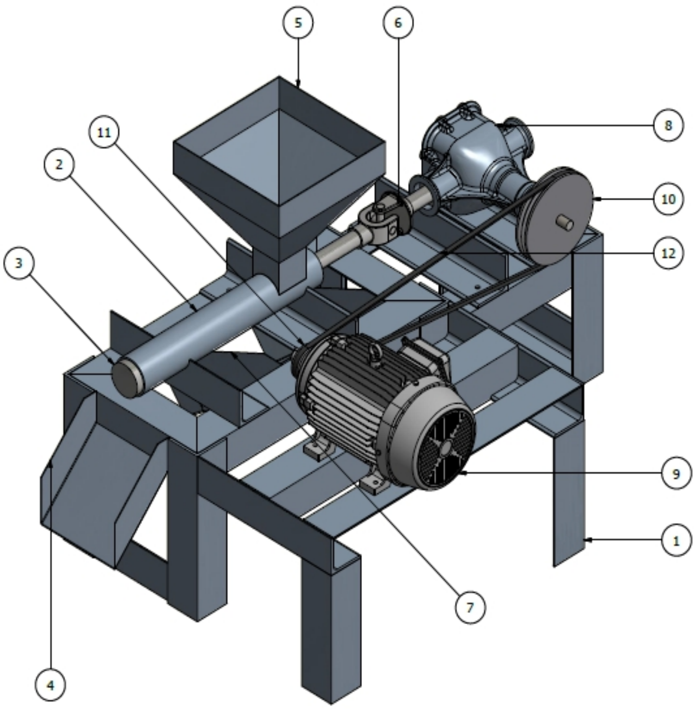
i. The hopper

The design of a hopper depends principally on the mechanical behavior of the material. The shape of the hopper is shown in Figure 2 was chosen to ensure free flow of both kernels and nuts under gravity. The feeding rate was controlled by feeding control plate, this was done by taking into consideration the angle of repose of the kernels. According to Kibar and Ozturk (2008); Davies (2009) and Dagwa and Ibhadode (2008), the dynamic angle of repose from experiment was determined to be 29.0° and 28.4° for groundnut and soya bean, respectively. Let us assume that 1.5kg of oilseed was used per batch.
Average angle of friction of the seeds = 29.0°

$$V_s = \frac{M}{\rho} = \frac{1500}{853.6} = 1.76 \text{ m}^3 \qquad (1)$$

Where: V_s = Volume of seed
M = Mass of oilseed
ρ = Density of oilseed

The height of hopper was calculated thus:



PARTS LIST			
S/N	QTY	PARTS	MATERIAL
1	1	FRAME	
2	1	SHAFT HOUSING	Mild Steel
3	1	WORM SHAFT	Mild Steel
4	1	CAKE OUTLET	Mild Steel
5	1	HOPPER	Mild Steel
6	1	FRONT YOKE	Mild Steel
7	1	OIL OUTLET	Mild Steel
8	1	DIFFERENTIAL	Cast Iron
9	1	AC MOTOR - 10HP	Composite
10	1	FINAL DRIVE PULLEY	Steel
11	1	MOTOR PULLEY	Steel
12	1	V-Belt	Rubber

Figure 1: Three dimensional view of the oil expeller

$$\tan 29.0 = \frac{h_1}{150.4} \tag{2}$$

h_1 =150.5 tan 29.00
h_1 = 150.5× 0.55431
h_1 = 83.42 mm

Capacity of the piling hopper: the hopper can be divided into 3 segments and the volume of each segment will be determine the overall capacity of the piling hopper.
Therefore capacity of the hopper was determined using the dimensions presented in Figure as:

$$V_t = V_1 + V_2 + V_3 \tag{3}$$

$$V_t = (a \times a \times h_1) + \frac{h_2}{3}\left(a^2 + b^2 + \sqrt{a^2}.b^2\right) + (b \times b \times h_3) \tag{4}$$

$$V_t = (0.3556 \times 0.3556 \times 0.087) + \frac{0.2}{3}\left(0.3556^2 + 0.09^2 + \sqrt{0.3556^2} \times 0.09^2\right) + (0.09 \times 0.09 \times 0.08691)$$

