Full Paper

DEVELOPMENT OF A DEVICE FOR DE-COATING ROASTED GROUNDNUTS

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ABSTRACT

The traditional practice of de-coating roasted groundnut manually is time and energy consuming in addition to being unhygienic. The objective of this study was therefore to develop a de-coating machine for roasted groundnut seeds with the aim of eliminating the drudgery and enhancing the hygiene of the de-coating process. Two varieties of groundnut (Virginia and Valencia) and a 5x5 Latin square experimental design was used to evaluate the machine developed with batch weight (96, 144, 192, 240 and 288 g), running time (varied from 25 to 65 secs in steps of 10 secs), and operating speed (156, 180, 200, 220 and 250 rpm) as variables for the experiment. A maximum de-coating efficiency of 90.30% for Virginia and 93.01% for Valencia groundnuts at 250 rpm operating speed and 65 secs running time were observed. The highest percentage seed damage of 19.84% for Virginia and 23.26% for Valencia groundnuts was also observed at 250 rpm operating speed and 65secs running time. The result got shows that the device was found efficient for use owing to its improvement in timeliness and removal of drudgery associated with groundnut processing.

Keywords: *Roasted groundnut, De-coating machine, De-coating efficiency, Percentage damage, Mechanical efficiency*

1. INTRODUCTION

Groundnut (*Arachis hypogea*), otherwise known as peanut, is one of the most important protein rich crops and it occupies the fifth position globally as an oil seed crop after soybeans, rape seed, cotton seed and sunflower seed (El-sayed *et al*., 2001). Groundnut is grown on about 26.4 million hectare of land worldwide, with a total production of 37.1 million metric tons and an average productivity of 1.4 metric tons /ha. Developing countries constitute 97% of the global area and 94% of the global production of this crop (FAO, 2011).

Akinjayeju and Ajayi (2011) and Kurien *et al*. (1972) defined de-hulling as the removal of seed-coat (hull) after the firmly attached seed-coat has been softened during cooking, drying, roasting, soaking or other processes. Therefore, it is the primary step in recovering the embedded seed or nut for further processing. For roasted groundnut, de-hulling (also known as de-coating) is traditionally done manually by rubbing the groundnuts in between palms and then cleaning by blowing off the coats. Traditional de-coating is a physically demanding job and also, a substantial amount of roasted groundnuts is usually lost in the process. It is characterized as back breaking work with low productivity (Akintade and Brattle, 2015). There have been several attempts to develop machines that de-hull legumes and other seeds such as sorghum, cowpea, and maize etc. Between 1972 and 1976, the then Nigeria's federal ministry of agriculture and natural resources in collaboration with north- eastern state ministry of agriculture and natural resources established a complete processing plant unit consisting of de-huller, hammer mill, and a diesel engine to drive the equipment in Maiduguri (Ajayi and Olasunkanmi, 2013). Campbell and Chubey (1985) designed and developed a buckwheat de-huller capable of removing the hulls from small samples with minimum damage to the inner grout. The de-hulling process took place by passing the seed between a rotating lower energy stone and a stationary top energy stone. It was observed also of capable of de-hulling basswood. Omobuwajo *et al.* (1999) designed a machine in order to remove the drudgery involved in de-hulling African breadfruit seeds. The machine comprised of a roller which cracks the hull with an oscillating cam follower which removes the cracked hulls through repeated shearing against a stationary wall, and an aspiration unit which sifts the hull from the endosperm. Akintade and Brattle (2015) developed and evaluated a roasted groundnut blanching machine. The machine comprised of larger (upper) opening, where the roasted groundnut kernel is being introduced into the blanching unit while the smaller (lower) opening connects the blanching unit to blowing unit. The blanching unit consists of the blanching drum which houses the inner drum with the brush-like projections where the blanching takes place.

While the previous works focused on the de-hulling of grains such as sorghum, little attempt has been made to de-coat roasted groundnut kernels. Therefore, this study developed a groundnut de-coating device with the aim of improving de-coating efficiency, reducing drudgery and difficulty associated with the manual de-coating of groundnut.

2. MATERIALS AND METHODS

The roasted groundnut de-coating machine developed is simple in design and easy to fabricate. It also consists of simple detacheable components, which are easy to repair and maintain. It is adaptable to use by any operator without previous technical training, and also, gender friendly. All its components were designed and fabricated in the department of mechanical engineering, obafemi Awolowo university, Ile-Ife, Osun State.

