Design and Evaluation of a Motorized and Manually Operated Groundnut Shelling Machine

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Abstract

The traditional method of shelling groundnut has proved to be inefficient, labourious, time consuming and low output. The search for more efficient and cost efficient way of shelling groundnut informs the objective of this paper. A combined motorized and manual operated groundnut Sheller was developed and evaluated. It consists of a feed hopper, frame, beaters mounted on the shaft drum, blower (fan) and a delivery chute. The machine is powered by an auxiliary engine for the motorized part and also by a handle comprising a gear system for the manually operated part. The Sheller was evaluated for percentage nut shelled, shelled nut broken and unshelled pods. The samples used are 10kg and 5kg for the electrically and manually operated parts respectively. Result of the electrically operated Sheller shows that with a mean shelling time of 45s, 4.49kg of nut were shelled with 0.11kg damage, 2.18kg unshelled and 0.67kg of winnowed chaff. The electrically operated Sheller has a shelling efficiency of 78%, cleaning efficiency of 85%, mechanical damage of 1.1% and a capacity of 345.4kg/hr. The manually operated Sheller shows that with a mean shelling time of 63.7s, 2.14kg of nut were shelled with 0.14kg damage and 1.74kg unshelled. It has a shelling efficiency of 65%, a mechanical damage of 2.8% and a capacity of 118.9kg/hr. The Sheller when operated electrically performs better than the manually operated.

*Keywords: Design***:** Fabrication; Motorized; Groundnut; Shelling Machine.

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1. Introduction
Groundnut (*Arachis hypogaea*) is a species in the legume or beans family. It was first cultivated in a valley in Peru. The groundnut seed composed of approximately equal weight of fatty and unfatty oil. The relative amount of each depends upon its variety and maturity. On the average, the oil content of groundnut seed is 42% - 52% [1]. These are obtained simply by crushing the seed. The oil contain about 80% unsaturated fatty acids, such as oleic and linoleic acids which are desirable in cooking and salad oil. Groundnut is also an excellent source of protein to balance diets that are high in cereals and starchy foods, and supplement animal proteins. The groundnut cake (*kuli-kuli*) contains concentrated proteins, minerals and vitamins [2]. In addition to the above, research findings revealed that no part of the nut is a waste. The whole plant without the nuts can be use as hay to feed animals, like horse, cattle, and goats, or otherwise it may be used as dried or ash manure.
Groundnut was first introduced to West-Africa by the Portuguese after the 16th century. In Nigeria, it is cultivated mostly in the north. The main exportation was first made to Europe in 1912. World output revealed over 14.5 million tons of unshelled nuts in 1963/64 with a production of over 1.13 million tons of shelled nuts in 1963/64 [3]. Nigeria is the world's third largest groundnut producer after India and China [4].

In developed countries groundnut processing is highly mechanized. However, in most developing countries like Nigeria, manual processing is still the norm despite the drudgery and time wastage involved [5]. The manual shelling method is achieved by applying pressure to crack the shell. In some cases, the groundnut are first wet and packed in a small sack. In this case pressure is applied by beating the bag on a stone or any hard surface. Motorized/manually groundnut shelling machine is similar to the various milling and grinding machine which are used for the crushing of the crop grains into finer grains and are mostly used domestically to facilitate or ease means of consumption. Groundnut shelling machine is a machine used to remove the shell of groundnut so as to obtain the groundnut seeds. Agrimal (Malawi) Ltd manufacture the Agrimal groundnut Sheller which is reciprocating Sheller equipment with interchangeable screens of groundnut of different sizes. Hinson PVT Ltd constructed a foot operated groundnut Sheller fitted with fly wheel for easy operation and with a blower to separate the shells from the kernels. The machine can be operated by one person and can shell 200kg in 8hr. A melon shelling machine was designed and constructed which shells by impact using a rotating impeller drum with efficiency of about 75% and capacity of 48kg/hr [6, 7]. The performance of a groundnut Sheller depends on its cylinder size, concave clearance, fan speed and sieve shaker speed [8]. The factors affecting the performance of a Sheller are classified into three categories; machine-based factors (cylinder speed, cylinder-concave clearance, type of cylinder and fan speed), crop-based factors (crop moisture content and orientation) and operator-based factors (feed rate, skill and experience) [9]. The performance indicator parameters are throughput capacity (kg/h), shelling efficiency (%), material efficiency (%) and mechanical damage (%) [10].

