Design and Fabrication of a Low Cost Roasted Groundnut Seed Dehuller

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ABSTRACT

Groundnut (*Arachis hypogeae*. L) is grown in over 100 countries. In order to improve its value and storability, various ways of processing the seeds have been adopted, among which is the roasting and removal of husk or rind from the roasted groundnuts. The process of removing the husk for roasted groundnuts is mostly done manually which is time consuming and tedious, especially when large quantities are involved. The major aim of the research is to contribute to the mechanization of the process of removing husk from roasted groundnuts seeds to enhance efficiency especially for small and medium scale processing. Hence, a low cost roasted groundnut dehulling machine was designed, fabricated using locally sourced materials, tested, and its performance evaluation was carried out.

The roasted groundnut seeds were conditioned to 2.0% moisture content (w.b) and machine operational speed of 35 rpm. The dehulling efficiency of 84.72% and a throughput capacity of 41.75 kg/h were recorded during the performance evaluation. A total of N 81,050 (205 USD) was spent for the fabrication. Thus, the machine would be affordable and suitable for small and medium processors.

(Keywords: groundnut, dehuller, design, efficiency, throughput capacity, mechanical milling)

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is a leguminous oilseed grown in the semi-arid and sub-tropical regions of the world; with China, India, Nigeria, USA, and Myanmar as the leading producers worldwide. Asia and Africa hold the highest area under cultivation with 11.6 m ha (47.15%) and 11.7 m ha (47.15 %), respectively. Groundnut is grown in over 100 countries; Nigeria is the largest groundnut producing country in West Africa, accounting for 51% of production in the region. The country contributes 10% of total global production and 39% that of Africa (Girei, et al,. 2013; Ajeigbe, et al., 2014).

America groundnut (*Arachis hypogeal*) and Africa groundnut, the Bambara nut (*Voandzeia subterranean*) are the two main varieties grown in West Africa as a source of protein. Groundnut also contains sufficient quantity of carbohydrates and fats. The seeds are a nutritional source of Vitamin E, niacin, falacin, calcium, phosphorus, magnesium, zinc, iron, riboflavin, thiamine, and potassium (Ayelegun and Ajewole, 2015; Juhee Yoon, 2019).

The roots and seeds are the edible parts of the groundnut; the root can be roasted, baked, boiled, fried, or dried for flour. The seeds are consumed directly as raw, roasted, or boiled. Oil extracted from the seeds is used as culinary oil. The seeds can also be substituted for beans or lentile in soups and stews (Nord Mark, et al., 2010). Groundnut also has some medicinal use: in treating haemophilia and stomatitis; prevention of diarrhoea and beneficial for children and pregnant women. The crop is used as an industrial material for producing oil-cakes and fertilizer. The multiple uses of groundnut makes it important as both food and cash crop for the available domestic or worldwide external markets in several developing and developed countries (Akobundu, 1998; Taru, et al., 2010).

Processing is the conversion of the primary agricultural products (i.e., groundnut) into finished commodities: groundnut oil, cake, among others. Various value chains involved in groundnut processing can create job opportunities; reduce food wastage thereby enhancing food security and improving the livelihood of low income people (Oluwatayo, et al., 2008; Taphee and Jongor, 2014). Various ways of processing the seeds have been adopted to improve its storability and increase shelf life. Roasting is among these methods; removal of husk or rind from roasted groundnuts is mostly done manually by women and children by rubbing them in between their palms. Cleaning is achieved by blowing away the chaff with their mouth. This process can be tedious and inefficient for commercial quantity of the product hence the need to mechanize it (Ogunwole, 2013).

In searching for a way to solve this problem, researchers had developed several machines to dehull roasted groundnuts seeds: Ogunwole (2013), developed a spike toothed dehuller which caused splitting of the dehulled groundnuts. Also, Ugwuoke, et al., (2014) constructed a manually operated groundnut seed peeler which is made of a specially designed chamber that reduces breakages during peeling operation. It was easy to operate with a peeling efficiency of 85% and capacity of 5.4kg/h. The machine is suitable for domestic and medium scale processors. A roasted groundnut blanching machine that uses a brush was designed by Akintade and Bratte (2015). Blanch clearance, speed, and feed rate were used for evaluating the machine's efficiency.

