

Development and Performance Evaluation of a Dehulling Machine for African Breadfruit (*Treculia africana*)

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Abstract: A motorized African breadfruit seed dehuller was designed, fabricated and tested. Results showed that the machine had a maximum dehulling efficiency of 86% at 225 rpm speed and a maximum dehulling capacity of 176.2 kg h⁻¹ at 425 rpm speed. There were significant effects of speeds on both the dehulling capacity and dehulling efficiency of the machine at 5% level of significance. The dehulling capacity increased with speed while the dehulling efficiency decreased with increased speed. The estimated cost of the machine was ₦35000 (USD250).

Key words: African breadfruit, dehuller, dehulling capacity, dehulling efficiency, seed, vegetable oil

INTRODUCTION

African breadfruit (*Treculia africana*) is a tropical African tree crop of the moraceae family and genus *treculia*. In West Africa, individual breadfruit trees are found scattered throughout the Southern rain forest zones (Omobuwajo *et al.*, 1999). The tree can grow up to 20 m high and produce compound fruit of considerable size on the tree trunk or on older branches. The fruit head is spherical in shape with a diameter of up to 0.5 m.

It is hard and spongy in texture and contains spherical shaped seeds embedded at various depths in the fleshy fruit head. A mature seed of the crop is made up of an outer covering, the husk and the inner edible endosperm. The husk is brown in colour but changes to dark brown after sometime due to oxidation during fermentation. It is coated with a gummy sticky substance which must be removed during processing. African breadfruit is an important food item in southern parts of Nigeria and other parts of West Africa but the crop is highly under utilized. The seeds may be eaten after boiling or frying.

Also delicious porridge is produced from the seed. Weaning foods, breakfast cereals and beverages can be produced from the seed. The seed is a rich source of vegetable oil (10%), protein (17%) and carbohydrates (40%) as well as several minerals and vitamins. The fleshy pulp is also used as fodder while the wood of the tree crop has potential use in paper manufacturing. The oil yield of the crop compares favourably with that of sunflower seed, cotton seed and palm kernel. The fat and

oil content of the seed places it as a possible commercial raw material for the production of vegetable oils, pharmaceuticals, soaps, perfumes and paints. The shell is rich in potash and may be used as filler, bedding for livestock and polishing of abrasives (Nwabueze *et al.*, 2008). The mechanization of breadfruit production and processing has received little attention in Nigeria. A traditional method of dehulling is still adopted by most of the local processors of African breadfruit. The traditional method of dehulling involves the manual removal of the seed coat of each of the parboiled bread fruit seed or by spreading the parboiled seeds on cemented floor or mat and rolling either pestle or empty bottle manually on top of them to reak up the seed coat and finally separate the seed coat from the seeds by using hand fans to blow them away.

These methods are however, laborious, time consuming and are bound to produce low output capacity. In most cases there are losses and delays in handling large volumes of products. Manual processors are prone to injury also the hygienic condition of the end products may be undesirable. Therefore, the development of a mechanized dehulling machine for breadfruit becomes an important venture.

The objective of this research is to design and fabricate a machine for dehulling African breadfruit and test the machine for performance during operation.

MATERIALS AND METHODS

Design considerations: The design of this dehulling machine was based on the following considerations:

availability and affordability of the construction materials; the hopper is shaped in such a way as to allow easy flow of the breadfruit seeds; the machine is to accommodate different speeds of operation; the rotating disc and shearing plate are spaced appropriately to ensure proper dehulling of the breadfruit seeds; the machine is to be powered by a 1 hp electric motor or internal combustion engine.

Description and operation of the breadfruit dehuller: The major components of the breadfruit dehuller are the hopper, transmission and dehulling unit. The machine is powered by a 1 hp single phase electric motor. The hopper is shaped as a pyramidal frustum with the walls sloping at 39° angle.

It is made of mild steel. At the base of the hopper is a control gate designed to control the flow of the breadfruit seeds into the dehulling chamber. The dehulling unit which is beneath the hopper consists of a rotating shearing disc mounted on a shaft driven by the electric motor through a V-belt and pulley drive and another plate fixed on the dehulling chamber, located at the end of the shaft. A clearance of 3 mm is maintained between the rotating shearing disc and the stationary plate. The shaft incorporates an auger towards the dehulling zone to aid in transporting the breadfruit seeds from the hopper to the dehulling zone. During operation, the seeds are brought into the space between the shearing disc and stationary plate. Dehulling is done by the shearing friction between the disc and plate while fineness of dehulling is determined by the space between the two and it is controlled by a regulating adjustable screw at the end of the dehulling chamber cover. The dehulling chamber is made of mild steel. The driving shaft is mounted on the frame work through two rolling resistance bearings (Fig. 1 and 2).