The groundnuts used to carry out the performance evaluation of the de-coating device were roasted Virginia (*epa kampala*) and Valencia (*epa pupa*) type which were procured from Sabo market Ile-Ife, Osun state Nigeria. Prior to fabrication of the machine, information on some physical, mechanical and aerodynamic properties of roasted groundnuts (Table 1) relevant to the design of the de-coating machine were obtained from literature as reported by Adekola (2017).

Table 1: Average Values of Some Physical, Mechanical, and Aerodynamic Properties of Virginia and Valencia Groundnut

Properties	Virginia groundnut	Valencia groundnut
Major diameter (mm)	13.25	7.23
Minor diameter (mm)	8.18	4.08
Intermediate diameter (mm)	8.03	4.35
Unit mass (g)	0.46	0.25
Bulk density (kg/m^3)	479.23	490.00
Static coefficient of friction on rubber surface	0.57	0.51
Terminal velocity (m/s)		
Whole	12.5	11.97
Split	6.32	4.95

2.1. General Description of the Machine

The de-coating machine consists of a simple arrangement of a shaft carrying the upper rotating disc brush, the electric motor, frame, the feeder, the lower stationary disc- brush, the de-coating chamber and the seperation unit which consists of an a.c. blower. The upper rotating disc-brush and the lower stationary disc-brush constitute the de-coating tools. The arrangement of the tools provides the necessary brush-groundnut and groundnut-groundnut rubbing actions needed to de-coat the roasted groundnuts. Figure 1 shows the exploded view of the de-coating machine while Plate 1 shows the developed de-coating machine.

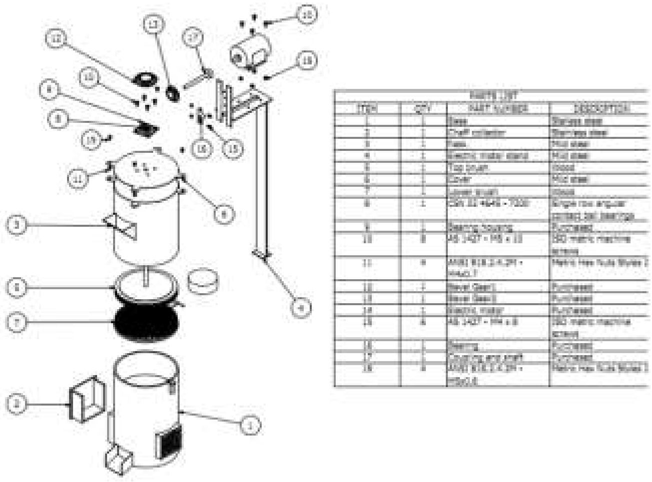

Figure 1: Exploded view of the groundnut de-coating device

Plate 1: Developed de-coating machine

2.2. Major Design Considerations

(i) Determination of the volume of the de-hulling chamber

This depends on the maximum mass of groundnut the device was designed for

$$V_g = \frac{m}{\rho} \quad (1)$$

Where ρ = bulk density of groundnut in kg/m^3
m = maximum mass of the groundnut the device is designed for in kg
V_g = volume which the groundnuts occupy in the chamber in m^3, Also,

$$V_C = \pi r^2 h \quad (2)$$

Where V_C = volume of the de-coating chamber in m^3
r = radius of the de-hulling chamber in m
h = height which the volume of groundnut occupies in the chamber, m

(ii) Power required to overcome friction in the de-coating chamber

The power required to overcome friction P_f was determined using Equation (3)

$$P_f = F_L V \quad (3)$$

Where F_L = total frictional load on the groundnut in the chamber, N
V is the assumed mean speed of relative motion between groundnut layers in the chamber, m/s

$$V = \omega r \quad (4)$$

Where, ω = angular speed, rad/secs
r = center of mass of the groundnut, m

The total load F_L was calculated by using Equation (5)

$$F_L = (F_H + F_V)\,\mu \quad (5)$$

Where F_H = frictional force due to the horizontal normal contact forces between the groundnuts in the chamber, N
F_V = frictional force due to the vertical normal contact forces between the groundnuts in the chamber, N

μ = internal coefficient of friction between the groundnuts

(iii) Power required to drive the rotating shaft unloaded

The kinetic energy of the rotating shaft is given by

$$K.E = \frac{I\omega^2}{2} \quad (6)$$

Where K.E = kinetic energy of the rotating shaft, J
I = mass moment of inertia, kgm^2
ω = angular velocity of the shaft, rad/secs