Three levels each of feed rate, brush speed and blanch clearance were compared: clearances of 10mm, 15mm, and 20mm were used for feed rates of 02.kg/h, 0.4kg/h and 0.6kg/h and blanch speeds of 100rpm, 150rpm, and 200rpm, respectively. They concluded that changes in blanching clearance, feed rate and blanch speed affected the blanching efficiency, cleaning efficiency and mechanical damage of the seeds.

The main aim of this research is to contribute to the efforts of mechanizing the process of roasted groundnut dehulling by designing and fabricating a low cost roasted groundnut dehuller and conduct a performance evaluation of the machine to ascertain its efficiency. The design, fabrication and evaluation were carried out in the department of Mechanical engineering, Ekiti State University, Ado-Ekiti, Ekiti state and National Centre for Agricultural Mechanization (NCAM), Ilorin, Kwara state, Nigeria.

METHODOLOGY

The following methods were used in the design, fabrication and evaluation of the roasted groundnut dehuller:

Machine Design and Description

Autodesk Inventor professional 2014 was used to design the machine model (Figure 1); the major components of the design include:

i. Hopper: a pyramidal shaped hopper of dimensions, 200 x 80 x 260mm was designed for the machine using stainless steel metal;

ii. Dehulling chamber: it contains a stainless steel shaft that bears the dehulling drum with conveyor worm wound around it at regular pitch. The dehulling drum is padded, this counteracts the movement of the roasted groundnut seeds with a minimal abrasive impact to perform the dehulling operation;

iii. Discharge units: the dehulled seeds are collected down the spout while the chaff is blown away and beyond the dehulled seed through an axial fan incorporated under the spout; and

iv. Frames: a 3 x 3 x 3mm mild steel angle iron was used. This would ensure strength, rigidity and stability during operation.

Design Considerations

These factors were considered in the design of the machine:

i. Durability: Strength and stability of the materials to be used;

ii. Availability of the materials locally to keep the price of the machine down guided the choice of materials for the fabrication;

iii. Contamination: all contact surfaces with the product were designed with stainless steel materials;

iv. Physical and mechanical properties of groundnut seeds were determined from literatures; and

