www.ijecs.in
International Journal Of Engineering And Computer Science ISSN:2319-7242
Volume 4 Issue 6 June 2015, Page No. 12529-12538

Design and Construction of Groundnut Oil Expeller

Akerele O. V. and *Ejiko, S.O.

Department of Mechanical Engineering
The Federal Polytechnic Ado-Ekiti, Ekiti State
lekelyzin@yahoo.com *jcdatjiko@yahoo.com

Abstract

Groundnut is a very important oil seed and food crop around the globe based on its nutritional and trade values, it also serves as food for humans or livestock, and in the absence of meat, forms a valuable dietary protein component. Oil extracted from groundnut by traditional means can produce about 20-30% from the groundnut whereas the mechanical methods will yield a higher percentage. A mechanical means of extracting oil was designed, constructed with locally available materials and tested for groundnut oil extraction. The machine consists of the frame, hopper, gear reduction unit and the power shaft. It was powered by a 15 hp three-phase electric motor. The expeller has an average extraction efficiency and capacity of 72.94 % and 61.4kg/hr respectively. The machine comes with a production cost of ₦197, 000. The expeller can be used for small scale groundnut oil extraction in the rural and urban communities.

Keywords*: Groundnut, Machine, Expeller, Efficiency, Oil*

Introduction

The groundnut, *Arachis hypogaea*, also known as the peanut or earthnut, is botanically a member of the *Papilionaceae*, largest and most important member of the *Leguminosae*. Hans and Frans. (1989). 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. Hammos (1994) Groundnuts are almost exclusively processed in combination with the utilization of the residue for human consumption. In fact often the bye-product, a kind of a snack called Kulikuli in Nigeria and some other African countries, is usually the main product and the processing of the groundnut oil only as part of the process. 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). Oil is extracted from groundnut through either traditional means (mostly dependent on human energy with about 20-30% of the oil extracted) or mechanical means with over 30% of the oil been extracted (Olaomi, 2008). Most vegetable oils are recovered by grinding, cooking, expelling and pressing, or by solvent extraction of the raw materials. The most common method of extracting edible oil from oilseeds is mechanical pressing of oilseeds (Bamgboye and Adejumo, 2007).

Extraction of groundnut oil could be done in two major ways that is the traditional and improved methods. The traditional method is usually a manual process and involves preliminary processing and hand pressing. The improved method consists of chemical extraction and mechanical expression. The chemical extraction method requires the use of organic solvents to recover the oil from the products. Mechanical method involves the application of pressure to already pre-treated oil-bearing products. It employs the use of devices like screw and hydraulic presses as a means of applying the pressure (Gunstone and Norris, 1983).

Vegetable oil expellers are of different types and forms based on design, construction and the raw materials they are to process. Alonge *et al.,* (2004) develop a small scale screw press for groundnut oil extraction while a mechanical compression rig was developed by Olaniyan and Oje (2007) for shea butter extraction. Olaniyan (2010) developed a manually-operated expeller for groundnut oil extraction and the performance of palm kernel oil (PKO) extracting machine was evaluated by Olawepo-Olayiwole and Balogun (2004). In most PKO and soya bean oil (SBO) extraction mills, large and commercial scale industrial expellers are used; such expellers are expensive, involve high level technology which cannot be afforded by small scale and low income oil millers. In order to assist the small scale oil millers in the rural communities, small scale screw press oil expellers need to be designed, constructed and integrated into the vegetable oil industry. The goal of this work is to design, develop and test a small scale screw press oil expeller for groundnut in the rural communities. This would go a long way in ensuring food security, alleviating poverty, and creating employment for the teaming youth in the communities.

The aim of this work is to design and fabricate an improved, durable and electrically powered oil expeller making use of accessible raw material. In order to achieve this, specific objectives such as develop a machine to extract oil from an oil bearing fruit, reduce the amount of time spent in extracting oil and increase oil yield by a considerable percentage, thereby increasing income and providing a suitable alternative to industrial oil millers that is affordable to small scale oil milling industries.

