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# Development and Performance Evaluation of a Roasted Groundnut Dehulling Machine

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**Abstract** - *The major problem facing the availability of groundnut in Nigerian market is the post-harvest processing in which removal of chaff is a major. This research was undertaken to develop and evaluate a roasted groundnut dehulling machine. The components of the machine were designed following the standard machine design procedures. Dehulling experiments were carried out at machine speed of 200, 300, 400 and 500 rpm and at clearance values of 0.0095, 0.0090 and 0.0085 m. In each run of the experiment, 1 kg of a well-prepared groundnut was used. Results from this study showed that at machine speed of 300 rpm, optimum dehulling efficiency was achieved and above this speed, the efficiency reduces. Also, it was deduced that change in the separation efficiency depends on machine speed followed by clearance although the effect is not significant (P<0.05). Furthermore, it was revealed that throughput capacity of the developed machine increases with increased speed. The change in the machine capacity significantly (P<0.05) depends on the machine speed followed by the clearance. Conclusively from the study, best conditions for dehulling roasted groundnut are clearance level of 9.50 mm at a machine speed of 300 rpm to yield a dehulling efficiency of 80.96 %, separation efficiency of 91.89 % and mechanical damage at a reduced value of 1.93 % at a throughput capacity of 55.27 kg/h. The study showed that the develop machine is efficient for groundnut dehulling operation.*

**Key Words: Roasted groundnut, dehulling efficiency, throughput capacity, machine speed, clearance**

## 1. INTRODUCTION

Groundnut (*Arachis hypogaea*) is a major cash crops grown in many parts of the world most importantly in Nigeria [1]). The basic essential needs for man to survive are food, shelter and clothing. It is therefore not surprising that the importance of agriculture cannot be overemphasized [1]. Groundnut is the sixth most important oilseed crop in the world. It contains 48 - 50 % oil and 26 - 28 % protein, and is a rich source of dietary fiber, minerals and vitamins [2]. It grows best on soils that are well drained, loosely textured and well supplied with calcium, potassium and phosphorous [3]. Over 100 countries worldwide grow groundnut. According to Ndjeunga *et al*. [4], developing countries constitute 97 % of the global area and 94 % of the global production of this crop. The production of groundnut is concentrated in Asia and Africa (56 % and 40 % of the global area and 68 % and 25 % of the global production, respectively) [4]. Dehulling is the removal of grains/seeds from their stalk, pod, cub or fleshy coatings either by stripping, impact action and rubbing or any combination of these methods. The most popular method of dehulling which is still widely used in the most part of Nigeria is the method of rubbing between the thumb and the finger to remove the fleshy coating or the back and release the seed. This method has low efficiency, it is time consuming, and has high demand of energy and not hygienic. In addition, the output per-man hour is as low as 1 - 2.5 kg of groundnut [5]. The major problem facing availability of groundnut in the market is the post-harvest processing. In order to reduce human drudgery involved in the processing of the groundnut, improve timelines and reduce unnecessary losses, it is essential to mechanize the processing of the crop [6; 7]). This would improve the quality of the product and for it to be in a better form that could meet the standard and taste. According to Ani *et al*. [8], over 330 products can be commercially produced from groundnut and jobs can be directly created from enhanced groundnut production with small improvement in the technology and the use of improved variety with corresponding increase of cultivated acreage. As a legume crop, groundnut adds nitrogen to the soil by increasing soil fertility. In recent times, there has been increased awareness in the cultivation of food legumes like groundnut, not only as food but as soil fertilizer. This reduces the farmers' demand for inorganic fertilizer. Groundnut is grown for export, oil extraction and local use such as roasting and as an additive to vegetable dishes. They are important for smallholder agriculture and for the national diet in Nigeria; they contribute significantly to dietary requirements in most parts of the country and provide more than 25 % of all smallholder income. As pointed out by Edriss and Simtowe [9], groundnut production need to be promoted, as it is, the main source of is can provide an alternative source of cash crop. Thus, it can contribute considerably as income source and as one-way of job creation for self-employment. Unpacking economic viability of groundnut production would help to identify opportunities and constraints that can be used as input information to devise improvement strategies that intensify groundnut production [10].