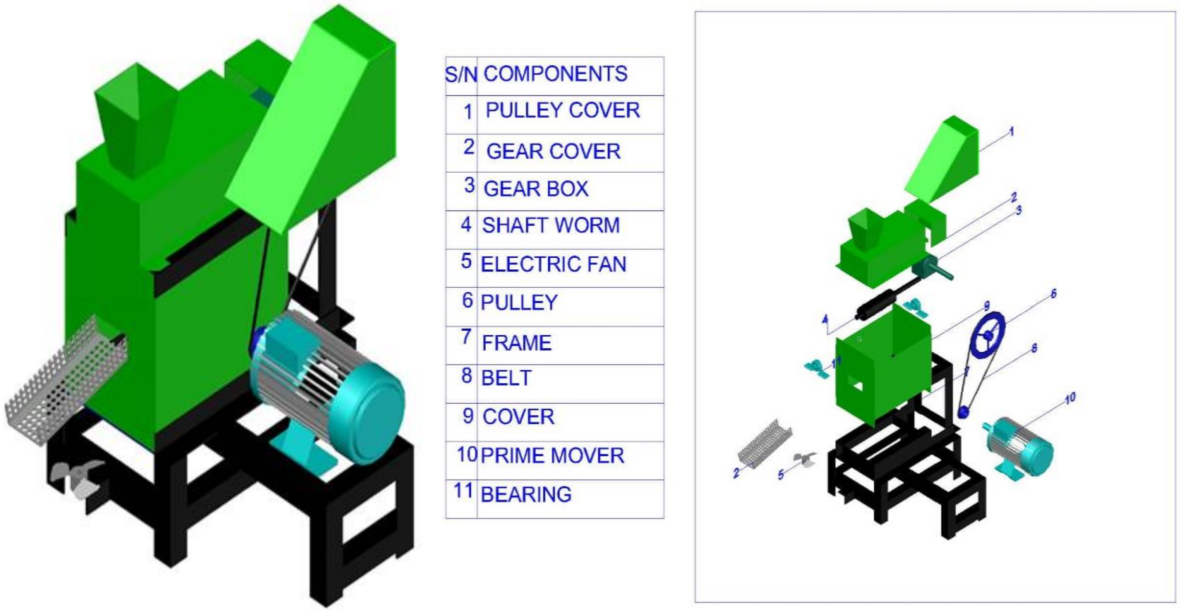

Figure 1: Isometric and Exploded Models of the Designed Roasted Groundnut Dehuller.

v. Size, dimension and capacity of the machine was also considered.

Design Calculations

The following calculations were made for the design:

i. Determination of outer and inner drums of dehulling chamber:

a) $Volume\ of\ the\ cylindrical\ drum = \pi r^2 h$ (1)

Where, h is the length of the drum, mm and r is the radius, mm.

Outer Drum: An assumed plate thickness of 1.50mm, length and radius was used for the design.

Length = 60cm = 600mm; $\pi = 3.142$,

$$Radius = \frac{12}{2} = 6cm = 60mm$$

From (1),

$Volume\ of\ outer\ cylinder\ drum =$

$$3.142 \times 60^2 \times 600 = 6786720\ mm^3 = 6786.72\ cm^3$$

Inner Drum:

Length = 55cm = 550mm;

$$Radius = \frac{6}{2} = 3cm = 30mm$$

$$Volume = 3.142 \times 30^2 \times 550 = 1555290.29\ mm^3 = 1555.29\ cm^3$$

From (1), volume of the inside of the dehulling chamber:

$$= 6786.72 - 1555.29 = 5231.43\ cm^3$$

ii. Determination of groundnut quantity (mass)

$$\rho = \frac{M}{V} \quad (2)$$

Where, ρ is density, g/cm^3; M is mass, g and V is volume, cm^3.

Using (2), mass of groundnut to be contained in the dehulling chamber was calculated with an assumed average density for roasted groundnut, ρ of 0.71g/cm^3 (Fekria, 2009); Volume, V = 5231.43 cm^3.

Therefore, Mass,

$$M = 5231.43 \times 0.71 = 3714.32g = 3.714kg$$

iii. Determination of power required

Total power required is calculated using the formula by Akintunde, *et al*., (2005):

$$P_T = P_{inner\,drum} + P_{shaft} + P_{peeling} \quad (3)$$

$P_{peeling}$ is negligible since seeds flow through, hence,

$$P_T = P_{inner\,drum} + P_{shaft} \quad (4)$$

Note: shaft and inner drum are together, therefore:

$$P_T = T_{inner\,drum\,with\,shaft} \times V_{inner\,drum\,with\,shaft} \quad (5)$$

$$V_{inner\,drum\,with\,shaft} = \frac{2\pi N}{60} \quad (6)$$

Where, V_{inner} drum with shaft is the velocity of the drum with shaft, m/s; N is the number of revolutions per minute of the inner drum and shaft; T is the torque of the inner drum with shaft, N-m.

$$T_{inner\,drum\,with\,shaft} = mass \times acceleration\,due\,to\,gravity \times radial\,dis\tan ce \quad (7)$$

From (7): Using a radial distance = 0.05m, g = 9.81m/s2, m = 3.714 kg

$$T_{inner\,drum\,with\,shaft} = 3.714 \times 9.81.05 = 1.822\,Nm$$

From (6),

$$V_{inner\,drum\,with\,shaft} = \frac{2 \times 3.142 \times 150}{60} = 15.71 m/s$$

Using (5),

$$P_T = 15.71 \times 1.822 = 28.624W \times 0.00134 = 0.0384hp$$

Hence, an electric motor of 1hp would be selected to power the machine.

iv. **Determination of torque transmitted by electric motor**

Using Shigley, (2004) proposed formula:

$$T = 9.55 \times \frac{P}{N} \quad (8)$$

Where, P is the electric motor power, W.

