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# Engineering Application of Locally Source Technology: The Reversed Engineering of Groundnut Oil Extractor

[1]**Maina, M. N.**, [2]**Hammajam, A. A.** [3]**Abubakar, A. B.** & [4]**Mshelia, Z. A.**
[1&3]*Ramat Polytechnic Maiduguri, Department of Mechanical Engineering*
[2&4]*University of Maiduguri, Department of Mechanical Engineering*

**Abstract**

Peasant farmers in Nigeria have been encountering groundnut oil extraction problems. Despite the effort made in the past the problems persist. Therefore, there is the need to always make improvements on the existing methods of extraction. A manually operated groundnut oil extracting machine was designed, constructed and performance evaluation carried out. The stages adopted include three (3) stages which are the design stage, construction stage and testing stage. The design put into consideration the techno-economic status of the rural life. A test to ascertain the performance of the machine was carried out. 1.5kg of groundnut paste and 0.41kg of hot water was charged into the extraction chamber and the quantity of oil extracted was recorded, this was repeated three times and the results were recorded. Average quantity of oil extracted from 1.5kg of groundnut was found to be 0.68kg and extraction efficiency was 74%. The average number of turns or revolution per minute was found to be 64r.p.m. An improvement in the design can be achieved by increasing the gear ratio to 3:1 or more to reduce the time of oil extraction.

**Keywords**: *Traditional, Groundnut, Oil, Extraction, Manually Operated.*

*Corresponding Author:* **Maina, M. N.**

**Background to the Study**

The groundnut, (*Arachishypogaea)*, also known asthe peanut or earthnut, is botanically a member of the *Papilionaceae,* largest and most important member of the *Leguminosae* (Akerele and Ejiko, 2015). It is a very important oil seed and food crop around the globe for its nutritional and trade values, (Shankarappa*et al.,* 2003). Mainly native to warmer climates, groundnuts frequently provide food for humans or livestock, and in the absence of meat, form a valuable dietary protein component, (Akerele and Ejiko, 2015). Groundnuts are almost exclusively processed in combination withthe utilization of the residue for human consumption. Groundnuts give edible and pleasant tasting oil for direct human consumption and are used as salad oil or for cooking. The oil is also further processed to margarine or Vanaspati in India, soaps, paints and cosmetics. The oil content of groundnut can contain up to 50% oil (although the usual range is 40% to 45%) and 25 % to 30 % protein (Hammos,1994).

Processing or oil extracting from groundnut involves a wide range of methods. Some of these include; traditional, mechanical, chemical and mechano-chemical method (Ewaoda*et'al*, 2008). Traditionally, oil is extracted from oil seeds, nuts and pulse by roasting and grinding to fine particles or paste. The mechanical methods involve the use of screw and hydraulic presses (Ojomo*et'al*, 2011). According to several studies( Khan and Hanna, 1983; Ibrahim and Onwualu , 2005) revealed that the technologies involved in the extraction of oil from oil bearing agricultural products and confirmed the above short comings of the traditional methods. Thus, there is the need to mechanize oil extraction to reduce the drudgery involved in the traditional means of extracting the commodity. Similar findings reported from, (Oluwole *et'al*., 2003; Oluwole *et'al*., 2007) There are a number of mechanical extractors with good oil recovery but the majority of these extractors are medium to large scale equipment. This equipment are normally complex and present the problem of maintenance, accessibility of spare parts and availability of power source inputs (Ibrahim and Onwualu, 2005) making them uneconomical to small-scale farmers. Therefore, small-scale manually operated oil expeller will no doubt be a suitable substitute to traditional means of extracting vegetable oil, because of its lower initial and operating costs and ease of handling and maintenance. This paper presents the reversed engineering of a manually operated groundnut oil extracting machine. The objectives are to evaluate the performance of the machine in terms of oil yield, extraction rate, and extraction efficiency.