V_t = 0.011 + 0.0111 + 0.000704
= 22.8×10^{-3} m^3

The handling capacity of the hopper is 22.80×10^{-3} m^3

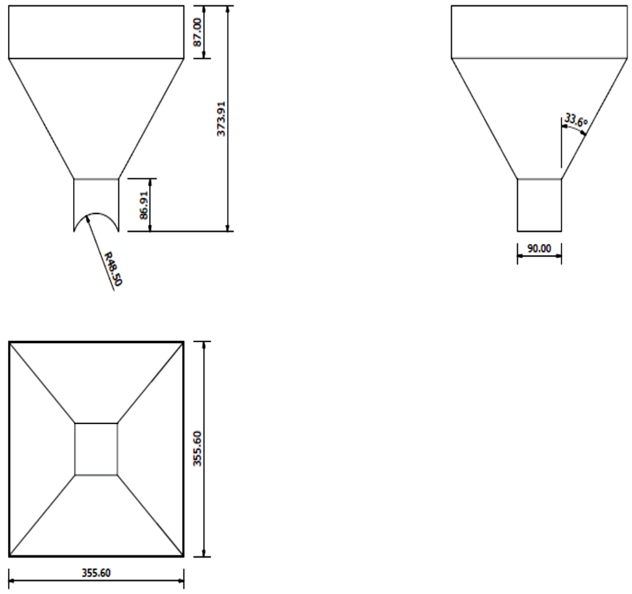


Figure 2: Orthographic view of the hopper

ii. The wormshaft

The screw worm consists of ϕ40 mm × 550 mm spiral worm shaft. At one end of the screw press shaft is a conical frustum with an angle of 45° with a length 125 mm and width of 87 mm as shown in figure 3.

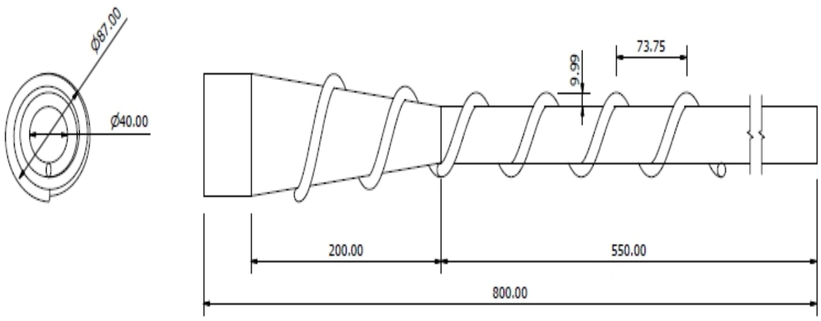


Figure 3: A cross- section of wormshaft

iii. Determination of wormshaft diameter

Assuming a power source of 35 kW as the prime mover for the machine, the tensional moment (Mt) due to the applied load can be determined (Hall et al., 1980):

$$M_t = \frac{9550 \times KW}{\frac{Rev}{min}} \tag{5}$$

Assuming that power = 35 kW and speed = 92.0 rpm

$$M_t = \frac{9550 \times 35}{92} \text{ Nm} = 3633.2 \text{ Nm}$$

Using the bending moment diagram in Appendix 1, the maximum bending moment (Mb) was found to be:

Mb = 342.104 Nm

The diameter of the shaft was then determined using equation below. (Hall et al., 1980)

$$d^3 = \frac{16}{\pi S}\sqrt{(K_b M_b)^2 + (K_t M_t)^2} \quad (6)$$

Where:-
S is allowable shear stress
Kb is shock and fatigue factor for bending moment
Kt is shock and fatigue factor for torsional moment
Mt is torsional moment
Mb is bending moment
Where:
S_s = 55 MN/m^2 (using a factor safety of 2.5)
K_b = 1.5
M_b =342.104 Nm
K_t = 1
M_t = 145.33 Nm

$$d^3 = \frac{16}{\pi \times 55 \times 10^6}\sqrt{(1.5 \times 342.104)^2 + (1 \times 145.33)^2}$$

$$d^3 = 4.938 \times 10^{-5}$$
$$d = 36.68 \text{ mm}$$

iv. The screw length

The equation of a helix wound on the shaft is given by;

$x = (r + mL) \cos \theta$ (7)

$y = (r + mL) \sin \theta$

and

$z = (r + mL) \text{Cot } \alpha$ (8)

x, y and z are the shaft axes. The length S of the helix curve is given by:

$S^2 = x^2 + y^2 + z^2$ (Hrankowski and Waldman, 2017) (9)

Hence

$$\left[\frac{ds}{d\theta}\right]^2 = \left[\frac{dx}{d\theta}\right]^2 + \left[\frac{dy}{d\theta}\right]^2 + \left[\frac{dz}{d\theta}\right]^2 \quad (10)$$

Where

$$\frac{\partial x}{\partial \theta} = (r + mL)\sin\theta \quad (11)$$

$$\frac{\partial y}{\partial \theta} = (r + mL)\cos\theta \quad (12)$$

$$\frac{\partial z}{\partial \theta} = (r + mL)\cot\alpha \quad (13)$$

$$\left[\frac{\partial s}{\partial \theta}\right]^2 = (r + mL)^2 \cos\alpha^2 \quad (14)$$

Or

$$\frac{\partial s}{\partial \theta} = (r + mL)\,\text{cosec}\,\alpha \quad (15)$$

$$= \frac{r+mL}{\sin\propto} \quad (16)$$

or

$$S = \frac{r+mL}{\sin\alpha}\int_{\theta_2}^{\theta_1}\partial\theta \tag{17}$$

$$S = \frac{r+mL}{\sin\alpha}(\theta_2 - \theta_1) \tag{18}$$

If θ_1 = 0° and α =17°, S becomes

$S = 3.4203(r + mL)\ \theta_2$ (19)

