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Research Article

Performance Evaluation of Groundnut Oil Extracting Machine Developed for Small Scale Farmers

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ABSTRACT

Groundnut oil extraction by a mechanical device is gaining more recognition in Nigeria but has been 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 was developed which is easy to operate and maintain at an affordable cost for local farmers using locally available material. This is to address the limitation of groundnut oil extraction in Nigeria, especially among local farmers. The machine was designed to run with a 3 hp single-phase variable speed electric motor at a specific speed of 540 rev/min and it works based on impact, compressing, and shearing force on the groundnut. The experimental machine is capable of extracting oil and at this same time process groundnut as a by-product into cakes called kuli-kuli. The experimental machine was tested with three replicates of roasted groundnut to determine its performance efficiency. The research showed that the machine had a performance efficiency of 60.1%. The machine developed was found to be cheap, effective, and affordable to the rural farmers.

Keywords: Groundnut; Oil; Extraction; Expeller; Kuli-kuli

INTRODUCTION

As of today, Nigeria has become one of the leading countries in groundnut productions which had necessitated for an effective preservation and processing of the nut to avoid spoilage associated with excessive production. In groundnut processing, the oil extraction is a well-established industrial activity in a number of developing countries. This is due to the fact that, since the early 1950's, most oil seeds growing countries had favored indigenous oil extraction in preference to the export of oilseeds [1,2] According to FAO, 1998, groundnut is rich source of edible oil which had in range 30%-45% oil, 20%-50% protein, and 10%-20% carbohydrate. Overtime, local farmers use manual method for the extraction of groundnut oil which tends to be more tedious, time wasting and the oil generated from the process contains impurity. Although, there are some existing oil-extracting machines which 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 purpose. This high cost of the oil extracting machine had result in the increase in 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 which 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.

MACHINE DESIGN

Design calculation

The low-cost groundnut oil extracting machine was developed with locally available materials. The machine was designed to run with 3 hp single phase electric motor at a speed of 540 rev/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.

Power requirement. The velocity of the shaft:

$$V = \frac{\pi ND}{60} \quad (1)$$

The average shaft speed required to extract oil from oil seed, N=540 rpm [3] If the shaft diameter, D=0.03 m. Hence, V=8.48 m/s.

The total force exerted on the shaft:

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$$F_T = F_P + F_S + F_C \quad (2)$$

If force 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 the force exerted by the cone on the shaft, F_C=78.48 N Hence, the total force exerted on the shaft, F_T=255.06 N

The maximum power rating:

$$P=F_T V \quad (3)$$

P=255.06 × 8.48=2162.9 W=2.2 KW=3 hp

From torsion equation:

$$\frac{T}{J}=\frac{\tau}{r} \quad (4)$$

Where the radius of the shaft, r=15 mm. The torsional Shear Stress, τ=56 N/mm². The polar moment of inertia of the shaft about the axis of rotation:

$$J=\frac{\pi \times D^4}{32} \quad (5)$$

J=79521.56. Therefore, the twisting moment (or torque) acting upon the shaft, T=296880.51 N/mm.

Belt drive. Considering figure below, length, L of the belt connecting shaft pulley and the motor pulley may be estimated as:

$$L=\pi(r_1+r_2)+2x+\frac{(r_1-r_2)^2}{x} \quad (6)$$

Where r_1=radius of shaft pulley (100 mm), r_2=radius of motor pulley (25 mm), *x*=distance between the center of shaft pulley and motor pulley (420 mm). Therefore, from the equation 6, L=1246.09 mm as shown in the Figure 1.

Considering the coefficient of friction μ=0.3 between the belt (rubber) and pulley (mild steel) at high speed.