Materials and Methods

The design was targeted toward achieving the following, high oil yield, high extraction efficiency, high quality of oil, availability and low cost construction of groundnut oil expeller. Other considerations included the desire to design the cylindrical barrel to accommodate the require quantity of raw material. Also considered is to design the worm shaft to ensure maximum conveyance, crushing, grinding and pressing of the nuts. Consideration was also given for a strong main frame to ensure structural stability and strong support for the machine.

Description of the machine

The machine has the following specifications; capacity of 100 kg/hr for expelling, speed range between 50 and 100 rpm, screw thread thickness of 5 mm, length of Power screw shaft 600 mm, integral cone length of 120 mm, screw threaded section of 530 mm length and an extraction chamber with 70 mm internal diameter and 308 mm length. The Isometric and orthographic view are shown in Figures 1 to 5, while Figure 6 represent the machine pictorial view.

Design Analysis

Hopper Design

The hopper design is based on the volume of frustum of a pyramid. The volume of the pyramid is obtained by subtracting the volume of a smaller pyramid from that of a larger one as given by Khurmi and Gupta (2004)

$$V = \frac{1}{3}\pi\left(R^2 H - r^2 h\right) \tag{1}$$

Where R = outer radius, H = external height, r = inner radius and h = internal height. There values are 175 mm, 350 mm, 50 mm and 100 mm respectively, when applied a volume of 0.011m^3 was obtained.

Extracting Chamber Design

The extraction chamber is designed based on internal pressure in the chamber, the extracting chamber is treated as a thin walled cylinder or vessel with equation 2 as given by hall et al, (2002) the tangential stress perpendicular to the axis of the cylinder is

$$\sigma = \frac{\rho d_{ec}}{2t} \qquad (2)$$

Where σ = perpendicular or hoop stress estimated as 36.25Mpa, ρ = internal pressure is given as 4.5MPa and d_{ec} = internal diameter of extracting chamber is given as 70mm to obtained a thickness of 5 mm. The volume of the extracting chamber (V_{ec}) is given as $1.473\times10^{-4}m^3$.

Forces Acting on the Screw Threads

The total axial force F acting on the screw threads is given by equation 3 as stated by Shigley and Mischke (1989) $F = P\frac{(\cos\mu\lambda - \mu\sin\lambda)}{\sin\mu\lambda + \mu\cos\lambda}$

(3)

Where P is the force needed to crush and move the groundnut seeds,

= 10,520.797N

Torque Required To Turn Power Screw Shaft

The torque, T_s required to turn the power screw shaft against the axial load according to Shigley and Mischke (1989) is given in equation 4.

$$T_s = Fr_m \frac{(\tan\alpha + f/\cos\theta n)}{(1 - \frac{f\tan\alpha}{\cos\theta\, n}} \qquad (4)$$

where F = axial load resulting from crushing of seeds, r_m is mean thread radiu, α is screw thread lead angle, f = coefficient of friction is 0.3, θ_n is angle between tangent to tooth profile and a radial line measured in a plane parallel to thread helix, θ is conical ejector lead angle (30°). Khurmi, and Gupta, (2004) established the equation for tanα as shown in equation 5.

$$\tan\alpha = \frac{lead\ angle}{2\pi rm} \qquad (5)$$

r_m, is mean radius of conical elector since it is very much in contact with the seed and does the actual pressing.

$$\therefore r_m = (72+45)/2 = 58.5mm$$

Since pitch = lead angle

$$\tan\alpha = \frac{75}{2\pi x 58.5} x75 = 0.2040$$

∴ The torque T_s, required to turn the power screw shaft is determined to be Ts = 3256Nm

Power Required To Drive Power Screw Shaft

If average N = 60rpm

$\therefore \omega_S = (2\pi 60) / 60$

∴ Using T_s = 3256Nm, the power P_e, required to drive the power screw shaft is determined from equation 6 by (Khurmi and Gupta, 2004).