This paper presents the design and fabrication of motorized/manually operated groundnut shelling machine that will remove groundnut seed from the husk.

2. Design Analysis and Calculations

In the design of any agricultural machine, the properties of the crop must be taken into consideration [10]. Since the Sheller will be employed to shell groundnut, some relevant physical and mechanical properties of groundnut needs to be understood. These properties include length, breadth, mass, hardness, moisture content, angle of repose, angle of internal friction, grain-straw ratio and bulk density.

2.1 Determination of Power Required to Shell Groundnut Pod

According to Kick's relation [11], the energy required to shell groundnut is given as;

$$E = K_k F_c \log_e \frac{L_1}{L_2} \tag{1}$$

The power required to shell groundnut pod is given by

$$H = W K_K F_C \log_e \frac{L_1}{L_2} \tag{2}$$

Considering the transmission efficiency, the required motor power is given as:

$$Hm = \frac{H}{Efficiency} \tag{3}$$

Where, E is the energy required to shell; H is power required to shell groundnut pod; Hm is the motor power; K_k is the Kick's constant; F_c is the crushing strength of groundnut (kg/ms^2); L_1 is the average length of unshelled groundnut; L_2 is the average length of shelled groundnut.

Assuming that the power transmission efficiency is 80%. Given that Shelling capacity (Sc) =10kg/s, average length of unshelled groundnut (L_1) = 3.54 x 10^{-2}m, average length of shelled groundnut (L_2)= 1.48 x 10^{-2}m, K = 1.2 and Fc = 50kg/ms^2 = 500N/m.
The values obtained from calculation using equations (1) to (3) is H = 523W and Hm = 654W

2.2 Determination of Torque Developed by Sheller Shaft
The torque developed by the Sheller shaft is obtained from the relation

$$M_t = \frac{9550(KW)}{rev/\min} = \frac{9550(KW)}{n_s}$$
(4)

The velocity ratio of the driven and driving pulley is given as;

$$\frac{d_2}{d_1} = \frac{n_1}{n_2} = i$$
(5)

The pulley load is given by

$$T = \frac{M_t}{D_p}$$
(6)

Hence, the vertical and horizontal components of belt tensions are

$$Tv = T\sin 60^0$$
(7)

$$T_H = T\cos 60^0$$
(8)

The motor pulley circumferential speed is given as

$$V = \frac{\pi dn}{60}$$
(9)

Where, Mt is Torsional moment; n_s is Shelling speed; d_1 is Effective diameter of larger pulley; d_2 is Effective diameter of smaller pulley; n_1 = Motor speed; n_2 = Shelling speed.
Given that the motor pulley circumferential speed is 6m/s and a speed ratio of 8, a single phase constant speed electric motor rated 1.5Hp at 1200rpm was adopted.

Using equations (4) to (9), the values obtained from calculations are; Mt = 71.316Nm, d_1= 95mm, d_2= 760mm, T = 751N, Tv =650N and T_H = 376N.

2.3 Belt Selection for the motorized Sheller
The required belt length is obtained from the relation

$$L = 2c + \frac{\pi(D+d)}{2} + \frac{(D+d)^2}{2c}$$
(10)

Using the belt length correction factor, the compensation for the smaller pulley diameter is

$$dc = d_1xf$$
(11)

The smaller pulley angle of contact is given by

$$\theta = 2\cos^{-1}\left(\frac{D-d}{2c}\right)$$ **(12)**

The required number of belts to transmit the developed power is given as

$$n = \frac{H}{Ht}$$ **(13)**

Where, L is length of belt; C is distance between driving and driven pulleys; D is diameter of driven pulley; d is diameter of driving pulley; θ is angle of wrap on smaller pulley; n is number of belt; H is power required to shell groundnut pod; Ht = power transmitted by a section of belt. The belt length correction service factors are obtained from table [12] as 1.14 0.83 respectively, when using an A-section belt.
The values obtained from calculations using equations (10) to (13) are L=3.55m; Φ =136.8^0; a_c =0.836; n=1; dc =108.3mm; p=1.133KW; H_t = 0.896KW