## 2. MATERIALS AND METHODS

### 2.1 Design Consideration

The following factors were considered in the development of the machine:

i. Most of the components (parts) were made of aluminum and wood, which are available locally, to reduce cost of production, weight and portability.
ii. The machine should be cheaper compared to already existing designs and also readily affordable so that it can be utilized by an average local farmer.
iii. The machine should be made with readily available materials which will in turn reduce the production rate and also allow easy repairs and availability of parts.
iv. It should reduce labour input, drudgery and fatigue usually experienced in traditional methods.
v. The fan must be designed to blow the required air velocity ($V_a$) necessary to separate the chaff from groundnut. ($V_i > V_a > V_c$).
vi. The mode of operation should be easy and understandable for average farmers.

### 2.2 Machine Conception

The groundnut dehuller consists of six main components: the hopper, the brush, brush housing, blower, the frame and the delivery chute. The machine intends to maximize the use of locally sourced materials for dehulling already roasted groundnut. The major component utilized in the removal of the coating of the roasted groundnut is the brush which was housed in wooden brush housing and powered by a portable electric motor. The wooden brush was cased with aluminum for aesthetic purpose. An adjustable electric motor was utilized so as to be able to control the machine speed. A blower was incorporated to blow out the removed groundnut coating to leave only the dehulled groundnut discharged via the delivery chute (Figures 1).

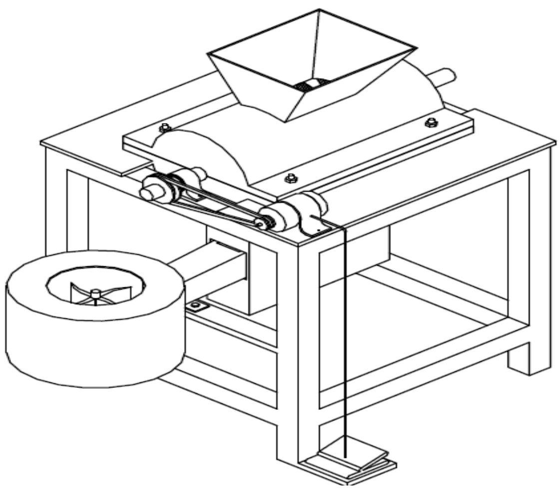


**Figure 1:** Isometric view of the groundnut dehulling machine

### 2.3 Design Analysis

#### 2.3.1 Hopper design

To design for the hopper, the capacity of the machine with respect to the hopper size was considered. The height of the hopper (h) is 0.24 m; the area of inlet for the hopper was taken as 0.20 m by 0.18 m and that of outlet of the hopper into the decorticating chamber is 0.10 m by 0.08 m. Volume of the hopper according to Khurmi and Gupta [11] was calculated using Equation 1;

$$Volume = h/3\left(A1 \times A2 + \sqrt{A1 + A2}\right) \quad (1)$$

Where

$A1 = Hopper\ inlet\ area = 0.20 \times 0.18 = 0.036\ m^2$

$A2 = Hopper\ outlet\ area = 0.10 \times 0.08 = 0.008\ m^2$

$Volume = \frac{0.24}{3}\left[0.036 + 0.008 + \sqrt{0.036 \times 0.008}\right]$

$= 0.08(0.036 + 0.008 + 0.017)$

$= 4.878 \times 10^{-3}\ m^3$

$The\ volume\ capacity\ of\ the\ hopper\ was\ calculated\ to\ be\ 4.878 \times$

#### 2.3.2 Belt and pulley design

i. **Determination of belt tension:** Equation 2 according to Khurmi and Gupta [11] was used in calculating the speed ratio which was later resolved to Equation 3 to calculate the speed of the driven pulley;

$$D_1N_1 = D_2N_2 \quad (2)$$

Where: $D_1$ is the diameter of electric motor pulley, $D_2$ is the diameter of shaft pulley, $N_1$ is the speed of electric motor and $N_2$ is the speed of driven pulley.

$$N_2 = \frac{D_1}{D_2} \times N_1 \quad (3)$$

$$N_2 = \frac{0.05}{0.1} \times 1000 = 500\ rpm$$

ii. **Belt tension:** According to Equation 4 as postulated by Khurmi and Gupta [11], the angle of wrap for open belt was calculated as follows,

$$\propto = 180° + 2\sin^{-1}\frac{RB - RA}{AB} \quad (4)$$

Where, RB is the radius of pulley of electric motor (driving pulley), RA is the radius of pulley of the shaft (driven pulley), α is the angles of wrap and AB is the center to center distance of the two shafts;

$$\alpha = 180° + 2\sin^{-1}\left(\frac{0.05 - 0.025}{0.3}\right)$$

$$\alpha = 180° + 2\sin^{-1}0.083 = 189.56°$$

Angle of wrap, α = 189.56°

$$Mass\ of\ belt, m = Density \times Volume$$

Length of belt for the machine was also derived using Equation 5 according to Akintade and Bratte [12].