$P = T_S \times w_s$ (6)

Where T_s = tongue on power screw shaft

w_s = angular speed of power screw shaft

$P_e = 3256 \times 2\pi = 20.458kW$

Shearing Forces/Bending Moment on Power Screw Shaft

The shearing forces arid bending moments are determined from fig. 3.4 below, considering the weight of the shaft (135N) and seeds (0.009N) and the load responsible for crushing and pressing of seeds using B. M diagram, maximum B. M occurs at point D, which is at 0.24 m to R_A. Maximum bending moment at D is 538.88 Nm

Determination of Power Screw Shaft Diameter

The power screw shaft being subjected to both torsional and bending loads, has its diameter obtained, based on the combined loading according to ASME design shafting code is given by Hall *et al.*, (2002) in equation 7.

$$D^3 = \frac{16\sqrt{(Kb-Mb)^2-(Kt\,Mt)^2}}{\pi\,Ss} \qquad (7)$$

where D is shaft diameter, M_b is bending load, M_t is torsional load , K_t is combined shock and fatigue factor applied to bending moment, K_b is combined shock and fatigue factor applied to torsional moment ,S_s is Allowable shear stress in shaft. From ASME design shafting code, K_b and K_t for rotating shaft experiencing minor shock equals 1.5 to 2.0 and 1.0 to 1.5 respectively

Using a factor of safety of 2

$$S_s - \frac{0.5 \text{ X } 621}{2} = 155.25Mpa$$

Using M_b = 1538.88Nm and M_t = 3766.7Nm from ASME design shafting code

$$D^3 = 16/\pi \text{ X } 162 \text{ X } 10^6 \text{ X } \sqrt{(1.5 \text{ X } 1428.88)^2 + (1.$$

$= 1.34976 \times 10^{-4}$m

∴ D = 51mm which is the design diameter

Actual diameter used is 45mm

Since actual diameter of shaft used is greater than calculated design the ASME design code for solid shafts is satisfied.

RESULTS AND DISCUSSION

Test was carried out to evaluate the performance of the machine. In carrying out this text, the machine was run without load for l0 minutes with a 3 phase, 1470 rpm, 11.2 KW electric motors.

At the end of the l0 minutes, the machine was loaded with 2,500g well dried groundnut seed through the feed hopper having adjusted the conical ejector clearance to 1.0mm. The adjustment was done with the aid of the four adjusters. The extraction time for the 2,500g of groundnut seeds was noted. Also the weights of the extracted oil and the resulting cake were recorded. At the end of the first trial, another two trials were made with the same conical ejector clearance (adjustment) of 1.0mm. On successful completion of test for adjustment of 1.0mm, the same procedure was followed in carrying out the test for conical ejector adjustments of 2.0mm and 3.0mm. The extraction time, weights of extracted oil and cake were recorded. The results of the test carried out to ascertain the performance evaluation are shown in Table 1. From Table 1, A1, A2 and A3 can be established as;

A1= Average of pressing time for 1mm = 8.4mins

For 2mm = 7.23mins

For 3mm = 6.47mins

A2= Average oil yield at clearance 1mm = 1068.3

2mm= 832.0

3mm = 723.7

A3= Average Feed Rate at clearance 1mm = 289.6 g/min

2mm = 345.7 g/min

3mm = 387.6 g/min

In carrying out the experiment, the pressure adjusting bolts and nuts was the only part of the expeller that was controlled and the cone clearance dictate the expeller feed rate, oil extraction rate, oil yield, pressing time for batch processing and the extraction efficiency.

From the test results obtained, it is obvious that with a decrease in clearance between the conical ejector and the extracting chamber, there is a corresponding decrease in the feed rate of the machine. The average feed rate at 1.0mm adjustment is 289.6g/min. This is smaller when compared to 345.7g/min and 387.6g/mm of 2.0mm and 3.0mm adjustment respectively.

This is so because, a smaller opening or clearance restricts the flow of material through the extraction chamber, and thus little difficult in machine operation.