$S = 3.4203\ (r + mL)\ n\pi$

According to Stephens (2015) the screw length S is given by:-

$S = 2\pi Rn^{\sec\alpha}$

Where:-

α is helix angle

R is radius of shaft screw

n is number of pitch thread

The volume of the spiral space between the crest of the screw and the inside of the barrel was found from:

$$V = \frac{M}{\rho m^3 h^{-1}} \tag{20}$$

reported that the input capacity per hour of the screw press can be found by using capacity:

$C = 60\ PANK_mK_n\rho$ (21)

Where:-

K_m is 0.35

K_n is 1.0

P is pressure

A is cross-sectional area

ρ is density of fluid

N is speed of the screw pitch

With N being varied between 46.6 and 92.0 rpm for screw pitches of 100 mm and ρ is 620 kgm^3, i.e.

$$V = \frac{M}{\rho} = \frac{10}{620} {m^3}/{h} \tag{22}$$

Hence: $V = 2.6882 \times 10^{-4} = {m^3}/{h}$ (Oyinlola et al., 2004)

$V = BSH = n\pi^2 D^2 h^{\tan\propto\sec\propto} = 2.6882 \times 10^{-4} m^3$

If h =5 mm, D = 38 mm, α = 17° from which n = 12 approximately.

Therefore the screw length as given by equation 3.16 equals

$S = 3.4203(r + mL)(n\pi) = 2.45$ m.

$= (r + mL)2\text{Cos}2\alpha$

Or

$$\frac{\partial s}{\partial \theta} = (r + mL)\cos\alpha \;\; = \frac{r+mL}{\sin\alpha} \tag{23}$$

If θ_1 = 00 and α = 450

$$S = 1.4142\,(r + mL)\,\theta_2 \tag{24}$$

$$S = 1.4142\,(r + mL)\,n \tag{25}$$

n = 0.6789

The pitch of the screw thread will be determined by considering the handling capacity of the screw press and the difference between the volumes of the untapered and the tapered end of the expelling section (Figure 4)

$$VH = (VU - VT)\,P \tag{26}$$

Where

P is pitch of screw thread.

V_H is handing capacity of the screw press

V_U is capacity of the untapered end of the cone

V_T is capacity of the tapered end of the cone

(i) The screw thread length = 0.5504 m

(ii) The desired range of speed for the screw press is 30 to 60 revolutions per minute (rpm).

(iii) An integral cone of 40 mm inner diameter, 87 mm outer and 800 mm length was incorporated in the press.

(iv) In one revolution of the screw, the output is advanced by one pitch of the thread.

(v) The handling (design) capacity of the screw press as obtained from Equation 20 is given as $8.64 \times 10^{-4}\,m^3$

Using equation 19, the pitch of the thread was calculated thus:

$V_H = 8.64 \times 10 \times 10^{-4}\,m^3$

$$V_U = \frac{\pi(0.12)^p}{4} \tag{27}$$

$= 11.31 \times 10^{-3} P\ m^3$

$$V_T = \frac{\pi(0.04)^p}{4}$$

$= 1.32 \times 10^{-3} P\ m^3$

Hence, $8.64 \times 10^{-4}\,m^3 = (11.31 - 1.32) \times 10^{-3} P\ m^3$

$$P = \frac{8.64 \times 10^{-4}}{(11.31 - 1.32)\times 10^{-3}} \tag{28}$$

P = 0.0864 m

P = 86 mm

$$\text{Efficiency of the machine} = \frac{\text{Mechanical advantage} \times 100\%}{\text{Velocity ratio}} \tag{29}$$

$$\text{Velocity ratio} = \frac{2\pi \times \text{distance moved by effort}}{\text{pitch}} \tag{30}$$

From equation 24, efficiency of the machine can Increase by a decrease in the velocity ratio. This could be achieved by an increase in the pitch (equation 27). This implied that the pitch length could be increased as from 73.75 mm. Pitch lengths of 90 mm was selected.

$$\text{The number of thread (n)} = \frac{\text{Lenght of screw thread}}{\text{pitch}} \quad (31)$$

Equation 3.27 will be used to calculate the number of thread if the length is constant.

v. Shaft housing

Shaft housing is cylindrical shape with outer ϕ97 mm and inner ϕ87 mm while the length is 600 mm. It was constructed from mild steel material with a hole of ϕ12 mm bore on the wall of the shaft housing. It was designed for the screw of material as shown in Fig 4

The handling capacity of the housing was calculated thus:

$$\begin{aligned} \text{Volume} &= \pi r^2 \times \text{height} \\ &= \frac{22}{7} \times 0.0435 \times 0.0435 \times 0.6 \\ &= 3.57 \times 10^{-2}\ m^3 \end{aligned}$$