**Material and Methods**

**Materials**: The materials selected for the fabrication are; mild steel sheet, angle iron and stainless steel rod.

**Method**

The design method adopted in this work was conceptual design, which is based on analysis. The design analysis of various component parts was carried out and the machine was constructed according to the results obtained from the analysis.

**Description of the Machine**

The machine consists of three (3) major units;

(i) The frame (ii) Gear box (iii) Hopper

Figure 1 below depict the 3D model diagram of the machine.


**Fig. 1:** 3D model diagram the oil extractor stand frame

**The Frame:** Is a four legged structural member made from angle iron to which other components parts are firmly welded and others tightened using bolts and nuts. The frame is made from 2 inches mild steel angle bar of 5mm thickness.

**Gear Box:** The gear box is the unit in which the rotation motion of the driver shaft is transferred to the driven shaft via the bevel gear assembly. The gear casing is a cubic box constructed from 1½ inches angle iron having 350×350×240mm dimensions.

**Hopper:** Is a cylindrical metal container which is centralized vertically upright within the frame of the machine by means of bolts and nuts at the base and a ring which holds it at the top to avoid mis-alignment or shaking during operation. The Hopper has a diameter and height of 210mm and 270mm respectively. Figure 2 below show the parts assemble of the machine .

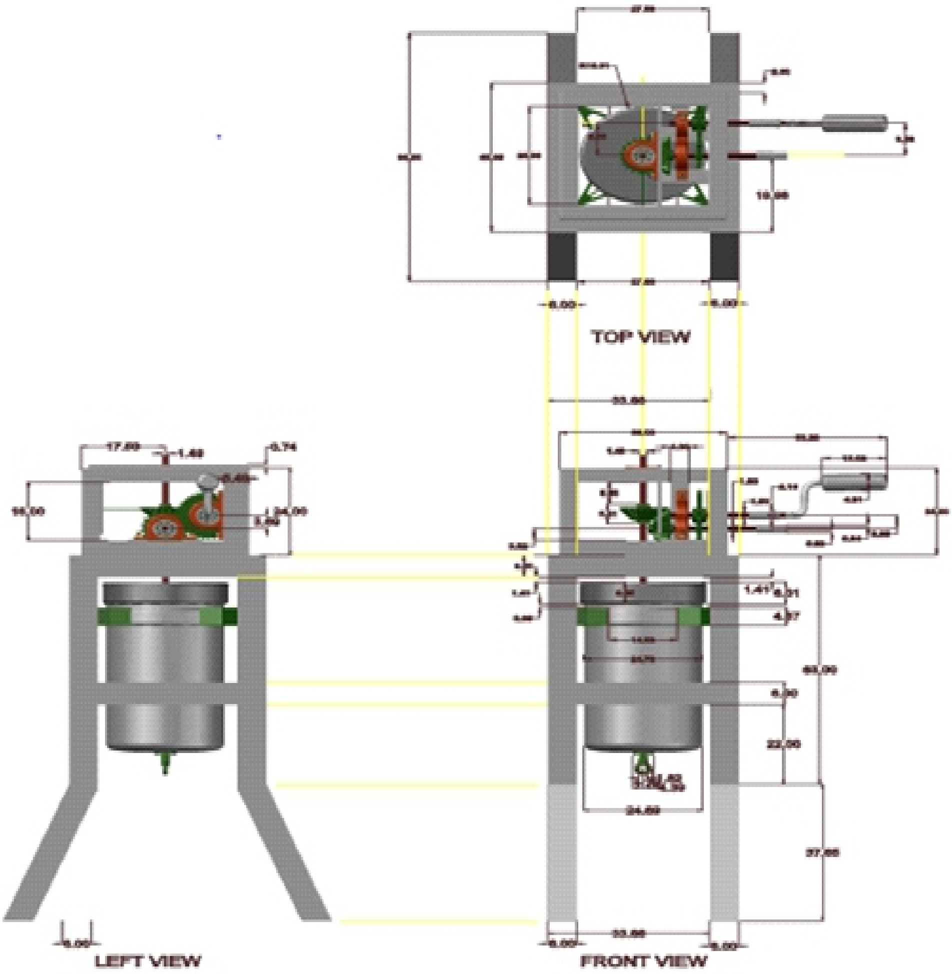


**Fig. 2:** Parts assemble of oil extractor

**Working Principle of the Machine**

The working principle of the machine is based on the arrangement of the gears. The two spurs gears are used to transmit horizontal rotation of the handle shaft to the two bevel gears which transmit