2.4 Determination of Sheller Shaft Loads and Reactions
Figure 1 and 2 shows a schematic representation of the shelling unit shaft in the vertical and horizontal planes respectively.
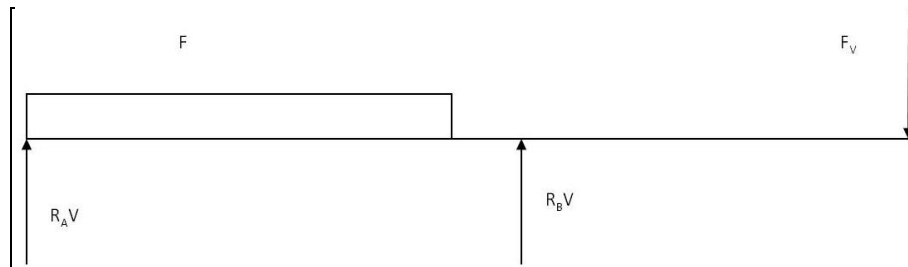

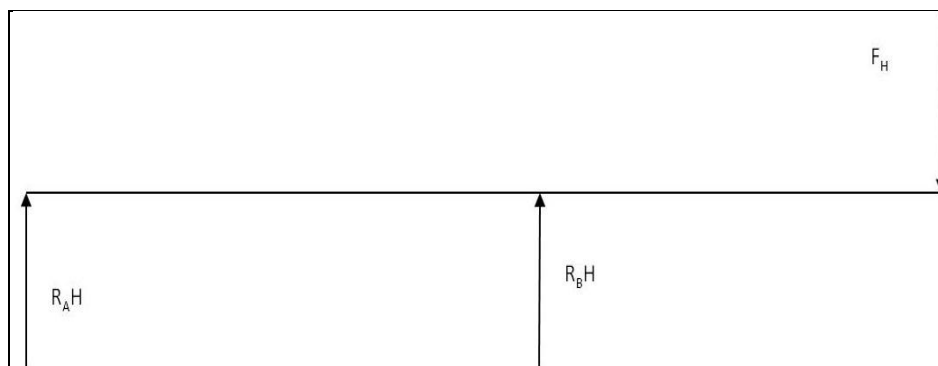Figure 1. Sheller shaft loading in the vertical plane

Figure 2. Sheller shaft loading in the horizontal plane

With reference to figure 1, the summation of forces in the vertical direction is given as

$$\sum Fr \uparrow = R_A V + R_B V - F - F_V = 0$$ **(14)**

With reference to figure 2, the summation of forces on the horizontal direction is given as

$$\sum Fr \uparrow = R_{AH} + R_{BH} - F_H \tag{15}$$

Using the crushing strength of groundnut to be 500N/m, the values obtained using equations (14) and (15) are $R_A V = 21N$, $R_B V = 879N$, $R_B H = 435N$, $R_A H = 59N$.

2.5 Determination of Shaft Diameter
For a shaft of uniform diameter and using ASME code, the required shaft diameter is given as

$$d_s = \left(\frac{N}{\pi \tau_s} \sqrt{(M_b k_b)^2 + (M_t k_t)^2} \right)^{\frac{1}{3}} \tag{16}$$

Where, ds is shaft diameter; k_b is Combine shock and fatigue factor applied to bending moment; k_t is combine shock and fatigue factor applied to torsional moment; τ_s is allowance shear stress for shaft; M_t is Torsional moment; M_b is Bending moment.

Assuming a bending and torsional moment factors $K_b = k_t = 1.5$ and $\tau_s = 35 MPa$, then for a factor of safety N = 16, the values obtained from calculation using equation (16) is ds = 12.5mm. Using a factor of safety of 0.5, the value adopted for the shaft diameter is ds = 25mm.

