Performance Evaluation Of Groundnut Oil Extracting Machine Developed For Small Scale Farmers

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ABSTRACT

Groundnut oil extraction by a mechanical device has gained recognition in Nigeria but is limited to industrial use only and becoming inaccessible to local farmers due to the sophistication, complexity, and high cost of available oil extracting machines. A simple and low-cost groundnut oil extracting machine that is easy to operate and maintain at an affordable cost for local farmers was developed. This addresses the limitation of groundnut oil extraction in Nigeria, especially among local farmers. It was designed to run with a 3Hp single-phase variable-speed electric motor at a specific speed of 540rev/min. This experimental machine is capable of extracting oil and process groundnut into cakes as a by-product called *kuli-kuli*. It was tested with three replicates of roasted groundnut to determine its performance efficiency. The performance efficiency of the machine is 60.1%. The machine developed was found to be cheap, effective, and affordable to rural farmers.

***Keywords*: Groundnut, oil, extraction, expeller, kuli-kuli**

1. INTRODUCTION

As of today, Nigeria has become one of the leading countries in groundnut production which had necessitated effective preservation and processing of the nut to avoid spoilage associated with excessive production (Weiss, 2000). In groundnut processing, oil extraction is a well-established industrial activity in several developing countries. This is because, since the early 1950s, most oil seeds growing countries had favored indigenous oil extraction in preference to the export of oilseeds (Curt Beckmann and Chriswaterguy, 2008). According to FAO, 1998, groundnut is a rich source of edible oil which had in the range of 30-45% oil, 20 - 50 % protein, and 10 to 20 % carbohydrate. Over time, local farmers use the manual method for the extraction of groundnut oil which tends to be more tedious, time-wasting and the oil generated from the process contains impurities. Although, some existing oil-extracting machines had been developed for the extraction of the oil from groundnut, yet they are inaccessible by rural farmers because they are very expensive, complex in their operation and maintenance, and were designed majorly for industrial purposes. This high cost of the oil extracting machine had increased the cost price of the edible oil; hence limit the production of groundnut oil in the country. To address this challenge, a low-cost groundnut oil extracting machine that can be operated easily and maintained by rural farmers needs to be developed and hence the objective of this study. A machine of this nature will be suitable for small and medium-scale applications in the processing of groundnut and production of its oil.

2. MACHINE DESIGN

2.1 DESIGN CALCULATION

The low-cost groundnut oil extracting machine was developed with locally available materials. The machine was designed to run with a 3Hp single-phase electric motor at a speed of 540rev/min based on impact, compressing, and shearing force on the roasted groundnut. The rubbing of the nuts between the shaft inner wall and the cone is capable of extracting oil from roasted groundnut.

i) *Power requirement*: The velocity of the shaft,

$$V = \frac{\pi N D}{60} \tag{1}$$

The average shaft speed required to extract oil from oilseed, N = 540 rpm (FAO, 2003). If the shaft diameter, D, = 0.03 m. Hence, $V = 8.48\ m/s$.

The total force exerted on the shaft,

$$F_T = F_P + F_S + F_C \tag{2}$$

If the force is exerted by pulleys on the shaft, $F_P = 49.05\ N$, the maximum force exerted by the groundnut on the shaft, $F_S = 127.53\ N$and the force exerted by the cone on the shaft, $F_C = 78.48N$. Hence, the total force exerted on the shaft, $F_T = 255.06N$.

The maximum power rating,

$$P = F_T V \tag{3}$$

P= $255.06 \times 8.48 = 2162.9\ W = 2.2KW$ = 3hp

From torsion equation;

$$\frac{T}{J} = \frac{\tau}{r} \tag{4}$$

Where the radius of the shaft, $r = 15mm$. The torsional Shear Stress, $\tau = 56N/mm^2$. The polar moment of inertia of the shaft about the axis of rotation;

$$J = \frac{\pi \times D^4}{32} \tag{5}$$

$J = 79521.56$. Therefore, the twisting moment (or torque) acting upon the shaft, T = $296880.51Nmm$.

ii) *Belt drive*: Considering Fig. 1 below, length, L of the belt connecting shaft pulley and the motor pulley may be estimated as:

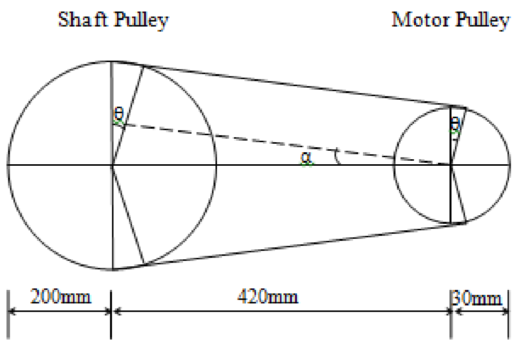


Fig. 1: Shaft and pulley diagram use with its dimension

$$L = \pi (r_1 + r_2) + 2x + \frac{(r_1 - r_2)^2}{x} \text{ (Ogundahunsi } et\ al., \text{ 2016)} \quad (6)$$

Where r_1 = radius of shaft pulley (100 mm), r_2 = radius of the motor pulley (25 mm), x = distance between the center of shaft pulley and motor pulley (420 mm). Therefore, from the equation 6, $L = 1246.09mm$

Considering the coefficient of friction μ = 0.3 between the belt (rubber) and pulley (mild steel) at high speed. T_1 = Tension on the tight side of the belt (N); T_2 = Tension on the slack side of the belt (N); θ = Angle of contact between the belt and pulley.

To obtain the tension of belt A and angle of wrap (θ);

$$\text{Sin}\,\alpha = \frac{r_1 - r_2}{x} \quad (7)$$

$$\theta = (180 - 2\alpha)\frac{\pi}{180} rad \quad (8)$$

$$2.3 \log\left(\frac{T_1}{T_2}\right) = \mu\theta \quad (9)$$

Therefore, $\propto = 24.625^0$ and $\theta = 2.28\ rad$; μ = 0.3

$$T_1 = T_2 . \ell^{\frac{\mu\theta}{2.3}}$$

$$P = (T_1 - T_2)V = T_2(\ell^{\frac{0.3 \times 2.28}{2.3}} - 1)\, 8.48;$$

Since P = 2162.9 W, therefore, $T_2 = 259.4N$ and $T_1 = 514.47N$.

iii) *Shaft*: Considering Fig. 2 below, the force exerted on shaft by cone, R_c = 8kg = 78.48N; by shaft pulley, R_p = 5kg = 49.05N; by conveyor, R_{co} = 4kg = 39.34N.