P = 120W, N= 1480

$$T = 9.55 \times \frac{120}{1480} = 0.774Nm$$

v. **Determination of belt length**

Using equations by Khurmi and Gupta, (2005)

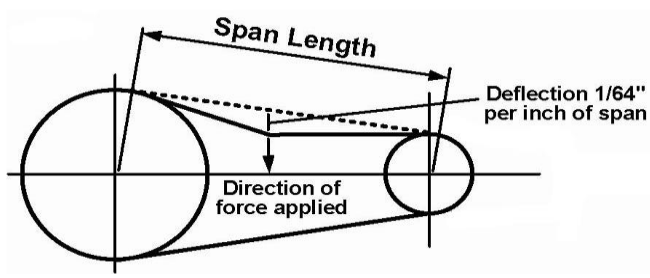

Figure 2: Schematic Diagram for Determination of Belt Length.

$$L = 2C + \frac{\pi}{2(D_1 + D_2)} \div \frac{D_1 + D_2}{2} \quad (9)$$

Center to center distance between the driving pulley and driven pulley is given as:

$$C = 2(D_1 + D_2) \quad (10)$$

Where, D1 and D2 are pulley diameters for driving and driven pulleys respectively, m; C is the center to center distance between driving pulley and driven pulley, m;

From (10), center to center distance, C is calculated:

D1= 40mm, D2 = 40mm

$$C = 2(40 + 40) = 160mm$$

Therefore, belt length was obtained:

$$L = 2 \times 160 \times \frac{\pi}{2((40 + 40))} \div \frac{2}{160} = 502.72mm$$

Speed of driving and driven pulley:

$$V_1 = \frac{\pi D_1 N_1}{60} \quad (11)$$

$$V_2 = \frac{\pi D_2 N_2}{60} \quad (12)$$

Where, N_1 and N_2 are the revolutions per minute for the driving and driven pulleys, respectively.

vi. **Determination of belt tension**

Akintunde, *et al*., (2005) gave the formula for determining belt tension as:

$$P = (T_1 - T_2)V \quad (13)$$

Where, P is belt power, W; V is belt speed, m/s and T1 and T2 are tensions on the tight and slack sides respectively, N.

Using the belt ratio for an open belt,

$$\frac{T_1}{T_2} = e^{f}\alpha \quad (14)$$

Where, f is coefficient of friction between the belt and pulley.

Given P = 120W, V = 15.71m/s, T1 – T2 = 382N,

From (14), belt ratio for open belt, f= 0.42 (Khurmi and Gupta, 2005).

$$\frac{T_1}{T_2} = e^{0.42 \times 3.142} = e^{1.3196}$$

$$T_1 = 3.74T_2$$

$$3.74T_2 = 382 + T_2$$

$$382 = 3.74T_2 - T_2$$

$$T_2 = \frac{382}{2.7} = 141.48N$$

Hence,

$$T_1 = 3.74 \times 141.48 = 529.14N$$

Principle of Operation of the Machine

The dehulling is achieved by rubbing and rotation forces. After feeding the seeds, the worm coupled with the cylindrical drum conveys the seeds and at the same time rub them with the padded cylinder wall. As the conveying progresses, dehulling is achieved. Dehulled seeds are collected through the spout while the fan blows the chaff away.

Figure 3: Final Model of the Fabricated Machine.

Test and Evaluation Procedures

The performance evaluation was carried out at the engineering and scientific services workshop of the National Centre for Agricultural Mechanization (NCAM), Ilorin, Kwara State, Nigeria. The procedure goes as thus:

Fresh groundnut seeds were obtained from Ganmo market in the Ifelodun Local Government Area of Kwara State. The groundnut was roasted and conditioned to 2.0% moisture content (w.b). 1kg of the roasted groundnut was weighed in three replicates using an OHAUS Scout Pro SPU4001 digital scale (Figure 4) with accuracy of ±0.1%+1 digit and fed into the machine. A digital stopwatch was used to record the operation time. The procedure was repeated for the three replicates.