the motion to a vertical stirrer shaft which is centralized within the hopper. As human force is transmitted (at right angle) to the stirrer which stirs the paste contained in the hopper of the machine. The continual stirring process results in extraction of the oil from the paste. Figure 3 below depict the working principle of the machine.

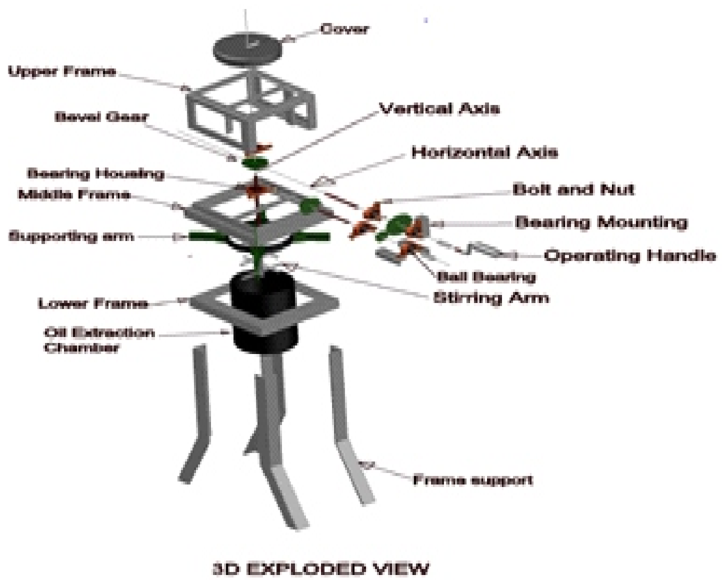


**Fig. 3:** Working principle of the different components of the machine

**Bevel Gear Speed**

The speed of the bevel gear can be obtained by using the formula

$$N_1 T_1 = N_2 T_2 \quad (1)$$

(Shigley and Misckhe, 1989).

Where: $N_1$= Speed of the pinion gear in Revolution per minute (*R.P.M*).
$T_1$= Number of teeth on the pinion gear.
$sN_2$= Speed of the bevel gear (which is the speed of the shaft, stirrer).
$T_2$= Number of teeth on the bevel gear.

From equation (1)

$$N_2 = {T_1 N_1}/{T_2}$$

Thus, if $N_1$ which is the average number of turns of the handle per minute is 64, $T_1$= 14 and $T_2$= 18, then $N_2$= 49.78 rpm.

**Force Analysis on the Shaft**

The two main forces on the shaft in consideration for this design are:
1. The shear stress acting on the shaft.
2. The torsional deflection of the shaft.

**Shear Stress Acting on the Shaft**

According to (Serway and Jewett, 2003), the shear stress acting on a shaft is given as:

$$S_S = {}^{T_r}/_{J} \qquad (2)$$

Where: *T*= Torque acting on the shaft.

*r*= Radius of the shaft.

*J*= Polar Moment of Inertia which is given

$${}^{\pi D^4}/_{32}$$

(Khurmi and Gupta, 2005)

Where *D*= diameter of the shaft

Also by (Serway and Jewett ,2003), torque is given as:

$$T = {}^{396000H}/_{2\pi N} \qquad (3)$$

Where *H*= Horse power transmitted.

*N*= Revolution per minute.

*T*= Torque acting on the shaft.

Average human power (*H*) =0.8 *kW* (Gibbs, 1999).