Therefore, power required to drive the shaft, P_s, is given by

$$P_S = \frac{K.E}{t} \quad (7)$$

Where t = time needed to accelerate the shaft to its maximum speed from zero velocity, secs

The total power P_T required to drive the system, assuming the drive is frictionless, was calculated using Equation (8)

$$P_T = P_f + P_S \quad (8)$$

The frictional efficiency of drive was assumed to be 70%
Therefore, the power required for the drive,

$$P = {P_T}/{0.7} \quad (9)$$

(iv) Torque transmitted by the drive shaft

The torque (T) transmitted by the drive shaft was calculated using Equation (10)

$$P = T\omega \quad (10)$$

Where T is the torque in Nm

(v) Shaft design

The Diameter (D) of the shaft was determined by Equation (11) (Shigley, 1986)

$$D = 36.5\left(\frac{P}{\tau N}\right)^{0.33} \quad (11)$$

Where P = power required to drive the shaft, W
N = speed of the shaft, rpm
τ = permissible shear stress, MPa

2.3. Principle of Operation

The shearing force generated by the groundnut-groundnut friction and groundnut-chamber surface friction causes the groundnut seed coats to be removed with little or no damages. The groundnut to be de-coated was first roasted to a certain level of moisture content, after which the electric motor was turned on at the required speed. The roasted groundnuts ere then fed into the de-coating chamber through the feeder. The de-coating was achieved due to the rubbing action of the upper rotating disc rubber brush against the lower stationary disc rubber brush. After de-coating, the lower stationary disc-brush was tilted to create a passage way for both the kernels and the coats to fall out of the de-coating chamber into the separation unit. The kernels fell freely to the bottom of the device by gravity and the coat was removed from the kernel with the help of the blower in the separating unit.

2.4. Performance Evaluation

The performance evaluation of the machine was carried out on to varieties of groundnut using a 5x5 Latin square experimental design and three operating variables: operating speed (156, 180, 200, 220, and 250 rpm), running time (25, 35, 45, 55, and 65 secs), and batch weight (96, 144, 192, 240, and 288 g). The performance criteria considered were the de-coating efficiency, percentage damage and mechanical efficiency.

The de-coating efficiency was calculated by Equation (12) as reported by (Atiku *et al*., 2004)

$$DE = \frac{M_1+M_2}{M_T} \text{ x } 100 \quad (12)$$

Where DE = de-coating efficiency
M_1 = Mass of roasted groundnut whole and completely de-coated.
M_2 = Mass of roasted groundnut split and completely de-coated.
M_T = Total mass of the roasted groundnut fed into the de-coating chamber.

Percentage damage is given as

$$PD = \frac{M_3+M_4}{M_T} \text{ x } 100 \quad (13)$$

Where PD = Percentage damage.
M_3 = Mass of roasted groundnuts de-coated and damage.
M_4 = Mass of roasted groundnuts not de-coated and damage.

Mechanical efficiency as calculated using

$$ME = \left[100 - \left(\frac{M_3+M_4}{M_T} \text{ x } 100\right)\right]\% \quad (14)$$

Where ME = Mechanical efficiency

3. RESULTS AND DISCUSSION

The result generated from the experimental runs on the machine developed was subjected to analysis of variance (ANOVA). Results showed that operating speeds and running times significantly affect the performance of the de-coating machine at 5% significance level. Batch weight, however, does not affect the performance of the machine at 5% significance level.

3.1. Effect of Machine Operating Parameters on the Machine Performance

The de-coating efficiency increased with increase in operating speed and running time. The plots of the interaction between operating speed and running time against de-coating efficiency (Figures 2 and 3) show that the highest values of the de-coating efficiency (90.30% and 93.01% for roasted Virginia and Valencia groundnuts respectively) were obtained when the operating speed was 250 rpm and the running time was 65 secs. This probably occurred due to the increase in the number of revolutions the de-coating tool performed in the de-coating chamber as the speed was increased and also due to the increase in the resident time of the groundnut sample in the de-coating chamber.

Analysis of variance (ANOVA) (Tables 2 and 3) show that the operating speed had significant effect on the de-coating efficiency of the machine at less than 0.05 significance level. Also, running time significant affected the de-coating efficiency of the machine. Batch weight did not significantly affect the de-coating efficiency of the machine.