The handling capacity of the housing is 3.57 × 10-2 m3

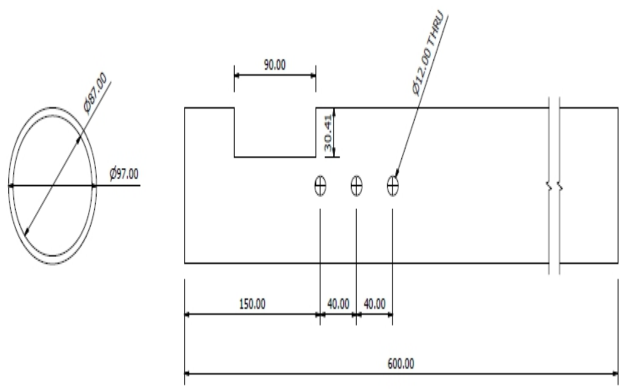


Figure 4: The expression chamber

vi. Cake and oil outlets

As shown in Figures 5 and 6, the outlets are meant for the collections of the cake and the oil, respectively.

vii. The standing frame

The standing frame is made up of angle iron 75 × 75 × 5 mm in cross-section. The frame is 1363 mm in length, 900 mm width and 475 mm in height. Other component parts of the machine such as differential unit, the expelling unit, hopper, front yoke, pulley and V-belt were mounted on it. The frame was designed to take care of the vibration and the alignment between the pulley on the electric motor and the differential (Fig 7).

2.2. Materials

The materials used for the project can be grouped into materials for machine fabrication, instrumentation material and oilseed materials (palm kernel, groundnut kernel and soya seed).

2.2.1. Materials for machine fabrication

The materials used in fabricating the multi-purpose oil expeller include angle bar (75 mm) - construction of the machine frame, stainless steel plate (1.5 mm) - for the construction of screw, press, cylindrical pipe (87 mm) - for the shaft housing, Rod (ϕ 40 mm), pulley and belt set - for driven and transmission of power, universal joint/front yoke – for connection of the worm shaft and final drive shaft, electric motor (15 hp) – for powering the machine, final drive - for speed reduction, electrode (both ordinary and stainless) – for joining of both mild steel and stainless materials, and paint – for preventing corrosion.