$$Lenght, L = 2AB + \frac{\pi}{2}(D_1 + D_2) \quad (5)$$

$$L = 2 \times 0.3 + \frac{\pi}{2}(0.1 + 0.05) = 0.836\ m$$

$$The\ width\ and\ thckness\ of\ belt\ are\ 0.02\ m$$

$$Volume\ of\ belt = Length \times width \times thickness$$

$$Volume\ of\ the\ belt, v = 0.836 \times 0.02\ x\ 0.02$$

$$= 3.44 \times 10^{-4}\ m^3$$

$$Density\ of\ rubber\ belt, \rho = 970\ kg/m^3$$

$$Mass\ of\ belt, m = \rho \times v = 970 \times 3.44 \times 10^{-4} = 0.324\ kg$$

The belt tensions were determined using Equations 6 and 7 as described by Khurmi and Gupta [11]

$$\frac{T_1}{T_2} = e^{\mu\theta} = e^{\mu\left(\alpha\pi/_{180°}\right)} \quad (6)$$

$$(T_1 - T_2)V = P \quad (7)$$

Where $T_1$ and $T_2$ are the tensions (N) at the tight and slack sides of the belt respectively, μ is the coefficient of friction, V is the speed in rev/sec and P is the power in watts. μ is taking to be 0.25 for rubber belt running over wood pulley [13].

From Equation 6;

$$T_1 = T_2 e^{\mu\left(\alpha\pi/_{180°}\right)} = T_2 e^{0.25\left(189.56\pi/_{180°}\right)} = T_2 e^{0.83} = 2.92T_2 \quad (8)$$

But, from Equation 7;

$$T_1 - T_2 = \frac{P}{V} = \frac{746 \times 60}{500} = 89.52\ N$$

Putting equations 8 and 9 together;

$$2.92T_2 - T_2 = 89.52$$

$$T_2 = 46.63\ N\ and\ T_1 = 136.15\ N$$

### 2.3.3 Blower design

Air is required and needed to separate the chaff from groundnut. The quantity of air that could be produced by a centrifugal fan is given in equation 10 [10].

$$Q = A_f V_a \quad (10)$$

Where Q is Volume flow (discharge), $A_f$ is area of fan air duct (outlet) and $V_a$ is the velocity of air stream produced by fan.

The selected diameter for the fan 'd' is 0.1 m and the speed of the selected electric motor 'N' is 500 rpm.

Then;

$$Q = \frac{\pi d^2}{4} \times \frac{\pi DN}{60} = \frac{\pi \times 0.01}{4} \times \frac{\pi \times 400 \times 0.1}{60} = 9.948\ m^3/s$$

The velocity of air $V_a$ produce by the four blades used will be;

$$V_a = 4\left(\frac{\pi \times 400 \times 0.1}{60}\right) = 8.378\ m/s$$

Thus, due to the sudden expansion of the air outlet from the fan into the cleaning chamber there will be about ten percent reduction in velocity of air produced by the fan to gives 7.540 m/s. However, 7.540 m/s is the velocity of air (Va) require to separate the chaff from the ground-nut. This confirm with the ($V_i > V_a > V_c$) the lowest $V_i$ is 10.9 m/s [10. $V_i$ is given as terminal velocity of groundnut, $V_a$ is given as velocity of air and $V_c$ is given as velocity of chaff.