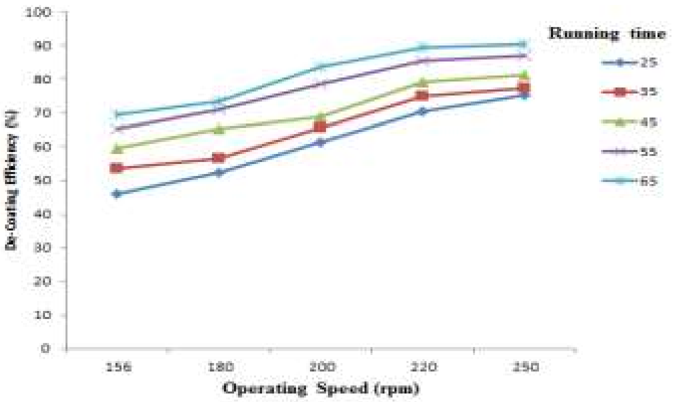

Figure 2: Variation of de-coating efficiency with operating speed at different running time for roasted Virginia groundnut

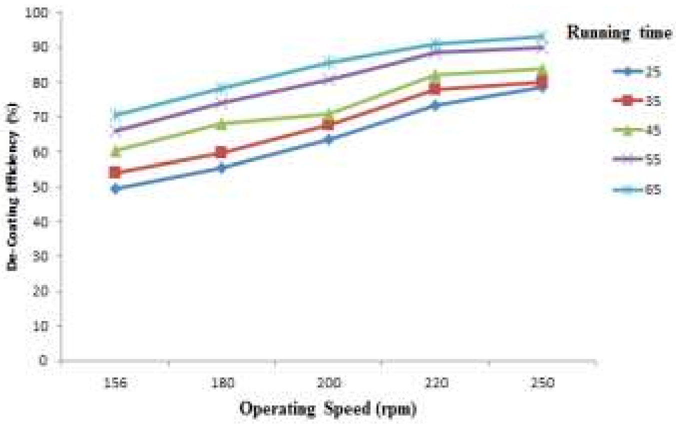

Figure 3: Variation of de-coating efficiency with operating speed at different running time for roasted Valencia groundnut

Table 2: ANOVA for De-Coating Efficiency of Roasted Virginia Groundnut

Source of Variation	Sum of Squares	Degree of freedom	Mean of Squares
Speed (rpm)	1575.32	4	393.83
Running time (s)	1882.93	4	470.73
Batch weight (g)	307.55	4	76.89
Residual	682.79	12	56.90
Total Average	4448.59	24	185.36

Table 3: ANOVA Table for De-Coating Efficiency of Roasted Valencia Groundnut

Source of Variation	Sum of Squares	Degree of freedom	Mean of Squares
Speed (rpm)	1626.582	4	406.65
Running time (s)	2843.451	4	710.86
Batch weight (g)	88.919	4	22.23
Residual	260.1452	12	21.68
Total Average	4819.10	24	200.80

The percentage of seeds damaged also increased with increase in operating speed and running time for both varieties of groundnut. The plots of the relationship between operating speed and running time against percentage damage in Figures 4 and 5 show that the highest values of the percentage seed damaged (25.12% for Virginia and 27.31% for Valencia groundnuts) were obtained when the operating speed was 250 rpm and the running time was 65secs. This probably occurred due to the higher shear force excited on the groundnuts, which cause the groundnut to have greater impact on the wall of the de-coating chamber.

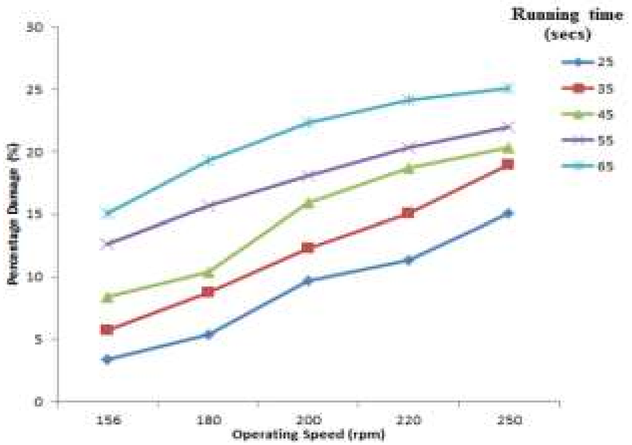

Figure 4: Variation of percentage damaged with operating speed at different running time for Virginia groundnut