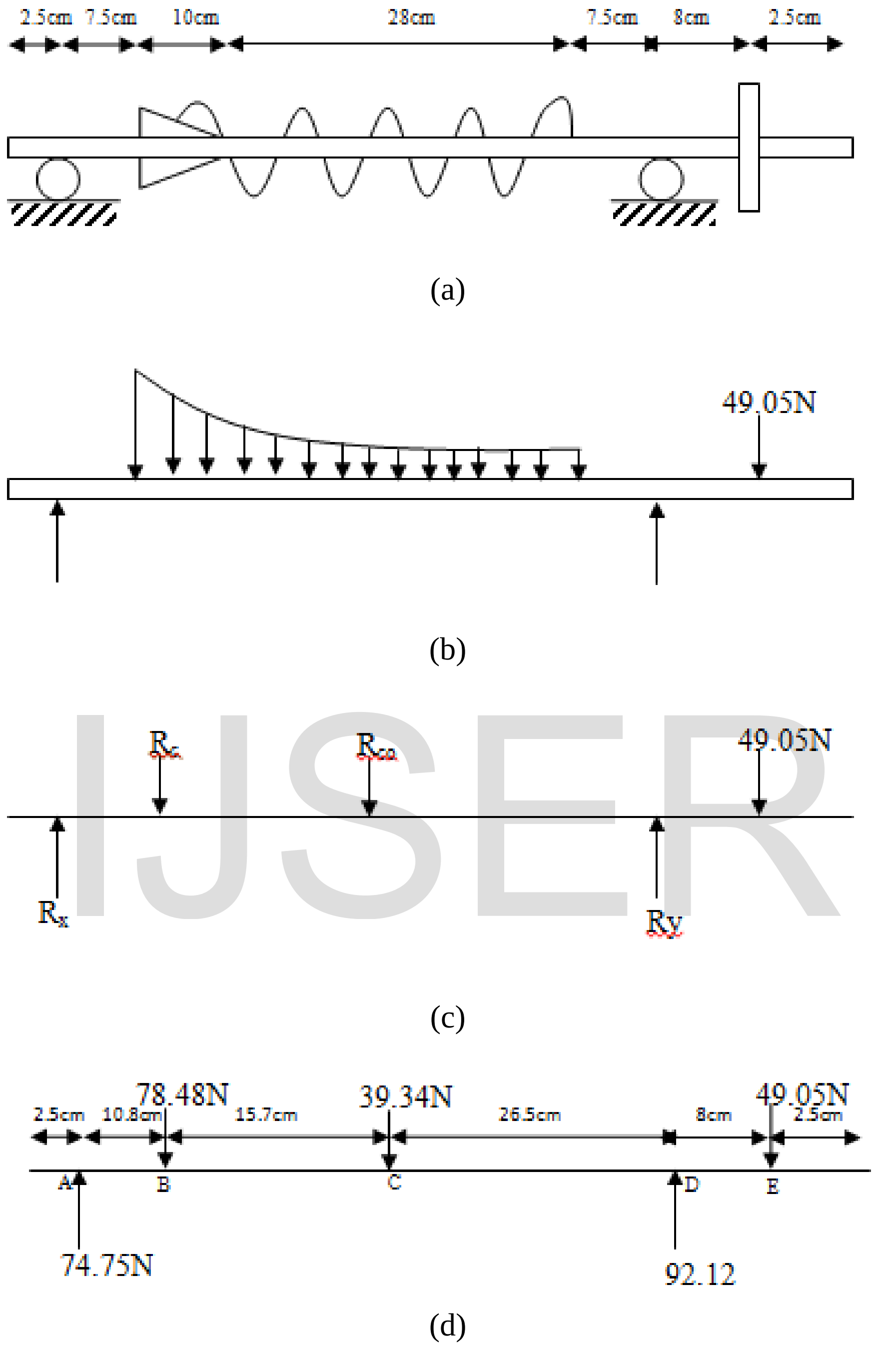


Fig. 2(a-d): Shaft loading diagram

To obtain the vertical loading, taking moment at point x, M_x=0.

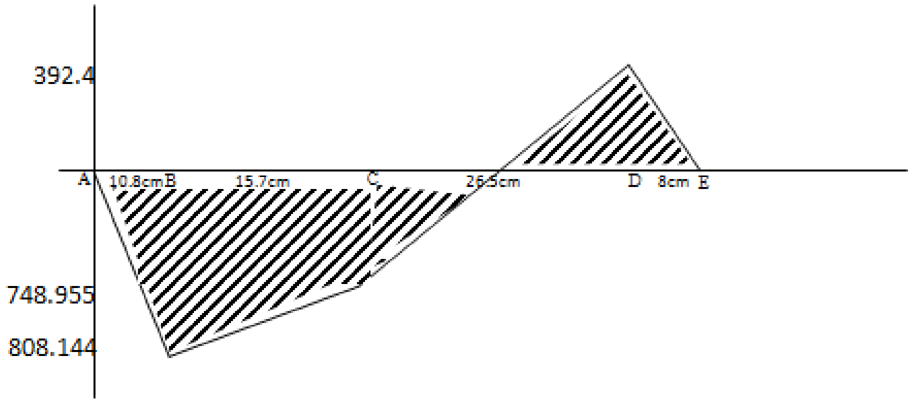
Therefore,

$(78.48 * 10.8) + (39.34\ (15.7+10.8)) - (R_y\ (7.5+19+15.7+10.8)) + (49.05\ (8+7.5+19+15.7+10.8)) = 0$; R_y = 92.12N.