### 2.3.4 Shaft Design

#### *2.3.4.1 Design of brush*

Determination of the weight of the spikes (Ws)

The length of spike used is 0.02 m, the diameter of each spike is 0.003 m, and density of plastic is taken to be 0.00138 kg/m³ (Polyvinyl chloride).

$$Volume\ each\ spike = Area \times Length = \frac{\pi d^2 l}{4} = \frac{\pi(0.003)^2 \times 0.01}{4} = 7.069 \times 10^{-8}\ m^3$$

$$Mass\ of\ the\ spikes = Density \times Volume = 0.00138 \times 7.069 \times 10^{-8} = 9.755 \times 10^{-11}\ kg$$

$$The\ weight\ of\ each\ spike\ used = 9.57\ N$$

The total number of spikes used for the design is 798.

$$Total\ weight\ of\ spikes = 798 \times 9.570 \times 10^{-10} = 7.637 \times 10^{-7}\ N$$

***2.3.4.2 Determination of weight of wood solid cylinder per unit length (Wc)***

The length and diameter of wood solid cylinder used are 0.30 m and 0.12 m respectively while the density of wood is 650 kg/m³.

$$Volume\ of\ solid\ cylinder = Area \times length = \frac{\pi}{4} \times 0.0144 \times 0.30 = 3.393 \times 10^{-3}\ m^3$$

$$Mass\ of\ solid\ cylinder\ = Density \times volume = 650 \times 3.393 \times 10^{-3} = 2.206\ m$$

$$Weight\ of\ solid\ cylinder = 2.206 \times 9.81 = 21.641\ N$$

$$Total\ weight\ on\ the\ shaft = weight\ of\ spikes + Weight\ of\ solid\ cylinder$$

$$Total\ weight\ on\ the\ shaft = 7.637 \times 10^{-7} + 21.641 = 21.641\ N$$

$$Weight\ per\ unit\ lenght\ on\ the\ shaft = \frac{21.641}{0.3} = 72.137\ N/m$$

**2.4 Assembly and Testing of the Machine**

The designed components of the groundnut dehulling machine were assembled and mounted on the fabricated frame. The machine was tested for performance and efficiency using roasted groundnut. Prior to the commencement of the experiment, well roasted groundnuts were procured from the market. The moisture content of the procured groundnut was determined so as to know the present moisture content of material for the purpose of reporting. Then, 1 kg of the samples was measured using weighing balance for each run of dehulling and separating experiments.

**2.5 Experimental Procedure**

The moisture content of the groundnut was determined using the oven dry method at 110 ± 5 °C for 24 hours. This experiment was done in three replicates. The average of the replicates was taken and used as the initial moisture content of the samples for this experiment. The moisture content of the sample was expressed mathematically as shown in Equation 11 on dry basis.

$$M_o = \frac{W_1 - W_{bd}}{W_{bd}} \qquad (11)$$

Where: $M_o$ is the moisture content of the sample, $W_1$ is the initial weight of the sample (g) and $W_{bd}$ is the final weight of the sample (g). In each run of the experiments, 1 kg of the prepared groundnut was used. At the commencement of the experiment, the machine was connected to the adjustable portable motor whose speed was regulated and determined with the aid of tachometer. Dehulling experiments were carried out at machine speeds of 200, 300, 400 and 500 rpm. Likewise the clearance space was determined by padding up the space between the pillow bearings. The clearance values used for these experiments were 0.0095, 0.0090 and 0.0085 m. The moisture content determination method utilized was gravimetric method. Each experiment was carried out in triplicate and the average value was used so as to increase the level of certainty of results.

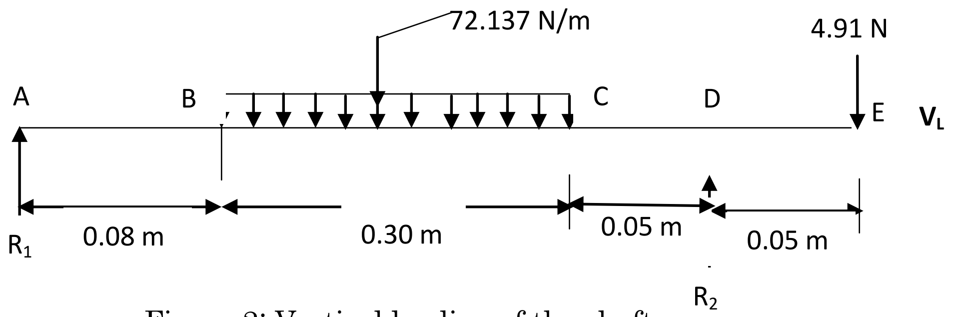
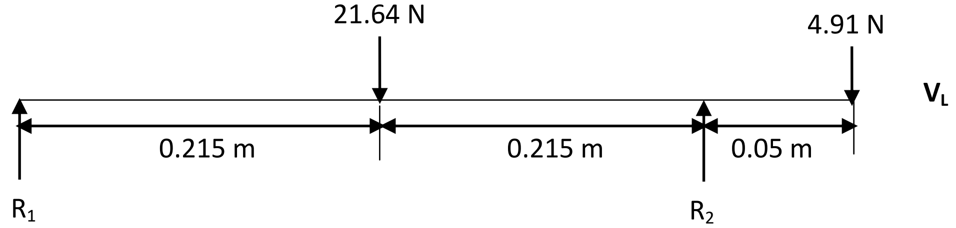



Figure 2: Vertical loading of the shaft.