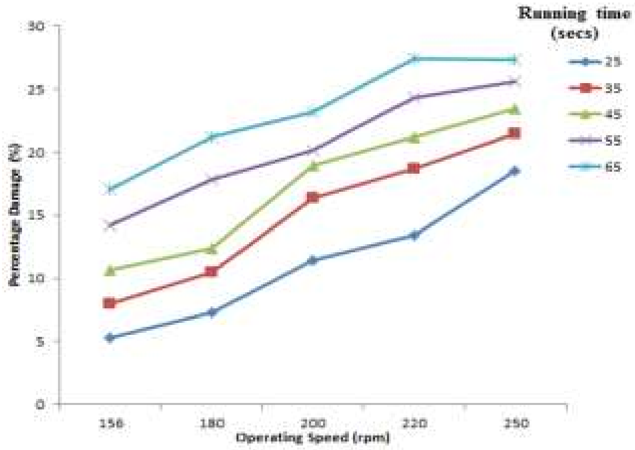

Figure 5: Variation of percentage damaged with operating speed at different running time for Valencia groundnut

Analysis of variance (ANOVA) as shown in Tables 4 and 5 show that the operating speed significantly affected the percentage damaged groundnuts at less than 0.05 significance level. Similarly, the effect of running time was significant on the percentage damaged nuts.

Table 4: Result of ANOVA Table for Percentage Damage of Virginia Groundnut

Source of Variation	Sum of squares	Degree of freedom	Mean square
Speed (rpm)	409.30	4	102.33
Running time (s)	446.91	4	111.73
Batch capacity (g)	2.71	4	0.68
Residual	36	12	3
Total Average	894.92	24	37

Table 5: Result of ANOVA Table for Percentage Damage of Valencia Groundnut

Source of Variation	Sum of squares	Degree of freedom	Mean square
Speed (rpm)	504.126	4	126.03
Running time (s)	447.356	4	111.84
Batch capacity (g)	0.653	4	0.16
Residual	17.613	12	1.47
Total Average	969.750	24	40.41

The mechanical efficiency for both types was calculated using Equation (14). The variation between operating speed and running time against mechanical efficiency ere also recorded. Figures 6 and 7 show that the highest values of the mechanical efficiency (96.58% for Virginia and 94.70% for Valencia groundnuts) were obtained at operating speed of 156 rpm and running time of 25 seconds. This implies that as the operating speed and the running time increases the mechanical efficiency decreases. This result is in close agreement with that observed by Akintade and Brattle (2015), where he discussed the effect of blanching speed on the mechanical efficiency of roasted groundnut device to be maximum at the lowest speed of the machine, which implies that decreasing blanch speed increases the mechanical efficiency within the blanching drum.

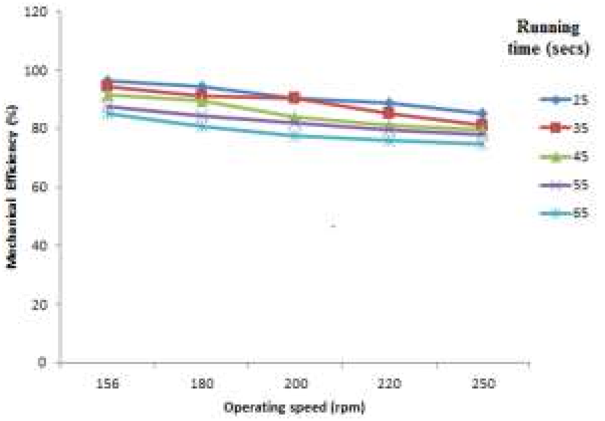

Figure 6: Variation of mechanical efficiency with operating speed at different running time for roasted Virginia groundnut

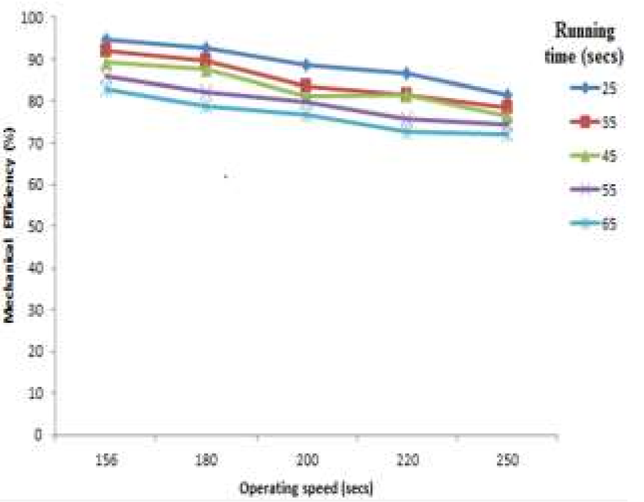

Figure 7: Variation of mechanical efficiency with operating speed at different running time for roasted Valencia groundnut