From the results obtained, it was discovered that oil yield from the groundnut seed was dependent on the clearance between the conical ejector and the extracting chamber. At a clearance or adjustment of 1.0mm, the average oil yield was 1068g. This is higher when compared to the 832g and 723.7g obtain from the adjustments of 2.0mm and 3.0mm respectively. The reason for this is the fact that when there is a large clearance there is not enough pressure to mill the cake to remove the oil. Hence there is loss of oil as the cake comes out containing some quantity of oil.

From the test results also, it can be deduced that the smaller the clearance or adjustment of the conical ejector, the higher the time needed to mill and extract oil from the seed. At an adjustment of 1.0mm, the average extraction time was 7.23 minutes and 6.47 minutes used at clearance 2.0mm and 3.0mm respectively. This is due to the fact that at smaller clearance, much time and pressure would be required to compress and force the material out of the small clearance.

Effect of Clearance on Fineness of Cake

The decree of fineness of the ground cake depends on the clearance between the conical elector and the extraction chamber. It was observed that the extracted cake at 1.0mm was finest. This observation is due to the fact that as the flow area decreases as the pressure exerted increases. This aids the grinding and compression of the cake against extraction chamber walls, thus producing a fine cake. On the other hand, when the flow area increases, the pressure exerted on the cake becomes relatively small, thus leading to coarse cake.

Capacity Rating of the Machine

The capacity of the machine was established based on the test carried out with the machine. The average capacity of the machine is calculated from the test results in Table 1, using the feed rates.

Average capacity = $\frac{289.6 + 345.7 + 387.6}{3} = 1022.9 g/\min$

$= 61.37 Kg/hr$

$\approx 61.4 kg/hr$

Efficiency of the Machine

Efficiency, η_m of the machine is obtained from the oil extraction efficiency E, which is given by

$$E = \frac{Y}{C_0} \text{ X } 100\%$$

Where Y = oil yield in percentage.

C_0 = oil content of nut (50% for groundnut seed-maximum)

The oil yield Y is calculated from

$$Y = \frac{(W_1 - W_2)}{W_1} \text{ X } 100$$

Where W_1 = weight of un-milled groundnut seed

W_2 = weight of cake (after milling) sample

Using averages from test results in table 1

$$W_1 = \frac{(2500 + 2500 + 2500)g}{3} = 2500g$$

$$W_2 = \frac{(1465 + 1613 + 1687)g}{3} = 1588.3g$$

∴

$$Y = \frac{(2500 + 1588.3)g}{3} \text{ X } 100 = 36.47\%$$

Oil extraction efficiency, $E = \frac{0.3647}{0.5} X 100 = 72.94\%$

:. Efficiency of machine, η_m = 72.94%

Conclusion

A groundnut expeller was designed, constructed, using locally available and easily accessible materials, and tested for groundnut oil extraction. The expeller was simple enough for local fabrication, operation, repair and maintenance. Powered by a 15 hp three-phase electric motor, the expeller has an average oil yield and extraction efficiency of 72.94 % groundnut seed with a production cost of ₦197, 000. The expeller can be used for small scale groundnut oil extraction in the rural and urban communities. A cottage groundnut oil processing plant based on this technology can make an individual to be self employed and also be employer of labour. The groundnut oil produced will be at affordable costs for consumers and also provide cake for livestock feed mill.

References

Alonge, A. F., Olaniyan, A. M., Oje, K., & Agbaje, C. O. (2004): Development of a screw pressfor village level groundnut oil extraction. Journal of Agricultural Engineering and Technology, 12,46-53

Bamgboye, A.I and Adejumo, A.O (2007); "Development of a Sunflower Oil Expeller" Agricultural Engineering International: the CIGRE journal, Vol. IX, pp. 1-7

Gunstone, F. D. and Norris, F. A. (1983). "Lipids in food; Chemistry", Biochemistry and Technology, Pergamon Press

Hall, A. S., Holowenko, A. E., & Laughlin, H. G. (2002). Schaum's outline series theory and problems of machine design. (4th ed.). New York: McGraw-Hill Companies, Inc., Pp 223-267.