*Taking moment about* $R_2$;

$$R_1 = \frac{(21.64 \times 0.215) - (4.91 \times 0.05)}{0.43} = 10.25\ N$$

$$R_2 = 21.64 + 4.91 - 10.25 = 16.3\ N$$

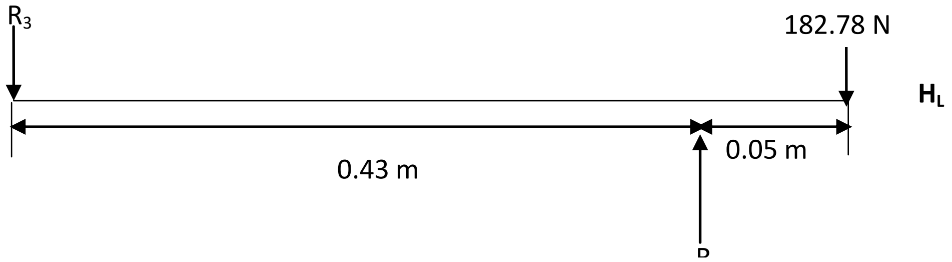



Figure 3: Horizontal loading of the shaft.

*Taking moment about* $R_4$;

$$R_3 = \frac{182.76 \times 0.05}{0.43} = 21.25\ N$$

$$R_4 = 21.25 + 182.78 = 204.03\ N$$

For the vertical loading;

$$BM\ at\ point\ A = 0; BM\ at\ point\ B = 10.25 \times 0.215 = 2.204\ Nm; BM\ at\ point\ C = 10.25 \times 0.43 - (21.64 \times 0.215) = -0.245\ Nm; BM\ at\ point\ D = 10.25 \times 0.48 - (21.64 \times 0.265) + (16.30 \times 0.05) = 0$$

$$d^3 = \frac{16}{\pi \times 40 \times 10^6}\sqrt{(9.4 \times 1.5)^2 + (14.248 \times 1.0)^2} = 2.552 \times 10^{-6}$$

$d = 0.014\ m$; *20 mm diameter was selected.*

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$$M_b = \sqrt{(M_{Vmax})^2 + (M_{Hmax})^2} = \sqrt{2.204^2 + 9.137^2} = 9.40\ Nm$$

$$M_t = (T_1 - T_2)R = (136.15 - 46.63)0.05 = 4.48\ Nm$$

The diameter of the shaft was determined using;

$$d^3 = \frac{16}{\pi\tau}\sqrt{(M_b K_b)^2 + (M_t K_t)^2}$$

Where;

$M_b$ is the maximum bending moment on the shaft (9.40 Nm), $M_t$ is the torsional moment applied to the shaft (4.48 Nm), τ is allowable shear stress on the shaft (40 MN/m² for shaft with keyway), $K_b$ and $K_t$ are the combined shock and fatigue factors applied to bending and torsional moments respectively (1.0 and 1.5 for load gradually applied shaft).

## 3. RESULTS AND DISCUSSION

Figure 4 shows the dehulling efficiency of the developed roasted groundnut chaff dehuller at different machine speed and clearance. According to the figure, the dehulling efficiency ranges from 62.2 % - 90.07 %. The maximum value (90.07 %) of the dehulling efficiency was recorded at machine speed and clearance of 300 rpm and 9.5 mm respectively, meanwhile, the minimum value (62.22 %) of the dehulling efficiency was recorded at machine speed and clearance of 500 rpm and 8.5 mm. the graphical representation shows that the dehulling efficiency of the machine increases at machine speed of 200 rpm to 300 rpm with increasing clearance but as the machine speed increases furthermore, there was a decline in the rate of dehulling also at increasing machine clearance. The mathematical relationship between the dehulling efficiency and the input parameter (clearance and machine speed) is shown in Equation 12 with a determination coefficient of 0.8224 and this shows that the equation can significantly (P<0.05) predict the 82.24 % change in the dehulling efficiency as a function of machine speed and clearance.

$$DE = -357.57 + 78.37C + 0.32S - 0.01CS - 3.7C^2 + -0.00039S^2 \quad (11)$$

Where;

DE is the dehulling efficiency, C is the clearance (mm) and S is the machine speed (rpm)

The combination of machine speed and clearance can significantly explain the variation in the dehulling efficiency at 95 % probability level. However, the change in the dehulling efficiency significantly (P<0.05) depends on the machine speed followed by the clearance.