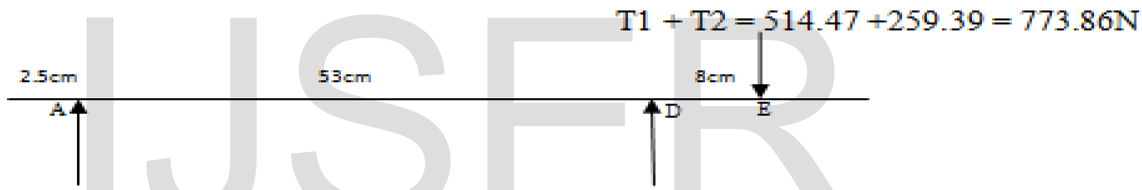
$\sum F_y = 0;$

$$R_x - 78.48 - 39.34 + R_y - 49.05 = 0;\ R_x = 74.75N$$

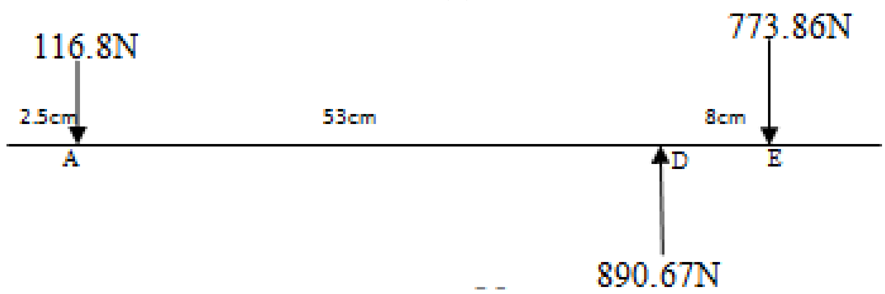
From Fig. 3, the vertical bending moment at point A $= 1.276N$; at point B $= 808.14N$; at point C $= 748.955N$; and at point D $= 392.4N$



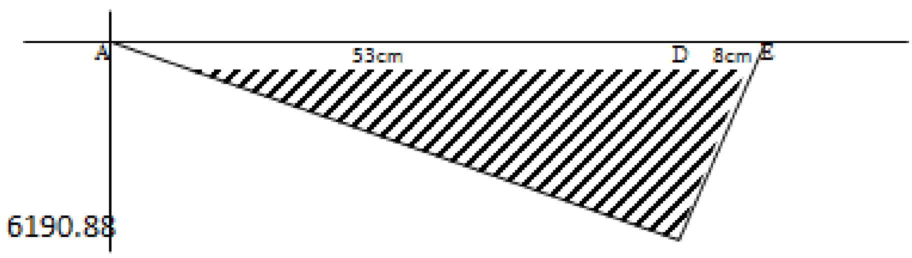
(a)



(b)



(c)



(d)

Fig. 3(a-d): The bending moment and deflection diagrams

To obtain the horizontal loading, taking moment at point A, M_y=0.

Therefore,

$$(D \times 53) - (773.86 \times 61) = 0; D = 890.67N; A + B = 773.86N$$

$$A = 773.86 - 890.67 = -116.8N = 116.8N\ (in\ opposite\ direction)$$

The horizontal bending moment at point A = $0N$; at point D = $6190.88N$; and at point, E = $0N$

Since the upward force acting on the shaft by the upward load is equal to the downward force which is given by the supports at the vertical loading, therefore the shaft will not bend or break at any point because there is a balanced force on the vertical loading.

2.2 Machine Description

The machine working principle was based on the compressive and shear force impacted upon the nuts by the cone against the inner surface of the pipe which did cause the shearing and oil extraction from the groundnut. When powered, roasted groundnuts were introduced into the machine through the hopper which opened directly to the extracting unit. The shaft rotates in a clockwise direction conveying the nuts to the cone by the screw conveyor where they are impacted upon by a compressive and shear force to extract the oil. The extracted oil filters out through the perforation beneath the pipe and is collected through the oil outlet while the groundnut cake which is the by-product is forced out as paste through the clearance between the cone and the pipe wall and collected through the cake outlet. The major part of the machine is the extracting unit consisting of two main components which include; extracting pipe that is perforated beneath and shaft on which there is cone and screw conveyor.

i) The Pipe is part of the machine that houses the mechanism that extracts the oil from the oilseed and then lets out the residues which is the groundnut cake. The pipe is perforated beneath to allow the passage of the extracted oil into the oil outlet. It is 41cm in length and it is made of steel.

ii) The Shaft has a screw conveyor with it and a cone. This part of the machine is responsible for the shearing of the groundnut and extraction of its oil as the shaft rotates in a clockwise direction powered by the electric motor.