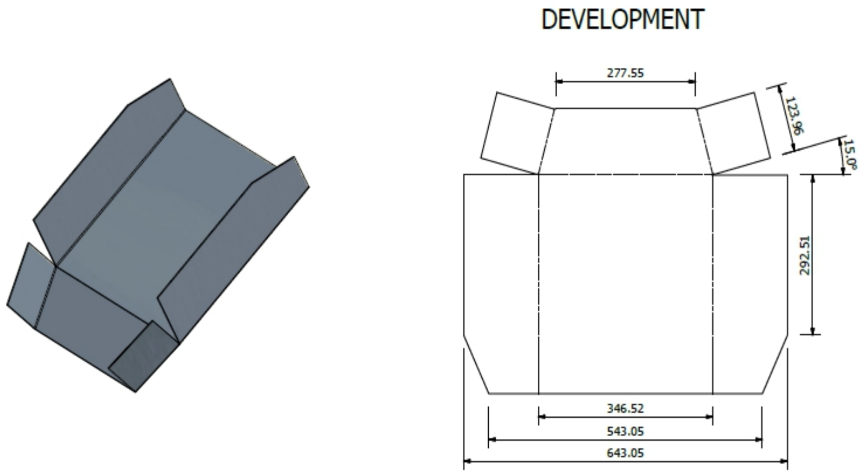


Figure 5: Cake outlet

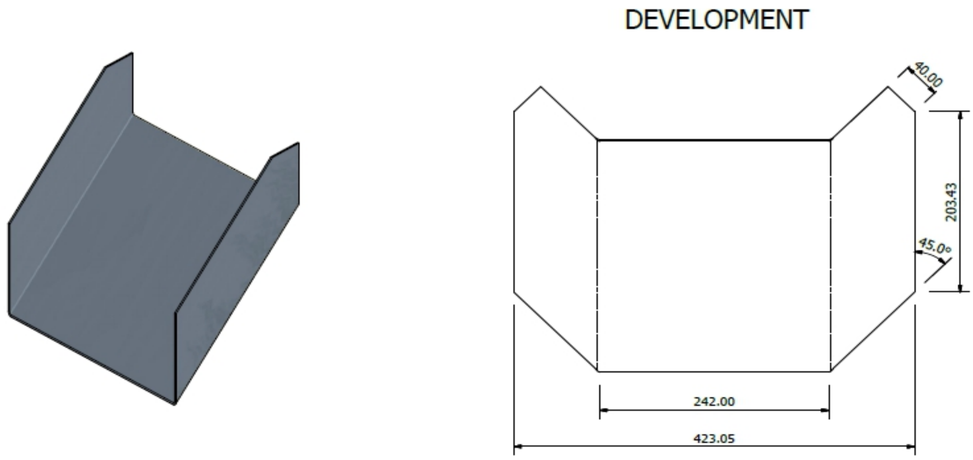
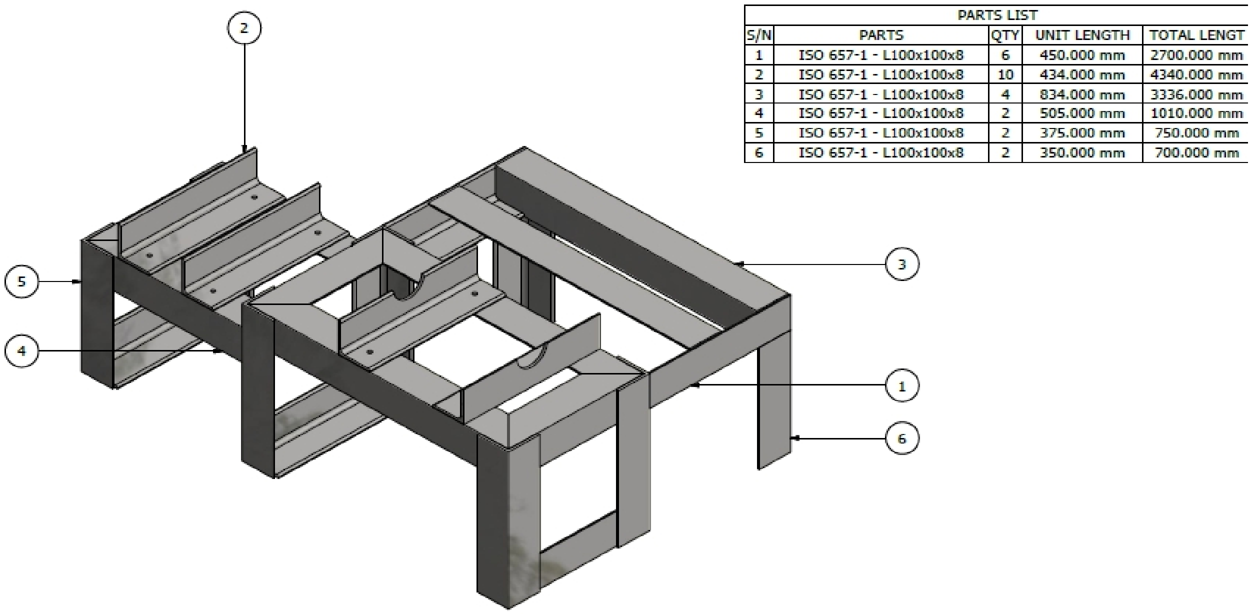


Figure 6: Oil outlet



PARTS LIST				
S/N	PARTS	QTY	UNIT LENGTH	TOTAL LENGT
1	ISO 657-1 - L100x100x8	6	450.000 mm	2700.000 mm
2	ISO 657-1 - L100x100x8	10	434.000 mm	4340.000 mm
3	ISO 657-1 - L100x100x8	4	834.000 mm	3336.000 mm
4	ISO 657-1 - L100x100x8	2	505.000 mm	1010.000 mm
5	ISO 657-1 - L100x100x8	2	375.000 mm	750.000 mm
6	ISO 657-1 - L100x100x8	2	350.000 mm	700.000 mm

Figure 7: The frame

2.1.2. Seed materials

Oil bearing materials used for the study, viz: - palm kernel, groundnut and soya bean were collected from Ile-Ife central market and Obafemi Awolowo University Research Farm. The seeds were subjected to various heat treatments after which they were processed with the machine.

Sample preparation

The fresh seed was conditioned and oven- dried at different temperatures (120, 90 and 70°C) as provided in ASAE standards (2002) to determine various moisture contents at each temperature level. The materials were kept in desiccators to avoid being acted by the atmosphere until it was processed with the expeller.

Moisture content determination

The ASAE S410 standard (ASAE, 2002) was used in determining the moisture content of the three materials (palm kernel, groundnut and soya bean). The samples were heated for 25 minutes, 15minutes and 10 minutes at temperatures of 120, 90 and 70°C (ASAE, 2002) and then kept in desiccators. A kernel sample of 1500 g was weighed into the dish and the weight of the dish plus lid and kernel recorded. The dish and sample was transferred into an oven set at 120, 90 and 70°C. Weight measurement was carried out at every thirty minutes until the weight become constant for three consecutive readings. The percentage moisture content of sample was obtained from equation 2.31.

$$M_w = \frac{W_{d_1} - W_{d_2}}{W_{d_2}} \times 100 \quad (32)$$

Where:

M_w is Moisture content of sample

W_{d_1} is Weight of sample before drying (g)

W_{d_2} is Weight of sample after drying (g)

Dynamic viscosity determination

The dynamic viscosity of the oil extracted from the three oil seeds was determined by using SM5001 viscometer (cup type) operation manual as reported by Owolarafe et al. (2008). The cup was put in the circular frame and the leveling leg of the viscometer was adjusted to make sure that the bubble on the cross frame was at the center as shown in Plate 1.

The oil extracted was poured into the flow cup and the backup was used to control the flow of the oil. The extracted oil was allowed to flow from the flow cup to another cup and the time of flow was taken by starting the stopwatch to test the oil appearing line shape. When the line was cut off then the stopwatch stopped. This process was replicated thrice and the values were recorded.