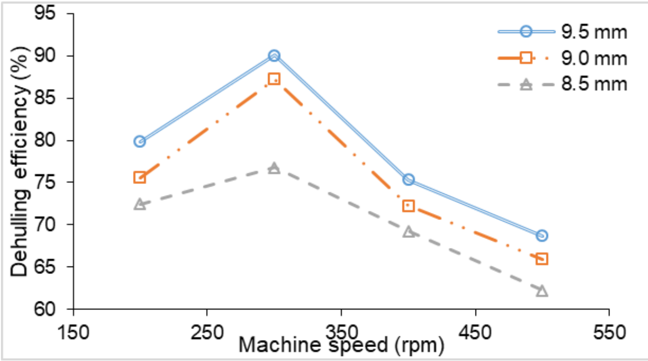


**Figure 4:** The dehulling efficiency of the roasted groundnut dehuller

This result has a similar trend with that reported by Akintade and Bratte [12] when they evaluated the performance of a roasted groundnut (A*rachis hypogaea)* blanching machine where they also reported that efficiency of blanching machine reduces at increased machine speed. The machine speed when increased about a certain point leads to reduced machine performance as the nuts either breaks or forced out of the dehulling chamber without efficient chaff removal. For this research, at machine speed of 300 rpm, the optimum dehulling efficiency was achieved and furthermore above this speed, the efficiency reduces.

### 3.1 Separation Efficiency of the Groundnut Dehulling Machine

Figure 5 shows the separation efficiency of the developed roasted groundnut film dehuller at different machine speed and clearance. According to the figure, the separation efficiency ranges from 82.79 % - 95.11 %. The maximum value (95.11 %) of the separation efficiency was recorded at machine speed and clearance of 300 rpm and 9 mm respectively, meanwhile, the minimum value (82.79 %) of the separation efficiency was recorded at machine speed and clearance of respectively 500 rpm and 9 mm. Ayelegun and Ajewole (2015); Akintade and Bratte [12] reported in their research also that as separation efficiency of the dehulling machine is affected by the machine speed and clearance level in between the dehulling drum and the and the casing. Separation efficiency for this research also is in line with the trend reported by Akintade and Bratte [12] where they postulated that separation and dehulling efficiency reduces with increased clearance dimension.

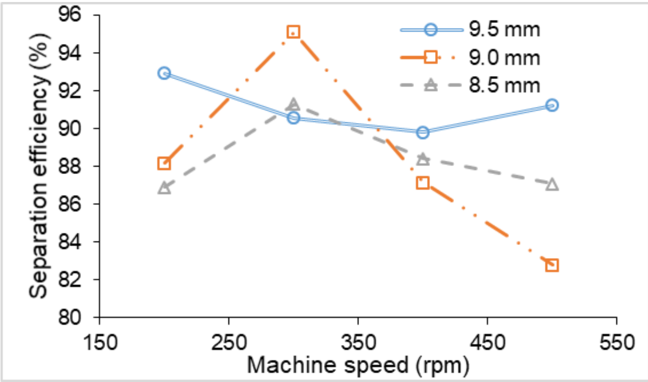


**Figure 5:** The separation efficiency of the roasted groundnut dehuller

### 3.2 Mechanical Damage of the Groundnut Dehulling Machine

Figure 6 shows the mechanical damage of the developed roasted groundnut dehuller at different machine speed and clearance. According to the figure, the mechanical damage ranges from 1.4 % - 9.3 %. The maximum value (9.3 %) of the mechanical damage was recorded at machine speed and clearance of 200 rpm and 8.5 mm respectively, meanwhile, the minimum value (1.4 %) of the mechanical damage was recorded at machine speed and clearance of respectively 300 rpm and 9.5 mm. This figure also depicts that as the as the machine speed increases from 200 to 300 rpm, the mechanical damage of the groundnut decreases with increase in machine clearance but the was an increase in mechanical damage as the machine speed increases beyond 300 rpm. The combination of machine speed and clearance can significantly explain the variation in the mechanical damage at 95 % probability level. However, the change in the mechanical damage significantly ($P<0.05$) depends on the clearance followed by the machine speed that has the least non-significant effect on the mechanical damage. As the speed increases, above 300 rpm minute, the mechanical damage percentage increases.