4. CONCLUSION

A groundnut de-coating machine was developed, designed and fabricated. Performance evaluation of the machine showed that:

i. The percentage of the seeds damaged was lowest (15.05%) at operating speed of 156 rpm and running time of 25 secs, and highest (25.12%) at operating speed of 250 rpm and running time of 25 secs for roasted Virginia groundnut, while it was highest (27.44%) at operating speed of 250 rpm and running time of 65 secs and lowest (17.03%) at operating speed of 156 rpm and running time of 25 secs for roasted Valencia groundnut.

ii. The mechanical efficiency was observed to be highest (96.58%) at operating speed of 156 rpm and running time of 25 secs, and lowest (84.96%) at operating speed of 250 rpm and running time of 65 secs for roasted Virginia groundnut type, while that of roasted Valencia groundnut was observed to be highest (94.70%) at operating speed of 156rpm and running time of 25 secs, and lowest (81.47%) at operating speed of 250 rpm and running time of 65 secs.

iii. The maximum de-coating efficiency (90.30%) was recorded at operating speed of 250 rpm and running time of 65secs for roasted Virginia groundnut, while for roasted Valencia groundnut type it was observed to be maximum (93.01%) at operating speed of 250 rpm and running time of 65 secs.

The results above indicated that the developed device can give high efficiency when used for de-coating roasted groundnuts thereby improving timeliness and removing the drudgery associated with groundnut processing at domestic and commercial levels.

REFERENCES

Adekola, A. F., Development of a Device for De-Coating Roasted Groundnuts. Unpublished M.Sc. thesis of the Department of Mechanical Engineering, faculty of technology, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria, 2017.

Ajayi, A. B. and Olasunkanmi, L. K., "Development of Groundnut Chaff removing Machine." International Journal of Engineering Science Invention, 2, 45-51, 2013.

Akinjayeju, O., and Ajayi, O. F., "Effects of De-hulling on Functional and Sensory Properties of Flours from Black Beans (Phaseolus Vulgaris)." Food and Nutrition Sciences. 2, 344-349, 2011.

Akintade, A. M. and Brattle, A. G., "Development and Performance Evaluation of Roasted Groundnut (Arachis hypogea) Blanching Machine." Journal of Multidisciplinary Engineering Science and Technology, 2, 271-276, 2015.

Atiku, A. A., Aviara, N. A. and Haque M. A., "Performance Evaluation of a Bambara Groundnut Sheller." Agricultural Engineering International: Journal of Scientific Research and Development. Manuscript P 04002, VI, July, Texas University Houston, USA, 2004.

Campbell, C. G., and Chubey, B. B., "A dehuller for buckwheat samples." Canadian Journal of Plant Science, 3: 771, 1985.

El-Sayed, A. S., Yahaya, R., Wacker, P. and Kutzbach, H. D., "Characteristics Attribute of Peanut (Arachis hypogea L.) for its Seperation." International Agrophysics. 15: 225-230, 2001.

Faires, V. M. (1965): "Design of Machine Elements" 4th Edition. The Macmillan Company, New York.

Food and Agricultural Organisation, The State of Food and Agriculture "Women in Agriculture closing the Gender gap for Development". FAO, Agricultural Bulletin No. 15, pp 34-35, 2011.

Kurien, P. P., Desikachar, H. S. R. and Parpi, H. A. B., "Processing and Utilization of Grain Legumes in India", Proceedings Sysmposium on Food Legumes, Tropical Agriculture Research Series No. 6, Tokyo, Japan. pp 225, 1972.

Omobuwajo, T. O., Ikegwuoha, H. C., Koya, O. A. and Ige, M. T., "Design, construction and testing of a dehuller for African breadfruit (Treculia africana) seeds." Journal of Food Engineering, 3, 173–176, 1999.

Shigley, J. E., "Mechanical Engineering Design", First Metric Edition, McGraw-Hill Book Company, New York, pp. 107-115, 1986.