Hammos, R.O. (1994) "The Origin and History of Groundnut" In: Smartt, J. (2nd Ed.), The Groundnut Crop: A Scientific Basis for Improvement, Chapman and Hall, New York, USA

Hans-Jurgen, W. and Frans, W.K. (1989) "Small Scale Processing of Oil Fruits and Oilseeds" Publication of German Appropriate Technology Exchange (GATE), D-65726, Eschborn, Federal Republic of Germany

Khurmi, R. S., & Gupta, J. K. (2008). A textbook of machine design. (14th ed.). New Delhi: Eurasia Publishing House (PVT) Ltd., (Chapters 7 & 14).

Olaniyan, A. M., & Oje, K. (2007). "Development of mechanical compression rig for dry extraction of shea butter from shea kernel". Journal of Food Science and Technology, 44 (5), 465-470.

Olaniyan, A. M. (2010). "Development of a manually operated expeller for groundnut oil extraction in rural Nigerian communities". Asia-Pacific Journal of Rural Development, 20 (1),185-201.

Olaomi, J. (2008) "Design and Construction of a Motorized Groundnut oil Expelling Machine" B. Eng Thesis, Department of Mechanical Engineering, University of Ilorin, Nigeria

Olawepo-Olayiwole, O. S., & Balogun, L. (2004). "Performance evaluation of a palm kernel oil extracting machine". Proceedings of the 5th International Conference and 26th Annual General Meeting of the Nigerian Institution of Agricultural Engineers, 26, 308-311.

Shankarappa T., Robert E. R. and Virginia N. (2003) "World Geography of Groundnut: Distribution, Production, Use and Trade". Available at http://www.lanra.anthro.uga.edu/peanut/knowledgedatabase (accessed April 2, 2013)

Shigley, J. E., & Mischke, C. R. (2001). Mechanical engineering design. (6th ed.). New York: McGraw-Hill Companies, Inc., (pp 193-206).

Table 1: Performance Evaluation of Groundnut Oil Extracting Machine

	Pressing time (mm)		Weight of cake before milling (g)		Weight of cake after milling (g)		Machine oil yield (g)		Feed rate (g/min)	
S/N	Trial	Average	Trial	Average	Trial	Average	Trial	Average	Trial	Average
1	8.0		2,500		1,480		1,070		312.5	
2	8.5	8.4	2,500	2,500	1,465	1,465	1,070	1068.3	294.12	289.6
3	8.7		2,500		1,450		1,095		287.36	
1	7.4		2,500		1,640		815		337.8	
2	7.2	7.23	2,500	2,500	1,610	1,613	835	832	347.2	345.7
3	7.1		2,500		1,590		846		352.1	
1	6.9		2,500		1,720		705		362.3	
2	6.4	6.47	2,500	2,500	1,680	1,687	724	723.6	390.63	387.6
3	6.1		2,500		1,660		742		409.84	