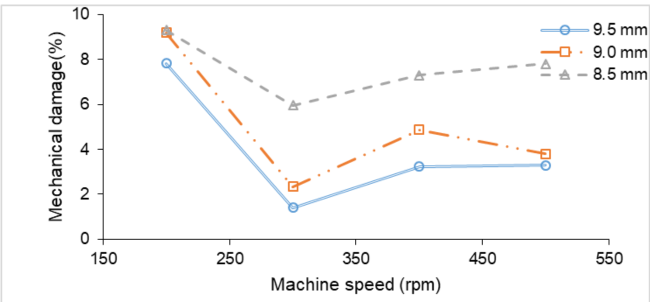


**Figure 6:** The mechanical damage of the roasted groundnut dehuller

### 3.3 Machine Capacity of the Groundnut Dehulling Machine

Figure 7 shows the machine capacity of the developed roasted groundnut chaff dehuller at different machine speed and clearance. According to the figure, the machine capacity ranges from 44.78 kg/h - 66.18 kg/h. The maximum value (66.18 kg/h) of the machine capacity was recorded at machine speed and clearance of 500 rpm and 8.5 mm respectively, meanwhile, the minimum value (44.78 kg/h) of the machine capacity was recorded at machine speed and clearance of respectively 200 rpm and 9.5 mm. However, the change in the machine capacity significantly ($P<0.05$) depends on the machine speed followed by the clearance that has the least and non-significant ($P<0.05$) effect on the machine capacity. The machine throughput capacity increases with increased machine speed and increased clearance level. Similar trend was reported by Olubo *et al.* [13] when they evaluated the effects of some test parameters on dehulling efficiency of a roasted groundnut seed dehulling machine. It was deduced also by Akintade and Bratte [12] that the throughput capacity of groundnut dehulling machine depends on the speed of machine.

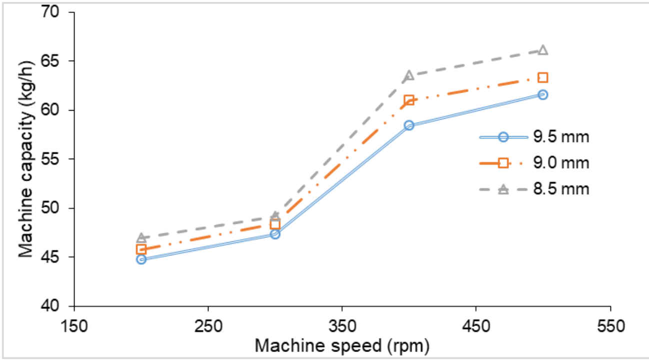


**Figure 7:** The machine capacity of the roasted groundnut dehuller

## 4. CONCLUSION

A roasted groundnut dehulling machine was designed and fabricated. The major components of the machine are the hopper with a capacity of 3 kg of roasted groundnut, the dehulling unit which housed the wooden drum with brittle brush fixed into it for the purpose of removing the chaff from the nut, the discharge chute for both the cleaned nuts and the chaff and lastly the blowing unit. The machine is easy to operate, efficient and affordable because of the material used and cost of production. The result from this study implies that the clearance and the machine speed are some of the important parameters for determining the optimal performance of the dehulling machine. Based on the machine evaluation it was concluded that dehulling efficiency reduces with increased clearance dimension. It was also observed that as the machine speed increases above 300 rpm, the mechanical damage increases. The best conditions derived from this study for dehulling roasted groundnut using the developed machine are clearance level of 9.50 mm at a machine speed of 300 rpm to yield a dehulling efficiency of 80.96 %, separation efficiency of 91.89 % and mechanical damage at a reduced value of 1.93 % at a throughput capacity of 55.27 kg/h.