To determine the viscosity manually the following formula was used

$$r = \frac{(t-6)}{0.223} \quad (33)$$

where r is the dynamic viscosity (mm^2/s)
t is the flow out time (s)

Plate 1: SM5001 Viscometer AMETEK Powervar Cary, NC, USA

2.1.3 Fabrication and assembly of the machine components

Figure 1 shows the three dimensional view of complete assembly of the machine components. Assemblage of the machine began with the welding of the frames, the hopper and the electric motor seat and the differential seat as well. The front yoke was welded to the main shaft from the differential unit.

2.2 Performance Evaluation of the Machine

Performance evaluation of the machine was carried out by operating the machine using four factors which include soaking time (which resulted in differential moisture content), three variable oilseeds (palm kennel, groundnut seed and soya bean) temperature and the extraction speed. Each of these factors was investigated using 1.5 kg of oilseed at three replicates to determine the optimal performance of the machine. The parameters determined include oil yield, throughput capacity and oil extraction efficiency. The effect of the processing conditions of the oil seeds on the performance of the machine was analyzed using one way analysis of variance (ANOVA) and Duncan's multiple range test.

Determination of yield of oil

The yield of oil in parentage was calculated as follows:

$$y_{oil} = \frac{Q_j}{Q_f} \quad (34)$$

Where

Q_j = quantity of oil extracted in kg

Q_f = quantity of oil seed processed in kg (quantity of oil extracted and the cake in kg)

Determination of throughput capacity of the machine

The capacity of the machine was calculated as shown:-

$$\text{Capacity of machine (capm)} = \frac{Q_f}{t} \quad (35)$$

Where

Q_f = Quantity of oilseed processed in kg.

t = Time taken in minute.

Determination of efficiency of the machine

Oil extraction efficiency (E_e) in percentage is the ratio of the weight of oil extracted to the product of the oil (moisture content) of the oilseed and the eaglet of the product before extraction. (Olaoye and Oyelade, 2012)

$$E_e = \frac{Qj \times 100}{X\, Qf} \quad (36)$$

Where

Q_j is quantity of oil extracted in kg.

X is the oil content (moisture content of oil) in %

Q_f is total quantity of material fed into the machine in.

3. Results and Discussion

Tables 1, 2 and 3 show the data obtained on oil yield, throughput capacity and efficiency of the machine at different conditions (moisture content and shaft speed) for the three oilseeds processed. The average oil contents of the oilseeds were used to compute the mean values of the efficiency of the machine. New Dungeons Multiple Range Test (DMRT) was used to determine the differences in the mean treatment effect of moisture content on oil yield.

3.1. Effect of Shaft Speed, Moisture Content and Type of Oilseeds on Oil Yield

As shown in Table 1, increase in moisture content from 5 to 15% and increase in shaft speed from 47.6 to 92.0 rpm increased the oil yield in all the oil seeds. At shaft speed levels of 47.6, 87.0 and 92.0 rpm, increase in the moisture content of Palm kernel oilseed increased the oil yield from 19.0 to 23.0%, 26.0 to 48.0% and 27.0 to 51.0% respectively. With the soya bean seed, there was no oil expelled at 5% moisture content but the oil yield later increased from 0.0 to 16.0 % as the moisture content increases for all the levels of the shaft speed as presented in Table 2. In the case of groundnut, as the moisture content was increased from 5% to 15%, the oil yield increased from 7.3 to 31.7%, 5.7 to 26.0% and 7.3 to 28.0% for the levels of shaft speed as presented in Table 3. These results obtained indicated that higher oil yield can be achieved at low shaft speed and moisture content of the seed between 5 to 10 %. These follow the trend reported by Orhevba et al. (2013) and Samuel and Alabi (2012) though their research work was based on neem seed.

Table 1: The mean values of Measured Parameters for Palm Kernel

Type of Oil seed	Mean Temperature (°C)	Mean Throughput Capacity (Kg/h)	Mean Oil Yield (%)	Mean Machine Efficiency (%)
M_1 S_1	97.00	1.81	19.0	39.4
M_1 S_2	95.33	1.94	26.0	51.1
M_1 S_3	92.33	0.89	27.0	52.1
M_2 S_1	92.33	0.91	22.0	33.9
M_2 S_2	83.33	0.79	19.0	36.9
M_2 S_3	82.33	0.53	27.0	52.1
M_3 S_1	85.00	0.83	23.0	45.6
M_3 S_2	84.33	1.07	48.0	93.2
M_3 S_3	83.33	0.62	51.0	99.6

Legend
S = Shaft speed (rpm)
M = Moisture content (%)
S_1 = 47.6 rpm
M_1 = 5%
S_2 = 87.0 rpm
M_2 = 10%
S_3 = 92.0 rpm
M_3 = 15%

Table 2: The mean values of Measured Parameters for Soya Bean

Type of Oil seed	Mean Temperature (°C)	Mean Throughput Capacity (Kg/h)	Mean Oil Yield (%)	Mean Machine Efficiency (%)
M_1 S_1	69.67	0.00	0.00	0.00
M_1 S_2	68.67	0.00	0.00	0.00
M_1 S_3	67.67	0.00	0.00	0.00
M_2 S_1	69.00	0.42	12.1	62.1
M_2 S_2	67.00	0.57	14.5	74.4
M_2 S_3	66.33	0.34	11.3	57.9
M_3 S_1	71.67	0.52	16.0	82.1
M_3 S_2	69.00	0.56	16.0	82.1
M_3 S_3	68.67	0.52	16.0	82.1