T_1=Tension on tight side of the belt (N)

T_2=Tension on 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):

$$\sin\alpha=\frac{r_1-r_2}{x} \quad (7)$$

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

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

Therefore,

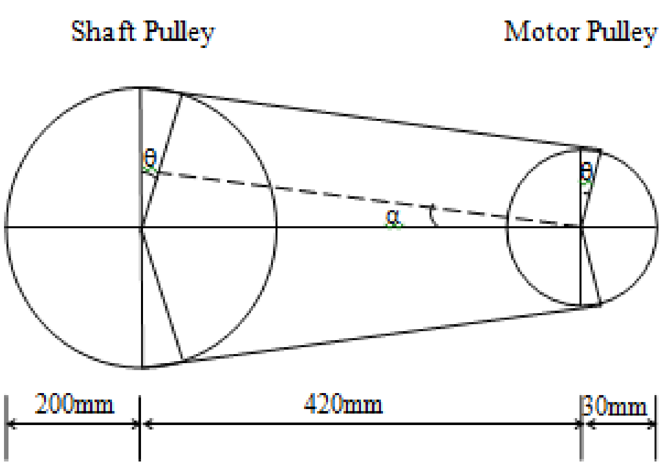


Figure 1: Shaft and pulley diagram use with its dimension.

$$\alpha=24.625^0 \, and \, \theta=2.28\,rad;\ \mu=0.3$$

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

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

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

Shaft. Considering figure below, the force exerted on shaft by cone, R_c=8 kg=78.48 N; by shaft pulley, R_p=5kg=49.05 N; by conveyor, R_{co}=4 kg=39.34 N. As shown in Figure 2.

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

Therefore,

$$(78.48\times 10.8)+(39.34\ (15.7+10.8))-(R_Y(7.5+19+15.7+10.8))+(49.05\ (8+7.5+19+15.7+10.8))=0;\ R_Y=92.12N$$

$$\Sigma F_y=0$$

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

The vertical bending moment at point A=1.276 N; at point B=808.14 N; at point C=748.955 N; and at point D= 392.4 N

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=0 N; at point D=6190.88 N; and at point E=0 N

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

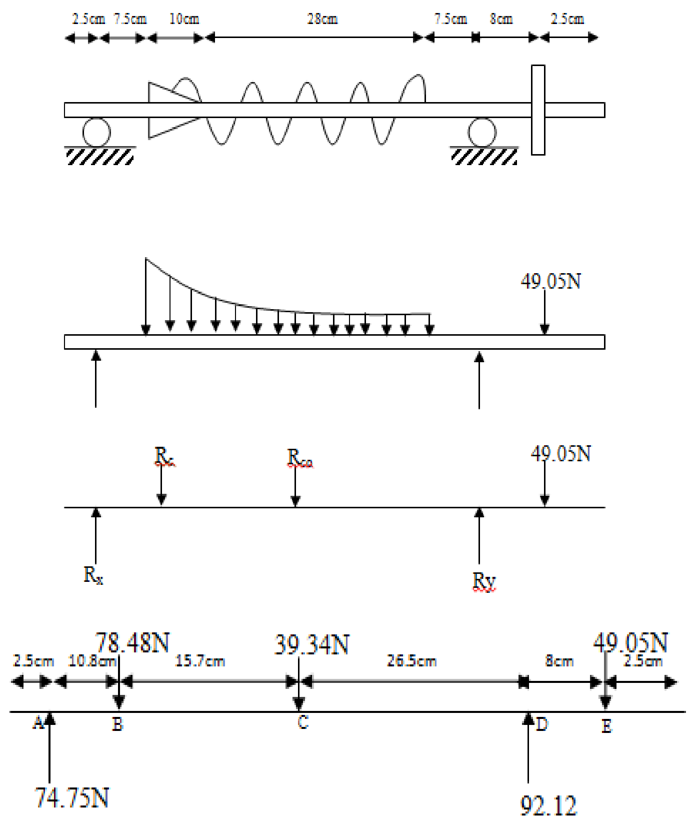


Figure 2: Shaft loading diagram.

vertical loading, therefore the shaft will not bend or break at any point because there is balanced force on the vertical loading. As shown in Figure 3.

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 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 cake outlet. The major part of the machine is the extracting unit consisting of two main components which includes; extracting pipe that is perforated beneath and shaft on which there is cone and screw conveyor:

- The Pipe is part of the machine that houses the mechanism that extracts the oil from the oil seed and then let 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 of 41cm in length and it is made of steel
- 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 rotate in a clockwise direction powered by the electric motor

The machine drawings and pictorial view of the experimental machine are shown in Figures 4-6.