2.6 Determination of Blower Design velocity
The inlet velocity U_2 is given by the expression [11].

$$\frac{P_0 + \frac{1}{2} \rho U_2^2}{\eta} = \rho U_2^2 \left(1 - \frac{\pi U_2 \sin \beta}{2} - Vin \cos \beta \right) \tag{17}$$

Where, P_o is the power; U_2 is Fan inlet velocity; ρ is density of Air; η is the required speed.
Using the following values: Fan duty Q = 2m^3/s, Fan statics pressure p = 450Pa at stp, Number of blades z = 4, $\beta_2 = 44^0$, $\eta = 83\%$, $Vm = 0.2$ and outlet velocity U = 0.25U_2. The value obtained from calculations using equation (17) is U_2 = 31.515m/s.

2.7 Determination of fan outlet diameter
The fan outlet diameter d_2 is given as

$$d_2 = \left(\frac{4Q}{\pi \phi U_2} \right)^{\frac{1}{2}} \tag{18}$$

Where, ϕ is volumetric coefficient; Q is volumetric flow rate; U_2 is Inlet velocity.
Assuming a volumetric coefficient $\phi = 0.19$, the value obtained from calculations using equation (18) is d_2=799mm.

2.8 Determination of power required to drive the fan
The power required to drive the fan is given as

$$H = \frac{Qp}{\eta} \tag{19}$$

The values obtained from calculations using equation (19) is H = 1.084KW.

2.9 Determination of Blade Stress

The blade stress is given by

$$f = \frac{\rho b^2 w^2 r \cos \beta}{2t} \tag{20}$$

Since stress value of $b^2 r$ is greatest at $r = r_i = 0.29$m, the blade stress obtained from equation (20) is $f = 114$mpa.

2.10 Checking for casing thickness

The casing thickness is given as

$$t_2^2 = \frac{Pa^2 b^2}{2f(a^2 + b^2)} \tag{21}$$

Where $f = 1.14 \times 10^8$ and assuming that $a = b = 15$m, the value obtained from calculation using equation (21) is $t_2 = 0.0015$m.

2.11 Performance Evaluation

The performance of the motorized and manually operated Groundnut Sheller was evaluated based on the following parameters: shelling efficiency, cleaning efficiency, mechanical damage, and machine capacity. These parameters are given by the following expressions;

Shelling efficiency (%) $= \frac{(Q_T - Q_U)}{Q_T} x100$ (22)

Mechanical damage (%) $= \frac{Q_B}{Q_T} x100$ (23)

Cleaning efficiency (%) $= \frac{Q_G}{W_C} x100$ (24)

Where, Q_T is the total quantity of groundnut sample (kg); Q_U is the quantity of unshelled groundnut (kg); Q_b is the quantity of damaged groundnut in the sample (kg); Q_G is the quantity of shelled groundnut (kg); and W_C is the weight of chaff received with the groundnut (kg).

3. Fabrication and Assembly

The Sheller has the following main components: the feed trough through which the groundnut sheaves are fed into the Sheller, the shelling unit which consists of a drum and a concave performs the shelling operation, the cleaning unit which consists of the belt and pulleys transmits motor power. The Sheller main frame, on which other parts of the Sheller rest is made of angular mild steel. The Sheller housing is made of a galvanized metal and the hopper is constructed using sheet metals. A 2HP electric motor is the prime mover that supplies power to the Sheller by belt drive. The shelling is achieved by shelling bars on the drum by both rubbing and beating against a stationary plate called concave. Clean nuts are obtained by the blower action which blows of the chaff and other debris from the nuts.

3.1 The Hopper:

This structure is the unit in which materials to be shelled is regulated and channeled into the shelling chamber. It is made of 20gage metal sheet into a rectangular section with dimensions of

370mm × 370mmwhich tippers towards the shelling mechanism for easy flow of the materials by gravity

3.2 The Frame:
It supports the entire machine and is made by joining 50mm × 50mm and 45mm × 45mm angle iron into shape by welding. It carries the prime mover, the shelling unit, the hopper and the fan.