The machine drawings and pictorial view of the experimental machine are shown in Figs. 4, 5, and 6.

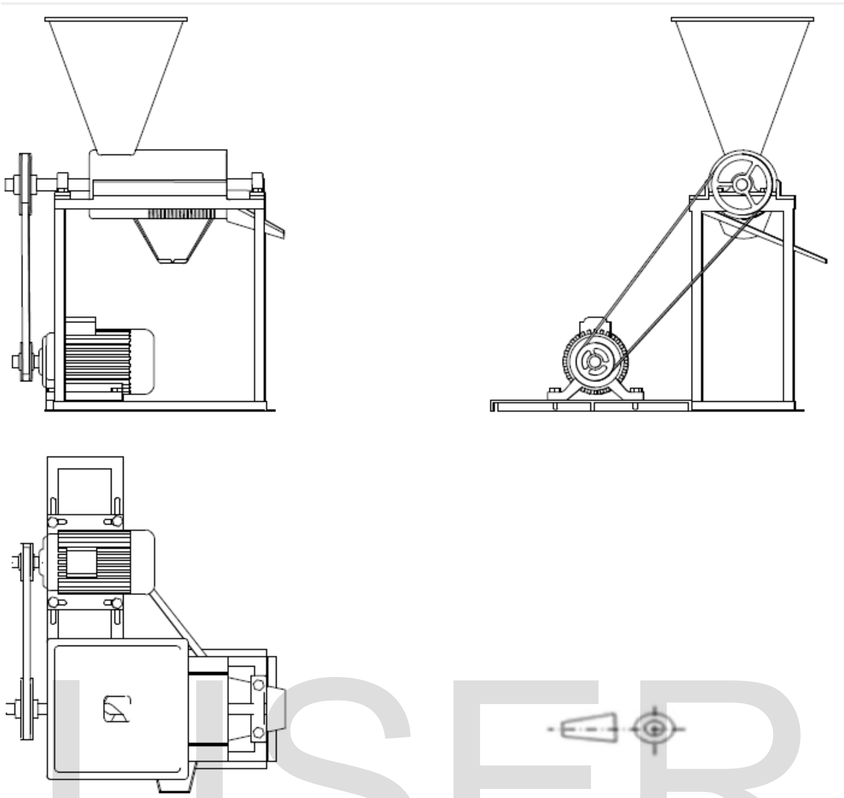


Fig. 4: Orthographic drawing

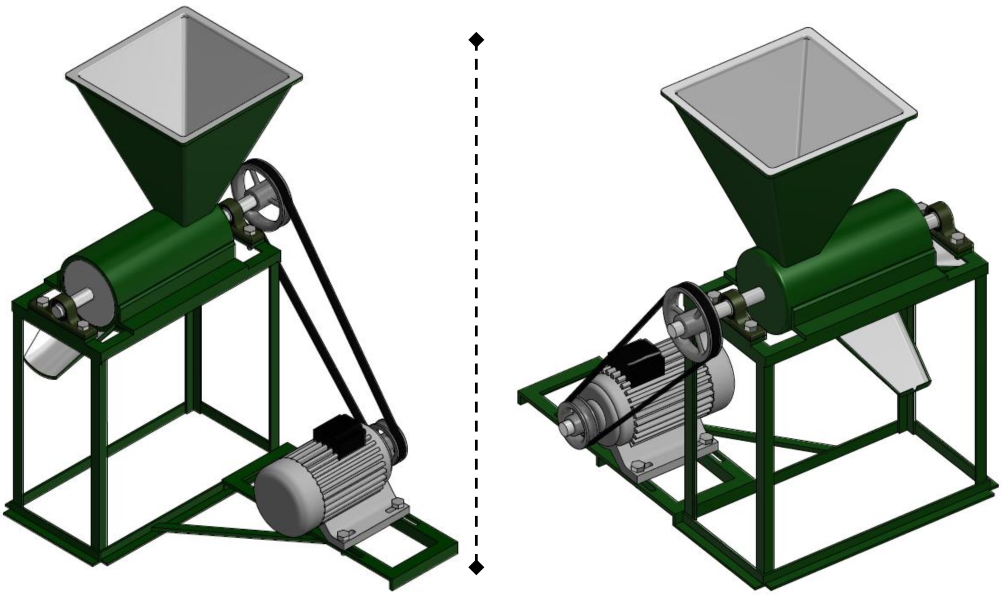
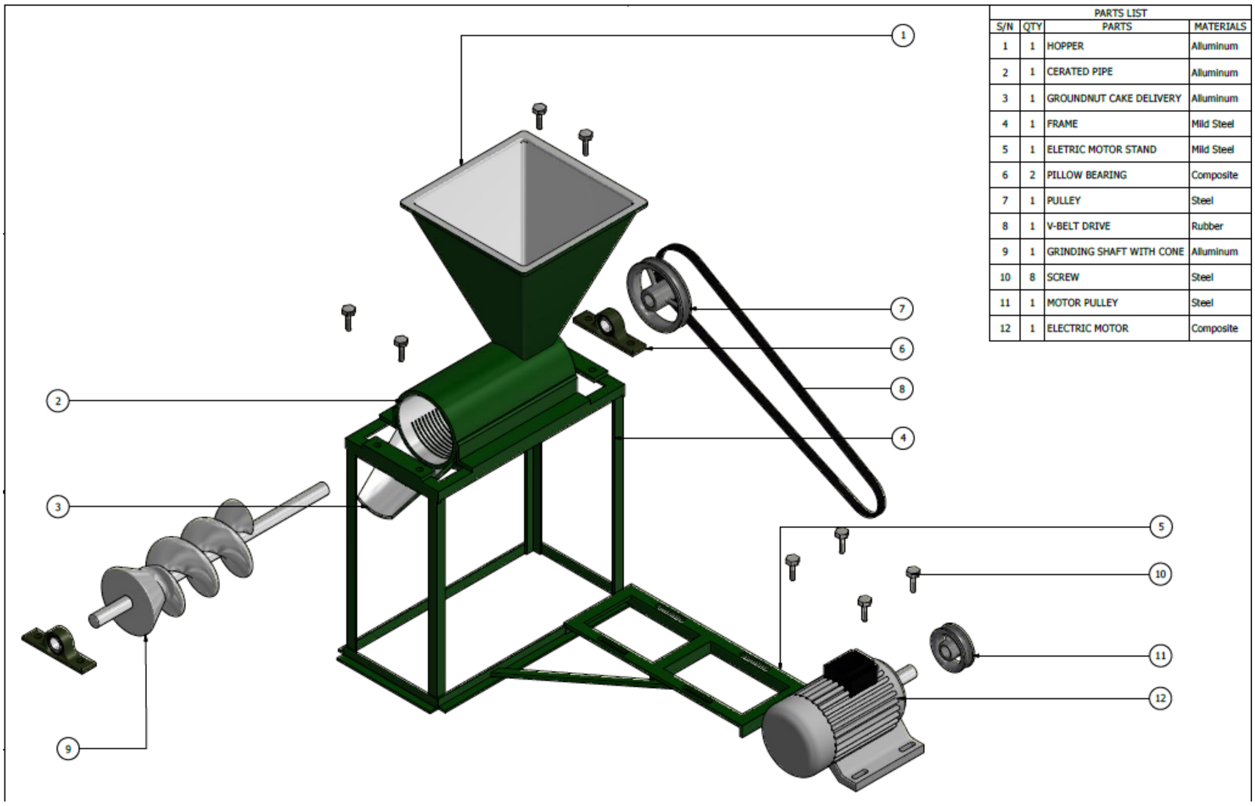


Fig. 5: Isometric Projection



PARTS LIST			
S/N	QTY	PARTS	MATERIALS
1	1	HOPPER	Aluminum
2	1	CERATED PIPE	Aluminum
3	1	GROUNDNUT CAKE DELIVERY	Aluminum
4	1	FRAME	Mild Steel
5	1	ELETRIC MOTOR STAND	Mild Steel
6	2	PILLOW BEARING	Composite
7	1	PULLEY	Steel
8	1	V-BELT DRIVE	Rubber
9	1	GRINDING SHAFT WITH CONE	Aluminum
10	8	SCREW	Steel
11	1	MOTOR PULLEY	Steel
12	1	ELECTRIC MOTOR	Composite

Fig. 6: Exploded view of the machine.