MACHINE PERFORMANCE

A 25 kg bag of groundnut was purchased from a local market in Ogbomosho, Oyo State. Following the investigations carried out by [4] 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°C

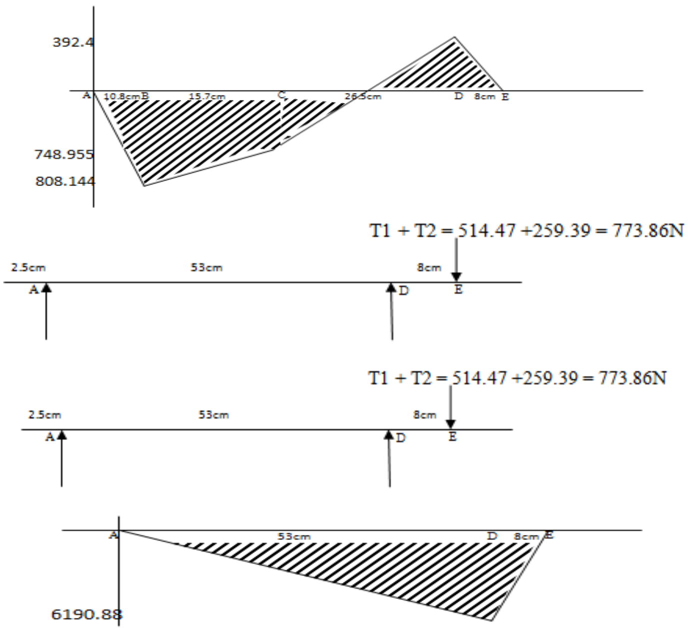


Figure 3: The bending moment and deflection diagrams.

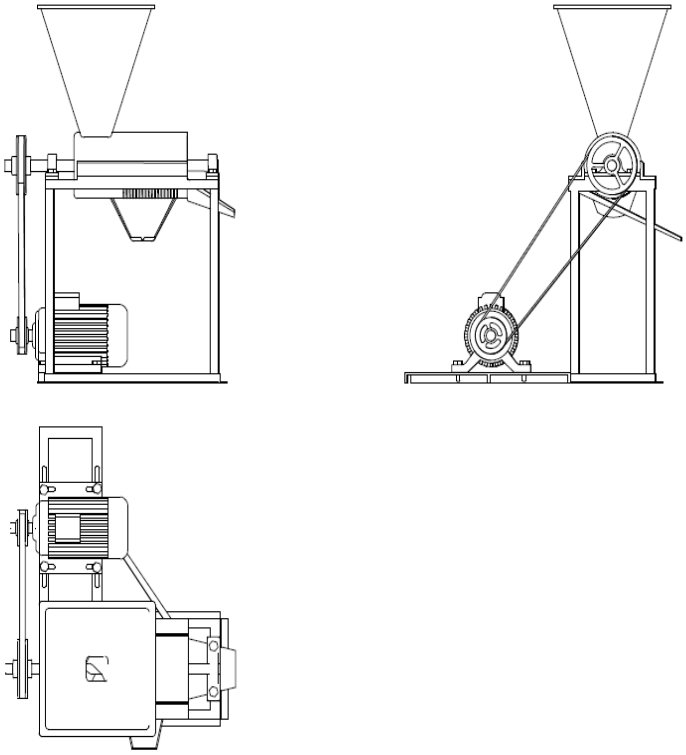


Figure 4: Orthographic drawing.