Legend
S = Shaft speed (rpm)
M = Moisture content (%)
S_1 = 47.6 rpm
M_1 = 5%
S_2 = 87.0 rpm
M_2 = 10%
S_3 = 92.0 rpm
M_3 = 15%

Table 3: The mean values of Measured Parameters for Groundnut

Type of Oil seed	Mean Temperature (°C)	Mean Throughput Capacity (Kg/h)	Mean Oil Yield (%)	Mean Machine Efficiency (%)
M_1 S_1	65.0	0.09	7.3	16.7
M_1 S_2	66.3	0.07	5.7	15.9
M_1 S_3	61.7	0.09	7.3	16.7
M_2 S_1	68.4	0.23	18.7	42.4
M_2 S_2	65.0	0.31	23.3	53.1
M_2 S_3	60.0	0.21	17.0	38.6
M_3 S_1	52.4	0.55	31.7	72.0
M_3 S_2	46.5	0.50	26.0	59.1
M_3 S_3	47.7	0.57	28.0	63.6

Legend	S	=	Shaft speed,
	M	=	Moisture content
	S1	=	47.6 rpm
	M1	=	5%
	S2	=	87.0 rpm
	M2	=	10%
	S3	=	92.0 rpm
	M3	=	15%

As shown in Tables 1, increasing the machine speed from 47.6 to 92.0 at 5% moisture content of palm kernel, caused an increase in the oil yield from 19.0 to 27.0 %, while at 10% moisture content, increase in the shaft speed caused variation in the oil recovery ranging between 19.0 and 27.0 %, and also at 15 % moisture content, increase in the shaft speed increased the yield from 23.0 to 51.0%. In the case of soya bean, at 5% moisture content, there was no oil expelled for all the levels of the shaft speed, and also at 10 % moisture content, the increase in the shaft speed varied the yield ranging between 11.3 and 14.5 %, while at 15 % moisture content, the yield was constant at 16 % for all the levels of shaft speed as presented in Table 2. This implies that moisture content of at least 10 % is required for oil extraction from soya bean. In the case of groundnut, at 5, 10 and 15% moisture content, increase in the shaft speed resulted to variation in the yield which ranged between 5.7 and 7.3%, 17.0 and 23.3%, also 26.0 and 31.7% as shown in Table 3. This observed pattern in the oil yield for the seeds being considered could happen as a result of the heat effect which helps in better rupture of the cell walls and globules which helped in easy oozing out of the hull. This trend was reported by Shukla et al. (1992).

3.2. Effect of Shaft Speed, Moisture Content and Seed Type on Machine Efficiency

As presented in Table 1, the efficiency of the machine when used in processing palm kernel increases with increase in moisture content and machine shaft speed. The machine reaches its optimum performance in terms of efficiency (99.6 %) when processing palm kernel at 15 % moisture content and machine speed of 92.0 rpm. For soya bean, 0% machine efficiency was obtained at moisture content below 10%, while the highest machine efficiency (82.1%) was obtained at 15% moisture content for all levels of the machine speed. Groundnut requires a low level of shaft speed and high moisture content to obtain the best machine efficiency. Highest machine efficiency of 72.0% was obtained at 5% moisture content and 47.6 rpm shaft speed. The lower machine speed increases the heat effect on the seeds which helps in better rupture of the cell walls and globules which helped in easy oozing out of the hull. This result is corroborated by the findings of Jimoh and Olukunle (2013); Orhevba et al. (2013); Ashaolu and Noibi (2013). The variation in terms of the optimum performance of the machine is as a result of the difference in properties of the seeds considered in the study.

3.3. Effect of Processing Condition on the Throughput Capacity

The throughput capacity of the machine varies with moisture content of the seed and machine speed. For palm kernel, the highest throughput capacity (1.94 kg/h) was obtained at 5% moisture content and machine speed of 87.0 rpm. As presented in Table 1, there was variation in the throughput capacity obtained at different levels of moisture content and shaft speed This variation may be as a result of the oilseed compressive strength and shearing force in the palm kernel. This follows the trend recorded by Omoruyi and Ugwu (2013).

The throughput capacity of soya bean at 5 % moisture content was 0.0 kg/h for all the levels of shaft speed, while throughput capacity of 0.42, 0.57 and 0.34 kg /h was obtained at 10 % moisture content for the 3 levels of the shaft speed. Also, at 15 % moisture content, the throughput capacity values were 0.52, 0.56 and 0.52 kg/hr for the 3 levels of the shaft speed (47.6, 87.0 and 92.0 rpm) respectively as shown in Table 2. The highest throughput capacity of soyabean was obtained at 10% moisture content and 87.0 rpm machine speed.