Figure 4: OHAUS Scout Pro SPU4001 Digital Weighing Scale.

Test Materials

Materials used for the experiment include: a roasted groundnut dehuller, OHAUS Scout Pro SPU4001 digital weighing scale (accuracy: ±0.1%+1 digit), polyethylene nylon, bowls and tachometer.

Determine Parameters

The following parameters were determined for the performance evaluation using formula by Olubo, *et al.*, 2020

a. Dehulling Efficiency, Ec, (%): expressed as:

$$E_c(\%) = \frac{m_f}{m_i} \times 100 \quad (15)$$

Where, Ec (%), is dehulling efficiency (i.e. % of dehulled seeds); mi, is mass of groundnut before dehulling, kg and mf, is mass of groundnut after dehulling, kg.

b. Machine Throughput, CT, (kg/h): given as

$$C_T = \frac{m_{i\,ave}}{t_{ave}} \quad (16)$$

Where, C_T is the machine throughput capacity, kg/h; $m_{i\ ave}$ is the average mass of groundnut before dehulling, kg and t_{ave}, is the average time taken for the operation per each batch, s.

RESULTS AND DISCUSSIONS

The results of the performance evaluation were presented in Table 1 with their interpretations discussed as follow:

a. Dehulling Efficiency (%): the average dehulling efficiency of 84.72% was recorded for the machine (Table 1), with a seed damage of 5.42%. Olademeji and Lawson (2019) reported similar efficiency of 80% for moisture content of 12% but stated that the result was best from different moisture contents conditioning given to the seeds (8%, 12%, and 16%). A higher dehulling efficiency of 92.14% and a seed damage of 32.09% was reported by Agbonkhese and Afoegba, (2018). Olubo, et. al., 2020 reported the best efficiency results at the lowest speed of operation, 30 rpm (80%, 78%, 77%, 90%, and 73%) for varied moisture contents of 1.4, 1.6, 1.8, 2.0, and 2.2%, respectively. This shows that the moisture content and speed of operation are important factors in influencing the performance efficiency of the machine.

b. Throughput Capacity, CT, kg/h: using equation (16):

$$C_T = \frac{m_{i\,ave}}{t_{ave}} = \frac{1000}{1000} \times \frac{3600}{86.23} = 41.75\,kgh^{-1}$$

With throughput capacity of 41.75kg/h recorded, the machine would be suitable for small and medium processors and can be improve through optimization of the machine's operation conditions. Ikechukwu *et al*., (2014) reported a 5.4kg/h capacity for their manually operated roasted groundnut dehuller this is low compared to the 37.78kg/h reported by Ayelegun and Ajewole, (2015) for their electric motor-powered roasted groundnut seed dehuller. This shows that effort of mechanizing the operation is yielding the desired objective of increasing productivity of this aspect of processing.

CONCLUSION

A low cost roasted groundnut dehulling machine was designed, fabricated and the performance efficiency evaluated. Autodesk inventor professional 2014 was used for the design; materials used for the fabrication were locally sourced to keep the cost down at N 81,050 (205 USD).

Groundnut seeds used for the evaluation were conditioned to 2.0% moisture content and an operating speed of 35 rpm. An average dehulling efficiency of 84.72% and seed damage of 5.42% was recorded with the average throughput capacity of 41.75kg/h. This makes the machine suitable for both small and medium scale processors and thereby increasing their productivity.

REFERENCES

1. Akintade, A.M. and A.G. Bratte. 2015. "Development and Performance Evaluation of a Roasted Groundnut (*Arachis hypogaea*) Blanching Machine. *Development, Journal of Multidisciplinary Engineering Science and Technology*. 2(3): 271-276.

2. Akobundu, E. 1998. "Farm-Household Analysis of Policies Affecting Groundnut Production in Senegal". Thesis submitted to the Faculty of the Virginia Polytechnic Institute and State University in partial fulfilment of the requirements for the degree of Master of Science in Agricultural and Applied Economics: Blacksburg, VA.