3.3 The Shelling Unit:
This unit is made up of sharp shaped projections called the beaters mounted on the shaft drum, on the two vertically rotating disc and the concave. The projections are 25mm long, each are mounted on the disc drum connected to the shaft that transmits power for shelling. The pods are drawn against the stationary concave by the beaters which cause the impact between the groundnuts thereby shelling the groundnuts.

3.4 The Cleaning Unit:
The cleaning unit facilitates cleaning of materials passing through the shelling unit. Air blast from the fan is connected across the falling material and effecting separation of chaff from seed. The fan blades are curved backward and made of 20 gauge mold steel sheet and mounted on a shaft. The whole assembly is enclosed in a metal housing termed as the fan housing.

3.5 The Delivery Chute:
This structure delivers and discharges the seed cleaned into a trough at the base of the machine. The structure is made of 20gauge metal sheet tapering slightly towards the base to ensure smooth delivery of groundnut.

3.6 Waste Disposal Chute:
This unit delivers and discharges chaff, dirt and unshelled pods out of the machine. The discharge is affected by the air blast from the fan. The structure is made 20 gauge metal sheets and it is rectangular in shape.

4. The Working Principle of the Sheller
The groundnut Sheller shells by impact. The machine derives it power from the electric motor or manual operation. The groundnut is lowered into the hopper, it passes through the throat (the hole on the hopper) to the surface of the concave sieve which is being rotated by the power transmitted to it through the shaft by handle or by electric motor. As the groundnut passes through the holes of the concave sieve, it is decorticated (shell) and comes out through the outlet. To achieve this, the torque transmitted must be sufficient enough to break the husk. The moisture content of the groundnut has to be moderate. If the moisture content is too low, there is bound to be too much breakage and if it is too high, there is a tendency of that some groundnut will slip off without being shelled. The Shelled nuts and chaff passing through the cutter rod sieve is channeled against an air blast from the fan for cleaning when operated electrically. Two separate channels are provided, one for the shelled seeds and the other to direct the waste chaff outside the machine. Separation of seed and chaff is provided by a winnowing fan power which is provided by a kilowatt auxiliary engine.

5. Test and Evaluation Procedure
Material use for the test includes a weighing balance, a stop watch and some containers for grain collecting. For the electrically operated procedure, a 10kg of groundnut sample were hand fed into the Sheller through the hopper for shelling. The time taking to shell the sample was noted

using the stop watch. The shelled seeds and chaff were collected and weighed on the weighing balance. The unshelled groundnut and damage groundnut were also collected and weighed. The procedure was then repeated three times and the time of completion of each was recorded. The above procedure was then repeated using a 5kg of groundnut sample for the manual operation.

6. Results

The results includes determination of the weight of the shelled seed, the weight of the unshelled seed, the weight of the damage seed, the weight of chaff collected and the effective shelling time. These are recorded in Table 1 and 2 for the motorized and manually operated machine respectively. The distribution for the motorized and manually operated Sheller is shown in Figure 3 and 4 respectively.

Table 1: Test Result for electrically (motorized) operation

S/N	Effective shelling time (s)	Weight of sample used (Q_T) (kg)	Weight of shelled nut (Q_G) (kg)	Weight of unshelled nut (Q_U) (kg)	Weight of damage nut (Q_b) (kg)	Weight of chaff (W_C) (kg)
1	45.00	10.00	4.49	2.19	0.13	0.70
2	43.00	10.00	4.46	2.10	0.09	0.60
3	46.00	10.00	4.51	2.24	0.10	0.69
X_m	45.00	10.00	4.49	2.18	0.11	0.67