In the case of groundnut, the throughput value at 5 % moisture content was 0.09, 0.07 and 0.09 kg/h for the 3 levels of shaft speed, while throughput capacity of 0.23, 0.31 and 0.21 kg/h was obtained at 10 % moisture content, 0.55, 0.50 and 0.57 kg/h was also obtained at 15 % moisture contents for the 3 levels of the shaft speed (47.6, 87.0 and 92.0 rpm) respectively as shown in Table 2. Higher moisture content causes plasticizing effect which reduces the level of compression (Shukla et al, .1992). Similarly, heat generated by the wormshaft during pressing can be fully transferred to the individual fat globules, which result in breakdown of the emulsion form of the fat and help in releasing more oil droplets. Olayanju et al. (2006)

3.4. Effect Processing Conditions on Volumetric Flow Rate of the Oil

The processing condition such as type of oil seed, moisture content and shaft speed on volumetric flow rate was discussed in this section.

In Table 4, it could be observed that the volumetric flow rate of palm kernel ranges from 0.7×10^{-6} to 1.77×10^{-6} m^3s^{-1}, the highest volumetric flow rate was observed at 5% moisture content and 92.0 rpm shaft speed. In the case of soya bean, the volumetric flow rate is between 1.31×10^{-7} m^3s^{-1} to 2.95×10^{-7} m^3s^{-1}, the volumetric flow rate reached its peak value 15 % moisture content and 92.0 rpm shaft speed. Similarly, the volumetric flow rate of groundnut ranges between 0.34×10^{-6} to 0.84×10^{-6} m^3s^{-1}, and reaches the maximum level at 5 % moisture content and 87.0 rpm shaft speed as shown in Table 4. This indicates that, the highest volumetric flow rate was observed in palm kernel while the lowest volumetric flow rate was observed in soya beans. Samuel and Alabi (2012), corroborated the findings stating that at constant temperature, excessive increment in moisture content of kernel seeds could reduce the expulsion ability and wear of mechanical parts of expeller.

From Table 4, it could be observed that increase in the moisture content from 5 to 15 % while the shaft speed is kept constant at 47.6 rpm, the volumetric flow rate of palm kernel fluctuate between 0.90×10^{-6}, 0.70×10^{-6} and 0.85×10^{-6} m^3s^{-1}. Also at 87.0 rpm, increase in the moisture content as stated caused the volumetric flow rate to also fluctuate between 1.22×10^{-6}, 1.21×10^{-6} and 1.17×10^{-6} m^3s^{-1}. While maintaining a shaft speed of 92.0 rpm and increase in the moisture content, the volumetric flow rate decreases from 1.77×10^{-6} to 1.73×10^{-6} m^3s^{-1}. This trend was also reported by Ezeoha et al (2017). Similar trend was also observed in the case of soya bean and groundnut and which was corroborated by the findings of Rouhollah and Seyyed, (2016).

Table 4: Processing condition of the volumetric flow rate of oil

Type of oilseed	Shaft speed (rpm)	Moisture content (%)	Volumetric flow Rate (m^3/s)
	47.6	5	0.90×10^{-6}
Palm Kernel	47.6	10	0.70×10^{-6}
	47.6	15	0.85×10^{-6}
	87.0	5	1.22×10^{-6}
Palm Kernel	87.0	10	1.21×10^{-6}
	87.0	15	1.17×10^{-6}
	92.0	5	1.77×10^{-6}
Palm Kernel	92.0	10	1.74×10^{-6}
	92.0	15	1.73×10^{-6}
	47.6	5	1.31×10^{-7}
Soya Bean	47.6	10	1.36×10^{-7}
	47.6	15	1.43×10^{-7}
	87.0	5	1.78×10^{-7}
Soya Bean	87.0	10	1.75×10^{-7}
	87.0	15	1.81×10^{-7}
	92.0	5	1.91×10^{-7}
Soya Bean	92.0	10	1.93×10^{-7}
	92.0	15	2.95×10^{-7}
	47.6	5	0.61×10^{-6}
	47.6	10	0.58×10^{-6}
Groundnut	47.6	15	0.34×10^{-6}
	87.0	5	0.84×10^{-6}
	87.0	10	0.67×10^{-6}
Groundnut	87.0	15	0.70×10^{-6}
	92.0	5	0.70×10^{-6}
	92.0	10	0.67×10^{-6}
	92.0	15	0.66×10^{-6}

4. Conclusion

Development of a machine to extract oil from different classifications of oil seeds (hard or soft) is possible provided the properties of the seeds are carefully considered at the design stage. The effect of processing conditions such as the moisture content of the seeds and shaft speed of the machine on properties such as the oil yield, throughput capacity and efficiency of the machine was examined. The study revealed that optimum performance of the machine in terms of oil yield for all the seeds (hard or soft) occurs at 15% moisture content of seed and 47.6 rpm machine speed. Volumetric flow rate of oil from the seeds is directly influenced by the shaft speed, moisture content and oil temperature. The highest efficiency of the machine will be attained at low shaft speed and moisture content of the seeds ranges between 5 to 10%. In general, the data presented in the study will be useful in optimizing the mechanics of mechanical oil extraction using the multi-seed oil expeller.

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