=0.8 x 4/3

=1.067 *HP*

$$Since\ N_1 = N_2 = 47.78$$

$$T = 96.000 \times {}^{1.067}/_{(2 \times 3.14 \times 47.78)}$$

$$T = 1407.27 lb.in\ (pound\ inches)$$

$$but\ 1\ lb.in = 0.133 Nm$$

Therefore, *T*=159.02*Nm*.

From equation (2), we know that shear stress

$$S_S = {}^{T_r}/_{J}\ and\ j = {}^{\pi D^4}/_{32}$$

Diameter of the shaft, *D* = 25*mm* = 0.984 *inch*.

Therefore:

$$j = 3.142 \times {}^{(0.984^4)}/_{32}$$

$$= 0.0921\ mm^4$$

$$S_S = 1407.27 \times {}^{0.492}/_{0.0921}$$

$$= 7517.664\ P.S.I$$

**Torsional Deflection**

According to (Serway and Jewett ,2003), torsional deflection of a cylindrical shaft is given as:

$$\emptyset = {}^{584LT}/_{GD^4} \qquad (4)$$

Where:

$\emptyset$ = Torsional deflection of the shaft.

$L$ = Length of the shaft in inches.

$T$ = Shaft torque in *Lb.in*.

$G$ = Modulus of rigidity.

$G$ for a steel shaft =14x106 psi (Serway and Jewett, 2003).

$D$ = Diameter of the shaft in inches.

$D$ = 0.984inch.

$L$ = 12.598inch.

$T$=1407.27Lb.in

$$\emptyset = {}^{584 \times 12.598 \times 1407.27}/_{[14 \times (10)^6 \times (0.984)^4]}$$

$$= 0.78883^{\circ}$$

**Determination of Forces Acting on the Gears**

The figure 4 below show Orthographic Front View of the Gears Train. While figures 5, 6 and 7 depict the angle of the pinion gear.

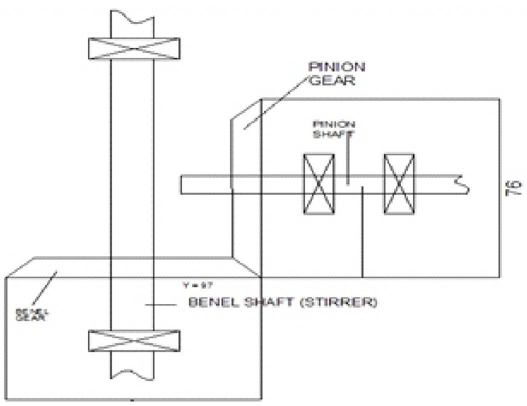


**Fig. 4.** Orthographic Front View of the Gears Train

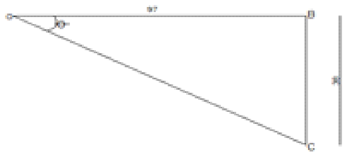

**Fig. 5**. Angle formed by the diagonal distance and the center line of the pinion shaft.

$\theta$=angle formed by the diagonal distance (*line CO*)
And the center line of the pinion shaft.
*Angle BOC*
*Tan*$\theta$*=38/97*
$\theta$*=Tan-1 0.3918*
$\theta = 21.393^0$

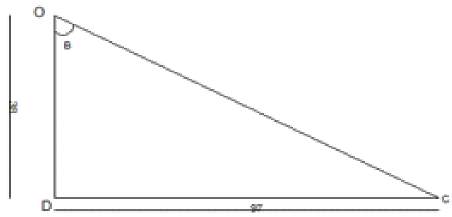


**Fig. 6.** Angle formed by the diagonal distance (line *CO*) and the center line of the bevel shaft.

B= angle formed by the diagonal distance (line *CO*) and the center line of the bevel shaft.
*Tan B = 97/38*
*= 2.5526*
$B = Tan^{-1}\ 2.5526$
$B = 68.607^0$

Line *CO* is the diagonal distance from meshing point to the Centre distance of the two (2) gears.