3. MACHINE PERFORMANCE

Plate 1 showed a pictorial view of the experimental machine. A 25 kg bag of groundnut was purchased from a local market in Ogbomosho, Oyo State. Following the investigations carried out by Olaomi (2008) and Ajao *et al.* (2010) which state that for groundnut to express its optimum oil, it has to be pretreated. The groundnuts were therefore pretreated by subjecting it to open pan roasting for 25 minutes at 100^{o}C following the traditional method reported by Adeeko *et al.* (1990), Ogunsina (2010), and Olatunde *et al*. (2014). About 5 kg of the pretreated groundnut was then introduced into the machine and the efficiency of extracted oil with other machine parameters was then calculated using the equations below. The test was replicated thrice.

$$Machine\ Efficiency\ (\%) = \left(\frac{Practical\ oil\ yield}{Theoretical\ oil\ yield} \times 100\right)\% \quad \text{(Aluko et al., 2020)} \tag{11}$$

Theoretical oil yield = Standard oil percent × Weight of groundnut (12)

Groundnut oil density = 0.9 g/ml (Jack *et al.*, 2012)

$$\text{Mass of oil extracted(g)} = \text{Density of the oil}\left(\frac{g}{ml}\right) \times \text{Volume of oil extracted(ml)} \tag{13}$$

The oil present in a groundnut seed is between 30-45% (FAO, 1998), and 30% oil content is adopted for this work.

As of February 2018, the experimental machine by one-off manufacture costs NGN 40,320 (forty thousand, three hundred and twenty naira only). The bill of engineering measurement and evaluation are shown in Table 1.

Table 1. Bill of Engineering Measurements and Evaluation for Groundnut Oil Extracting Machine.

S/N	Description	Material	Dimension Obtained from market	Aggregate Cost (₦)	Required Specification	Prorated Cost (₦)
1	Electrode	Mild Steel		250	Gauges 12	2,500
2	Belt drive		30cm radius	120	V - belt	120
3	Pulley		9.5cm radius	1,200		1,200
4	Shaft with cone	Mild Steel	80cm long	5,000		5,000
5	Bolt and Nut		3cm	30		450
6	Pillow Bearing		1.2 radius	1500		3,000
7	Pipe	Mild Steel	10.5cm radius	2,000		2,000
8	Frame Stand	(38 x 38) mm Angle Iron	2m	4,000		4,000
9	Hopper	5mm flat Galvanised steel	(0.35 x 0.35) m	2,000		2,000
10	Cutting Disk			750		1500
11	Grinding Disk			750		750
12	Painting	Green		800		800
13	Workmanship			10,000	-	10,000
14	Miscellaneous			7,000	-	7,000
	Total					**40,320**

4. RESULT AND DISCUSSION

The results obtained from the performance evaluation of the constructed machine showed that its average efficiency for groundnut oil extraction is 60.11% when compared to the 30% oil content of groundnut as shown in Table 2 below. This value is quite close to the result of Olawepo, *et. al*., (2000) that fabricated a palm kernel oil extracting machine with an efficiency of 65 %. The machine is cost-effective at the cost rate of ₦40,320 compared to other groundnut oil extracting machines such as that of Olatunde *et al*. (2014) which cost ₦160,000

Table 2. Shows the Result of the Machine Testing

Parameters	1	2	3	Average
Weight of groundnut (g)	4200.00	4600.00	4200.00	4333.33
Theoretical oil yield (g)	1260.00	1380.00	1260.00	1300.00
Volume of oil extracted (ml)	787.50	1027.00	799.50	871.33
Mass of oil extracted (g)	708.75	924.30	719.55	784.20
Efficiency (%)	56.25	66.98	57.11	60.11

5. CONCLUSION

A groundnut oil extracting machine was developed which is simple to operate and maintain at an affordable cost for local farmers using locally available materials. It is capable of extracting oil from groundnut thereby producing groundnut cake as a by-product. This proves a significant step in solving the problem of complexity and cost ineffectiveness of the existing extracting machines. A machine of this nature will be suitable for small and medium-scale applications in the processing of groundnut and the extraction of its oil.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the contribution of Mrs. Abiola Alamu during the processing stage of the material used for the machine testing.

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