Table 2 Test Result for manually operation

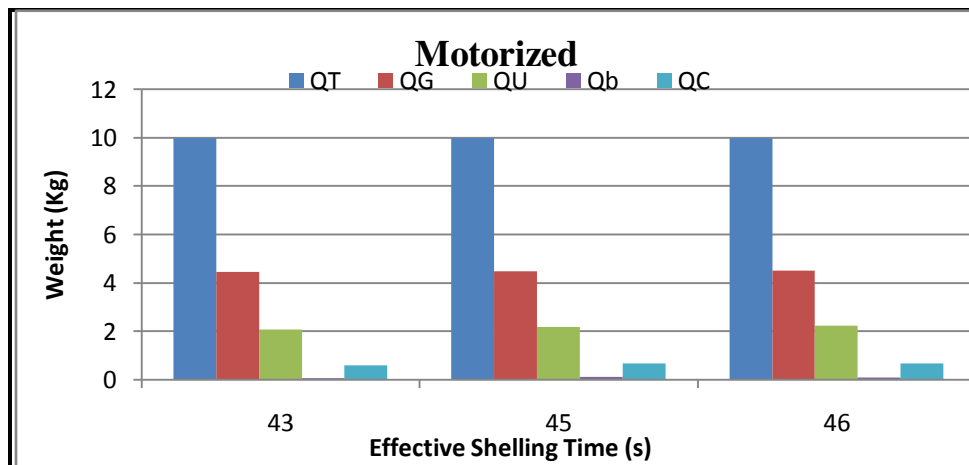| S/N	Effective shelling time (s)	Weight of sample used (Q_T) (kg)	Weight of shelled nut (Q_G) (kg)	Weight of unshelled nut (Q_U) (kg)	Weight of damage nut (Q_b) (kg)
1	62.00	5.00	2.12	1.75	0.15
2	64.00	5.00	2.10	1.70	0.17
3	65.00	5.00	2.20	1.78	0.11
Xm	63.7	5.00	2.14	1.74	0.14

X_m = Mean

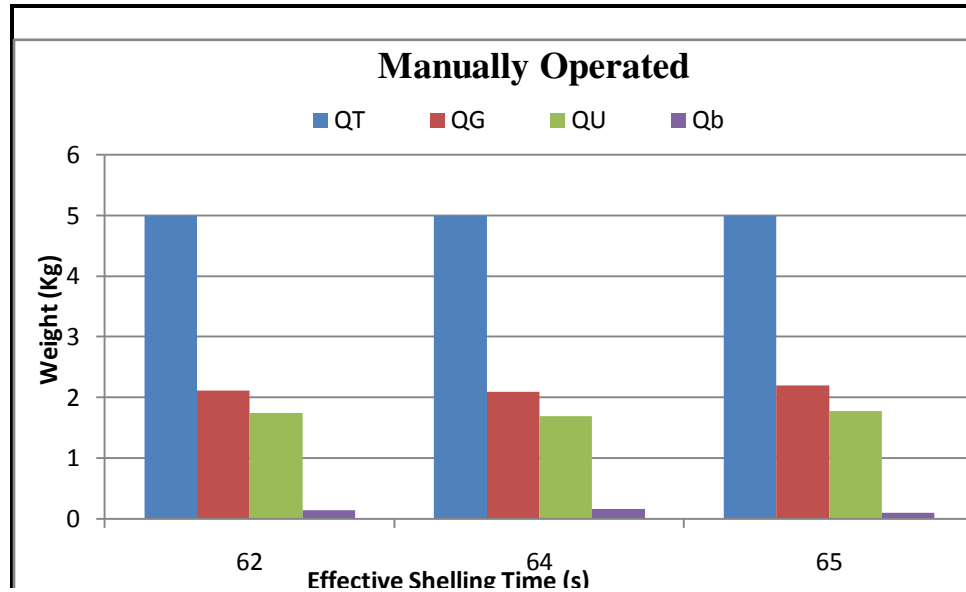Figure 3. Distribution for motorized Sheller

Figure 4. Distribution for manually operated Sheller

7. Discussions

Using equation (22) to (24) and values obtained from experiment (Table 1 and 2), for Shelling efficiency, Mechanical damage and Cleaning efficiency are 78%, 1.1% and 85% respectively when the Sheller is operated electrically. While the values obtained when operated manually for shelling efficiency and mechanical damage are 65% and 2.8% respectively. The performance of the electrically operated Sheller was evaluated in terms of its shelling efficiency, cleaning efficiency, mechanical damage and shelling capacity. The result shows that when the machine is operated electrically with 10kg of groundnut being fed in, the mean effective shelling time of 45s is used. At this time an average of 4.49kg of the nut was shelled with 0.11kg damaged nut/seed, 2.18kg unshelled pod and 0.67kg chaff as shown in Table 1 and Figure 3. The Shelling capacity is 345.4kg/h.