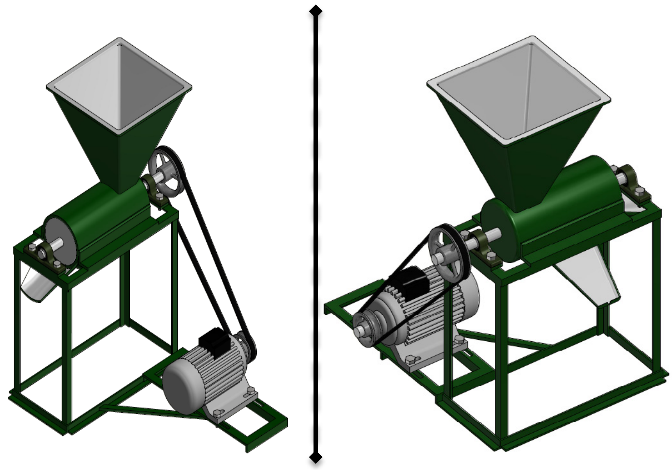
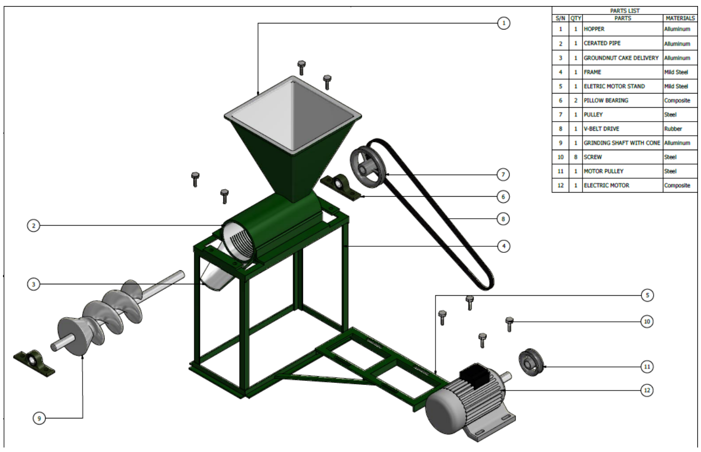


Figure 5: Isometric projection.



PARTS LIST			
S/N	QTY	PARTS	MATERIALS
1	1	HOPPER	Alluminum
2	1	CERATED PIPE	Alluminum
3	1	GROUNDNUT CAKE DELIVERY	Alluminum
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	Alluminum
10	8	SCREW	Steel
11	1	MOTOR PULLEY	Steel
12	1	ELECTRIC MOTOR	Composite

Figure 6: Exploded view of the machine.

following the traditional method reported by [5-8] About 5 kg of the pretreated groundnut was then introduced into the machine

Table 1: Bill of engineering measurements and evaluation for groundnut oil extracting machine.

S/N	Description	Material	Dimension	Aggregate	Required Specification	Prorated
			Obtained from market	Cost (₦)		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 Galvanized 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**

Table 2: Shows the result of the machine testing.

Parameters	1	2	3	Average
Weight of groundnut (g)	4200	4600	4200	4333.33
Theoretical oil yield (g)	1260	1380	1260	1300
Volume of oil extracted (ml)	787.5	1027	799.5	871.33
Mass of oil extracted (g)	708.75	924.3	719.55	784.2
Efficiency (%)	56.25	66.98	57.11	60.11

and the efficiency of extracted oil with other machine parameters was then calculated using the equations below. Bill of engineering measurements and evaluation for groundnut oil extracting machine shown in Table 1.

The test was replicated thrice.

$$\text{Machine Efficiency (\%)} = \left(\frac{\text{Practical oil yield}}{\text{Theoretical oil yield}} \times 100\right)\% \quad (11)$$

$$\text{Theoretical oil yield} = \text{Standard oil percent} \times \text{Weight of groundnut} \quad (12)$$

$$\text{Groundnut oil density} = 0.9\ \text{g/ml}$$

$$\text{Mass of oil extracted (g)} = \text{Density of the oil (g/ml)} \times \text{Volume of oil extracted (ml)} \quad (13)$$

RESULT AND DISCUSSION

The results obtained from 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 that fabricated a palm kernel oil extracting machine with an efficiency of 65%. The machine has been found to be cost effective at the cost rate of ₦ 40,320 compared to other groundnut oil extracting machines such as that of [7] which cost ₦160,000 [9,10].

CONCLUSION

A groundnut oil extracting machine was developed which is simple to operate and maintain with 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.

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