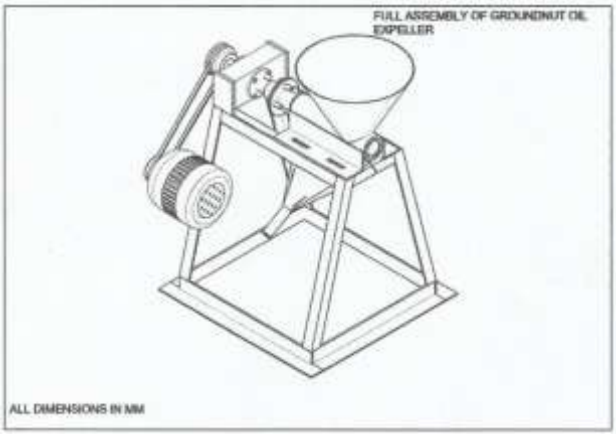

Fig 1: Groundnut Oil Expeller Assembly diagram

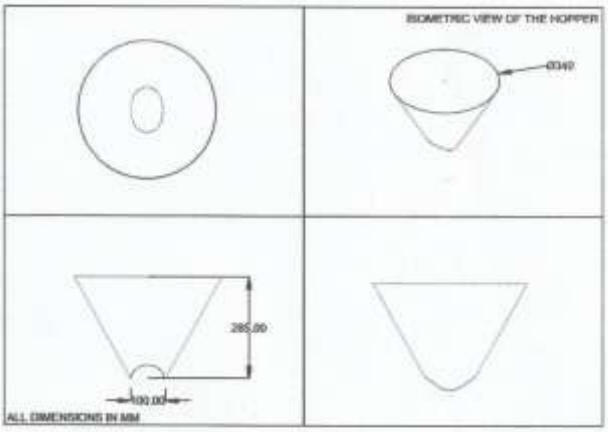

Fig 2: Isometric view of the hopper

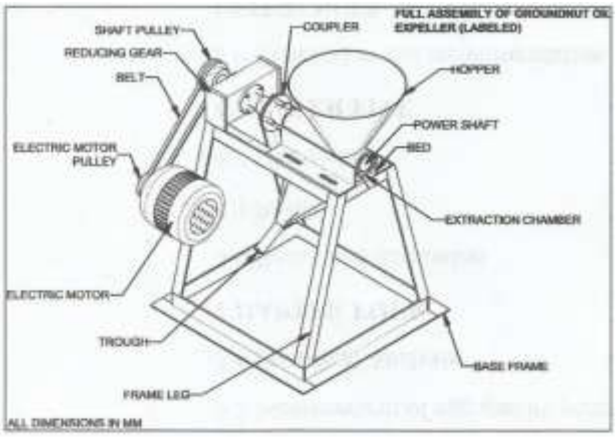

Fig 3: Assembly Machine diagram with labels

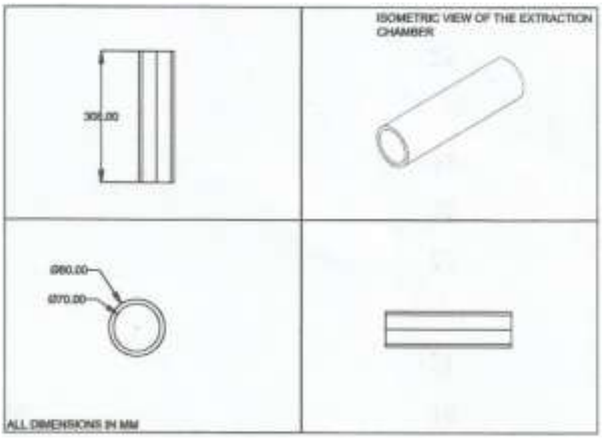

Fig 4: Isometric view of Extraction Chamber

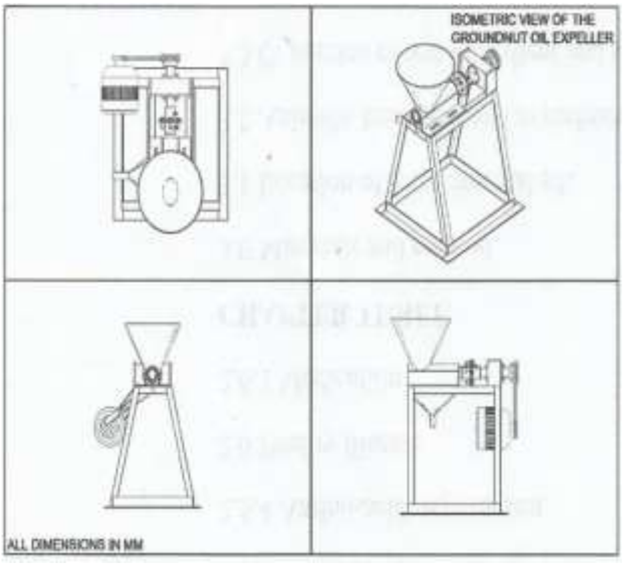

Fig 5: Orthographic view of the assemble Machine

Fig 6: Groundnut Oil Expeller pictorial view