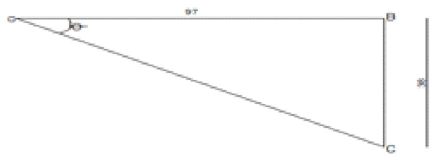

**Fig. 7.** Right angle triangle formed by the diagonal distance, center line of the pinion shaft and the pitch radius of the pinion gear.

*Triangle OCB*
$OC^2=BC^2+OB^2$
$OC^2=38^2+97^2$
$OC=\sqrt{10853}$
*OC=104.2mm*

The three main forces acting on the gears are:

$$1. \textit{the tangential force } Ft = {}^{Mt}/_{X} \qquad (5)$$

Where:
*X*= Pitch radius of the pinion.
2. The pinion thrust force Fp.

$$Fp = Ft\ TanB\ Sin\ \theta \qquad (6)$$

3. The lever thrust force

$$Fps = Ft\ TanB\ Cos\theta \qquad (7)$$

(Khurmi and Gupta, 2005)
The pinion torque Mt can be obtained from maximum allowable stress on the bevel gears.

$$S_S = {}^{16T}/_{\pi D^3} \qquad (8)$$

(Khurmi and Gupta, 2005)
Where $S_s$= Maximum allowable stress on bevel gears in psi.
*T* = pinion torque in Nm.
*D* = Diameter of the shaft carrying the gears in meters= 0.016m
(Khurmi and Gupta, 2005) gave the Ss for a gear of steel as 11000psi.
From equation (8),

$$T = S_S\ \pi\ D^3/16$$

$$T = 11000 \times 3.142 \times {}^{(0.016)^3}/_{16}$$

$$T = 0.00885\ Nm = pinion\ torque$$

$$X = Pitch\ radius\ of\ the\ pinion\ gear\ (Fig\ 2.1)$$

$$= 38mm = 0{,}038m$$

Therefore, from equation (5)

$$F_t = {}^{0.00885}/_{0.038}$$

$$= 0.232895N$$

2. The pinion thrust force $F_p$, from equation (6)

$$0.23289 \times Tan\ 68.607 \times Sin\ 21.393$$

$$= 0.2168N$$

3. The gear thrust force or bevel thrust force $F_G$ from equation (7)

$$= 0.23289 \times Tan\ 68.607 \times Cos\ 21.393$$
$$= 0.232895 \times 2.55268$$
$$= 0.5535N$$

**The performance evaluation of the machine**

The machine was evaluated using a 1.5kg groundnut mixed with these hot water in the following variation ( 0.08l/s, 1.0l/s and 0.15l/s), the mass of oil extracted, mass of the residue and time taken for the evaluations were presented in the table 3.1 and $R^2$graph was presented in the fig (5,6 and 7)

**Table 1:** The mass of oil extracted, mass of the residue and time taken

| Treatment L/s | mass of oil extracted (kg) | mass residue (kg) | times (min) |
|---|---|---|---|
| T1(0.08) | 0.6667b | 0.93b | 4.6533b |
| T2(0.1) | 0.7733a | 0.8133c | 3.89c |
| T3(0.15) | 0.59c | 1.0033a | 4.9067a |
| SE± ( 0.079) | | | |

The results of varying quantity of hot water used in the performance evaluation of groundnut oil extractor were presented in table 1 above. The analysis of variance (ANOVA) revealed that there is no significance difference among the variation of the quantity hot water at $p < (0.05)$ as shown in appendix A, however the highest mass of oil extracted of (0.7733 kg) was remarkably induced by T2, closely followed by T1 with value (0.6667kg) and least mass of oil extracted was recorded in T3. Similarly, variations on the hot water used for oil extraction was not statistically influenced by the mass of the paste residue, but the highest mass of the residue of (1.0033kg) was observed in T3, closely followed by T1 and T2 with correspondent paste mass of (0.8133 and 0.93 kg) respectively. Furthermore the time taken for the extraction were significantly influenced by the treatment used, but highest time taken of 4.9min and 4.6min was recorded from both T3 and T1 and least of 3.8min was induced from T2 .