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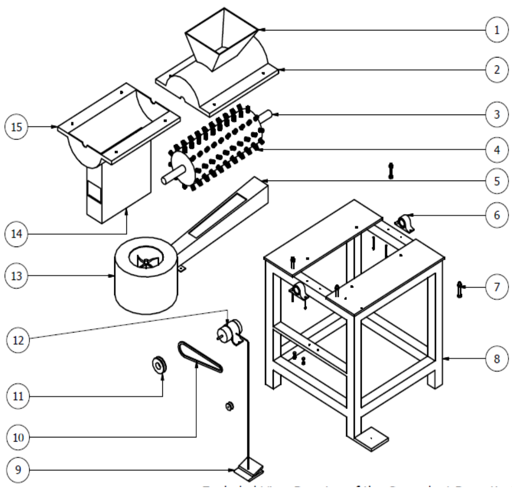
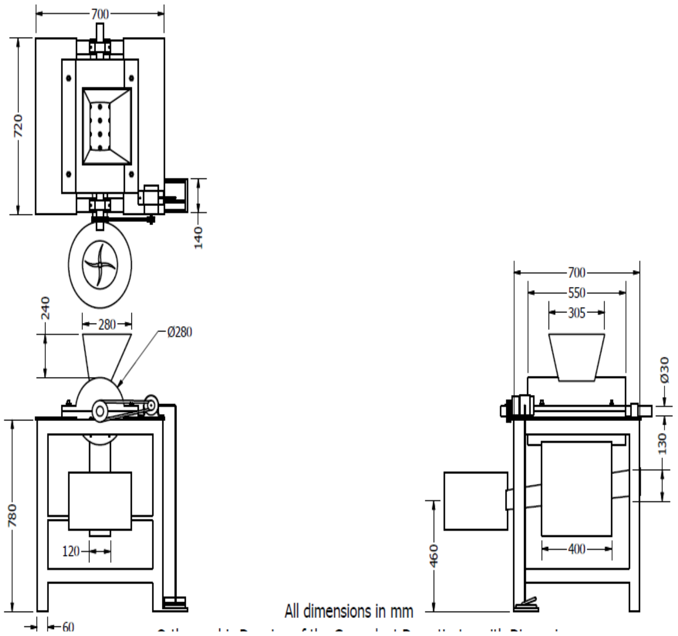
## APPENDIX



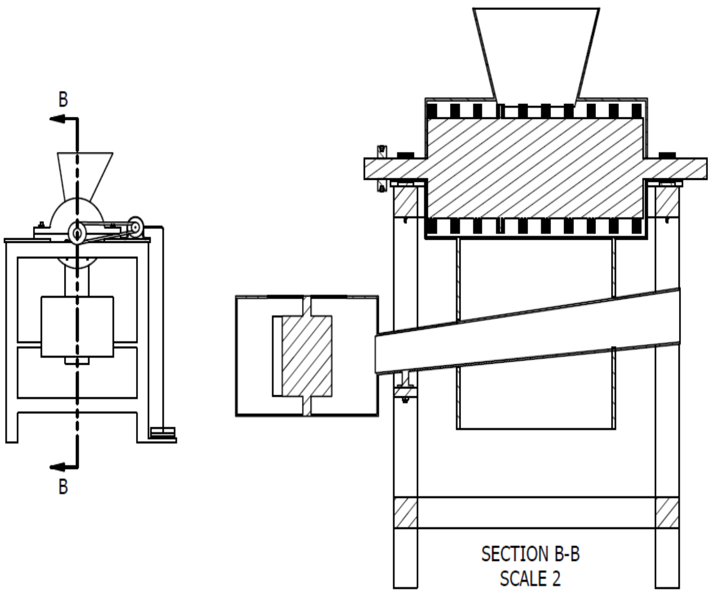
PARTS LIST

| ITEM | QTY | PART NAME |
|---|---|---|
| 1 | 1 | hopper |
| 2 | 1 | upper trough |
| 3 | 1 | shaft |
| 4 | 30 | brush |
| 5 | 1 | chaff outlet |
| 6 | 2 | bearing |
| 7 | 10 | bolt&nut |
| 8 | 1 | frame |
| 9 | 1 | motor control |
| 10 | 1 | belt |
| 11 | 2 | pulley |
| 12 | 1 | electric motor |
| 13 | 1 | electric blower |
| 14 | 1 | groundnut outlet |
| 15 | 1 | lower trough |

Exploded view of the Roasted Groundnut Dehulling Machine




Orthographic view of the Roasted Groundnut Dehulling Machine




Sectional view of the Roasted Groundnut Dehulling Machine