The performance of the manually operated Shelly was evaluated in terms of its shelling efficiency and mechanical damage. The result obtained shows that when a 5kg of groundnut is fed into the Sheller, the mean effective shelling time is 63.7s and 2.14kg of the nut were shelled and 0.14kg damage nut were recorded as shown in Table 2 and Figure 4. These outputs are far higher than the one obtained by the local shelling method. It also has less seed losses due to unshelled and broken seed while the manual operation also has a relatively high output compare to the local method but relatively low compare to the electrically operated.

8. Conclusion

A motorized and manually operated groundnut Sheller was developed. The Sheller when operated electrically with 10kg of groundnut sample performed at 78% and 85% for shelling and cleaning efficiency respectively, with a mechanical damage of 1.1%. It has a throughput capacity of 345.4kg/h. The manually operated Sheller has 5kg of groundnut sample and performed at 65% shelling efficiency with a mechanical damage of 2.8% and a throughput capacity of 118.9kg/h. With these performances, efficient shelling has been achieved. The shelling machine, if made available to small and medium scale farmers, more groundnuts will be produced with less

drudgery in less time. The Sheller was design based on the physical and mechanical properties of groundnut and therefore shells only groundnut.

References

[1]   Young, T.S. 1982. Field crop production in tropical Africa. Macmillan publishers, New York.

[2]   Hamman, A. and P. Caldwell 1974. Oil crops of the world. Heineman Education Books, Ibadan. Nigeria. pp. 319-320.

[3]   Food and Agricultural Organization, (1985 F.A.O); "Handling and storage of Food grains". Food and Agricultural Operation, Rome. pp 7

[4]   Oyenuga.V.A.(1965);"Nigeria Food and Feeding Stuffs" 3rd Edition, Ibadan, Nigeria.

[5]   J. N. Maduako, M. Saidu, P. Matthias, I. Vanke (2006). Testing of an Engine-Powered groundnut shelling machine. Journal of Agricultural Engineering and Technology, 14: 29-37.

[6]   Kassim M. James, Victor Umogbai and Isaac Itodo (2001). Development and Evaluation of a Melon Shelling and Cleaning Machine. *Journal of Emerging Trends in Engineering and Applied Sciences*, 2 (3): 383-388.

[7]   Adekunle A. S., Ohijeagbon I. O. and Olusegun H. D. (2009). Development and Performance Evaluation of Manually and Motorized Operated Melon Shelling Machine using Impact Technique. Journal of Engineering Science and Technology Review, 2 (1): 12-17.

[8]   Kaul, R.N. and C.O. Egbo 1990. Introduction to agricultural mechanization. Macmillan Education Ltd., London. pp. 132, 133, 135.

[9]   Asota, C.N. 1996. Cowpea/Soyabeans shelling: principles and practice. Proceedings of a Commonwealth-sponsored Workshop on Technology, Tools and Processes for Women. Institute for Agricultural Research, Samaru. Ahmadu Bello University, Zaria-Nigeria p.111.

[10]   Kutte, M.T. 2001. Reactivation and performance evaluation of the threshing unit of a combine harvester scrap for stationary threshing of rice. M.Eng. Thesis, Dept of Agricultural Engineering, Federal University of Technology, Yola-Nigeria. pp. 47-48.

[11]   Osborne.W.C.(1977); Fans,"2nd Metric Edition Pergamum Press" Ltd Exeter, Great Britain, London, pp 228.

[12]   Gition M.M and Prasad L.V. (1986). "Handbook of Mechanical Design". Tala McGraw Hill publishing company, New Delhi. pp 114- 146.