Additionally, the regression $R^2$ relationship between the treatments used for the extraction were analyzed and presented using graph as shown in Figure 8-11, the regression relationship between the mass of oil extracted and mass of the paste residue exhibited the highest $R^2$ of (0.9986), these shows that there is positive relationship between the two variables. Similarly, the analyses revealed that there was positive regression between the time taken for the oil extraction and mass of oil extracted exhibited $R^2$ of (0.9651) which shows the highest relationship, likewise, the least $R^2$of (0.3878) was recorded between the volume of hot water used and the mass of oil extracted, which exhibit low relationship between the variable.

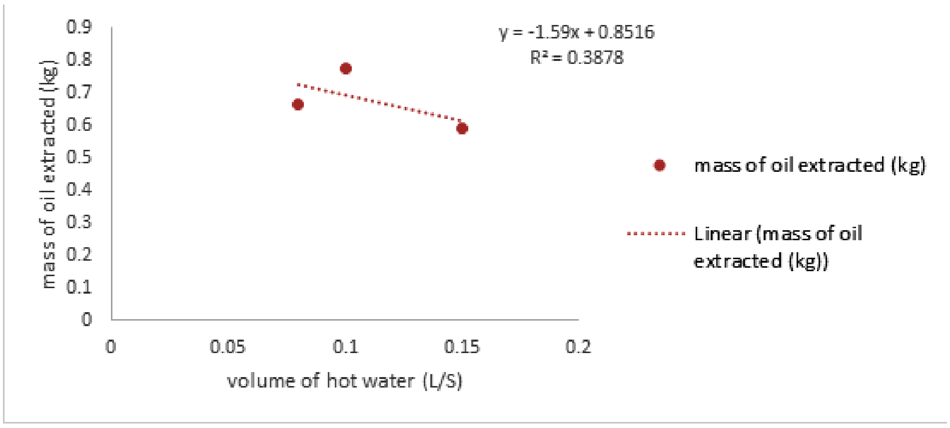


**Fig. 8:** Mass of oil extracted (Kg) vs volume of hot water (L/S)

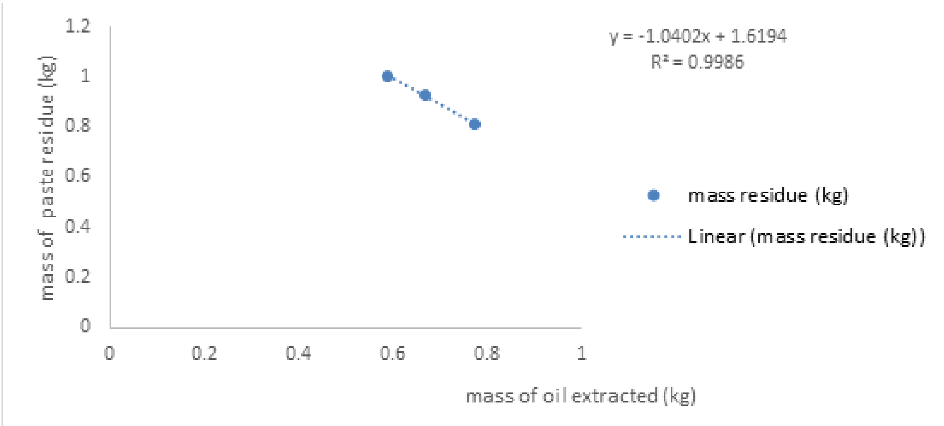


**Fig.9:** Mass of paste residue (Kg) vs mass of oil extracted (Kg)

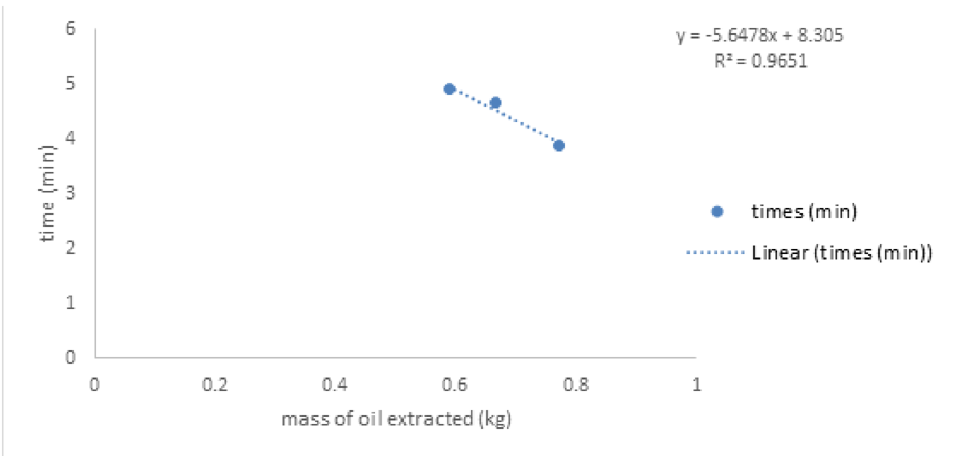


**Fig. 10:** Time (mins) vs mass of oil extracted (Kg)

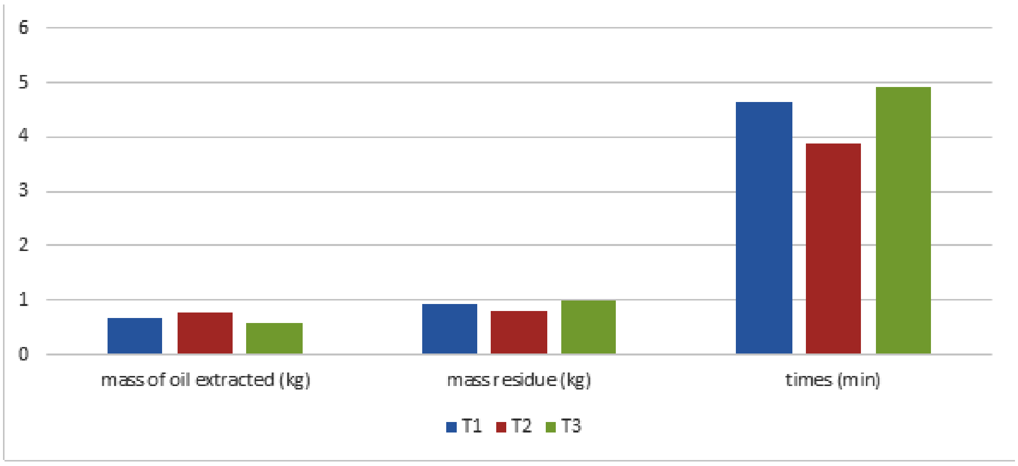


**Fig. 11**

**ANOVA:** Single Factor

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| T1 | 3 | 6.25 | 2.083333 | 4.970878 |
| T2 | 3 | 5.4766 | 1.825533 | 3.196917 |
| T3 | 3 | 6.5 | 2.166667 | 5.673541 |

**ANOVA**

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 0.189777 | 2 | 0.094889 | 0.020566 | 0.979712 | 5.143253 |
| Within Groups | 27.68267 | 6 | 4.613779 | | | |
| | | | | | | |
| Total | 27.87245 | 8 | | | | |

## Conclusion

The groundnut oil extractor was designed, constructed and tested to improve the traditional method of oil extraction using materials readily available and cheap. This is a substitute to mortar and pestle. The operation of the machine is simple, requiring little or no training and skills to perform. The efficiency of the groundnut oil extractor was found to be 74% and has an output of 0.15kg/min. The improved method of extraction; speeds up the extraction process and reduces wastage of oil and residue. The residue of groundnut produced by this machine can further be processed to groundnut cake for human consumption or can be used as animal feed.

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