3. Ayelegun, T.A. and P.O. Ajewole. 2015. "Design, Fabrication and Performance Evaluation of a Low-Cost Portable Roasted Groundnut Seeds Dehuller". *International Journal of Innovative Science, Engineering & Technology*. 2(10): 896-901.

4. Girei, A.A., Y. Dauna, and B. Dire. 2013. "An Economic Analysis of Groundnut (*Arachis hypogea*) in Hong Local Government Area of Adamawa State, Nigeria". *Journal of Agriculture and Crop Research*. 1(16): 84-89.

5. Juhee, Yoon. 2019. "The Nigerian Peanut Market: Waking Up from Slumber". Article Retrieved 11th January, 2020 from: www.tridge.com/stories.

6. Nord, M., A. Coleman-Jensen, M. Andrews, and S. Carlson. 2010. "Household Food Security in the United States". 2009.ERR-108, U.S. Dept. of Agriculture, Econ. Res. Serv. November 2010.

7. Ogunwole, O.A. 2013. "Design, Fabrication and Testing of A (Manually and Electrically Operated) Roasted Groundnut Decorticating Machine". *Food Science and Quality Management*.14: ISSN 2225 – 0557.

8. Oladimeji Azeez Olaposi and L. Olorunwa Sunday. 2019. "Development and Performance Evaluation of a Roasted Groundnut Dehulling Machine". *International Journal of Applied Research*. 5(9):246-249

9. Oluwatayo, I.B., A.B. Sekumade, and S.A. Adesoji. 2008. "Resource Use Efficiency of Maize Farming households in Rural Nigeria: Evidence from Ekiti State". *World Journal of Agricultural Sciences*. 4(1): 91-99.

10. Shigley, J.E., R. Charles, G.B. Richard, L. Xiangfeng and G. Zhi. 1989. *Mechanical Engineering Design*. Vol. 10. McGraw-Hill: New York, NY.

11. Taphee, G.B. and A.A.U. Jongur. 2014. "Productivity Efficiency of Groundnut Farming in Northern Taraba State, Nigeria". *Journal of Agriculture and Sustainability*. 5(1): 45-56.

12. Taru, V.B., I.Z. Kyaga, and S.I. Mshella. 2010. "Profitability of Groundnut Production in Michika Local Government Area of Adamawa State, Nigeria". *J. Agric. Sci*. 1(1): 25-29.

13. Ugwuoke, I.C., O.J. Okegbile, I.B. Ikechukwu, and T.J. Robert. 2014. "Design and Development of Manually Operated Roasted Groundnut Seeds Peeling Machine". *International Journal of Recent Development in Engineering and Technology*. ISSN 2347-6435 (Online) 2 (4): 30–33.

14. Ajeigbe, H.A., F. Waliyar, C.A. Echechwu, K. Ayuba, B.N. Motagi, D. Eniayeju, and A. Inuwa. 2014. *A Farmer's Guide to Groundnut Production in Nigeria*. Patancheru. 502 324. International Crops Research Institute for the Semi-Arid Tropics: Telangana, India. 36pp.

15. Olubo, A.S., J.T, Stephen, A. Adeyinka, and O.O. Opadotun. 2020. "Effects of Some Test Parameters on Dehulling Efficiency of a Roasted Groundnut Seed Dehulling Machine. Article DOI://doi,org/10.30574/gjeta.2020.5.2.0087.

16. Agbonkhese, A. Kingsley and Afoegba S. Clement. 2018. "Design and Fabrication of a Portable Dry Groundnut Husk Peeling Machine". *Pyrex Journal of Engineering and Manufacturing Technology*. 3(3): 20-27 September, 2018, ISSN: 2550-7877.

17. Ikechukwu, C.U., O.J. Okegbile, I.B. Ikechukwu; and R.J. Temitope. 2014. "Design and Development of Manually Operated Roasted Groundnut Seeds Peeling Machine". *International Journal of Recent Development in Engineering and Technology*. 2(4). April 2014, ISSN 2347 - 6435 (Online).

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