Design analysis: The force required to dehull a seed like breadfruit is given by Olakanmi (2004) as:

$$F = \mu(w + 2m\omega^2) \quad (1)$$

Where:

- F = Dehulling or shelling force (N)
- μ = Coefficient of friction between rotating disc and breadfruit, experimentally determined as 0.38
- m = Average mass of the breadfruit seed = 0.0269 kg
- ω = Angular velocity (rad sec⁻¹) 48.9 rad sec⁻¹
- w = Mean weight of the breadfruit seed (0.0269×9.8) = 0.264 N

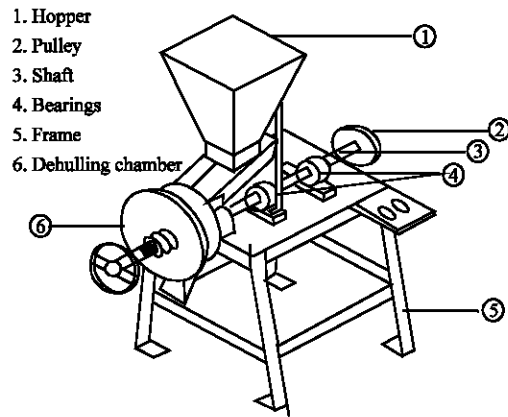


Fig. 1: Isometric drawing of the breadfruit dehuller

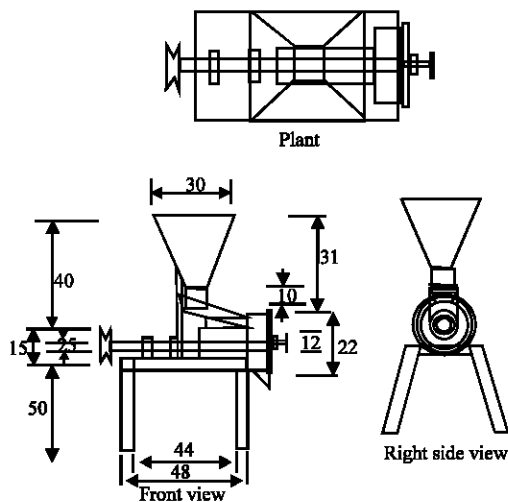


Fig. 2: Orthographic drawing of the breadfruit dehuller

The torque developed by the disc plate:

$$T = Fr \text{ (Nm)} \quad (2)$$

Where:

- r = Radius of disc = 0003 m
- F = Dehulling force

Power required by the disc is given by Khurmi and Gupta (2005) as:

$$P = T\omega \quad (3)$$

Where:

- ω = Angular velocity rad sec⁻¹
- T = Torque developed

From Eq. 3, the power developed is 86.256 W or 0.12 hp. A 1 hp single phase motor was therefore selected. The diameter of the shaft was determined using the maximum stress theory by Hall *et al.* (1980).

$$d = \left[\frac{16}{\pi s} \left(\sqrt{(K_b M_b)^2 + (K_t M_t)^2} \right) \right]^{\frac{1}{3}} \quad (4)$$

Where:

- M_b = Maximum bending moment on shaft Nm
- M_t = Maximum torsional moment on shaft Nm
- s = Allowable shear stress for steel ($55 \times 10^6 \text{ N m}^{-2}$)
- K_b, K_t = Fatigue and shock factor for torsional and bending moments (1.5 and 1.0)
- π = Pi

The value obtained for d was 21.5 mm, therefore a 25 mm shaft was selected. In designing the hopper it is recommended that the angle of inclination of the hopper walls be 10° higher than the natural angle of repose of the stored material (breadfruit seeds) (Richey *et al.*, 1961). This is to avoid tunneling and arching during the discharge of the breadfruit seeds.

The hopper shape is that of a frustum of a pyramid. The angle of repose obtained experimentally for the breadfruit seeds was 28.6.

Therefore, an angle of inclination of 39° was used in designing the hopper. The volume of the hopper was determined as 0.54 m^3 using the equation by Adgidzi (2007) given as:

$$v = \frac{h}{3} \left[A_1 + A_2 + \sqrt{(A_1 \times A_2)} \right] \quad (5)$$

Where:

- V = Volume of hopper (m^3)
- A_1 = Area of top (m^2)
- A_2 = Area of base (m^2)
- h = Height of the hopper (m)

Performance tests: After the fabrication an experiment was designed to determine the dehulling efficiency and dehulling capacity of the machine using three different speeds of operation 225, 325 and 425 rpm, respectively.

A commonly available local variety of breadfruit bought from Umuahia market was used. The breadfruit was parboiled and cooled before dehulling. The Dehulling Efficiency (DE) was calculated as;

$$DE = \frac{m - c}{m} \times 100\% \quad (6)$$

Where:

- m = Mass of breadfruit seeds fed to the machine kg
- c = Mass of undeulled breadfruit seeds kg

Dehulling Capacity (DC) was rated in kg h^{-1} and was calculated as:

$$DC = \frac{m}{t} \quad (7)$$

Where t is the time to complete dehulling of the breadfruit seeds (h).

RESULTS AND DISCUSSION

The data collected from the tests were analyzed using the Completely Randomized Design (CRD). This is because the design has the maximum degrees of freedom for estimating the error variance and also the number of replications and the factors are restricted only by the number of experimental units available (Federer, 1976). From Fig. 3, the dehulling capacity increased with the speed of the machine, having a maximum value of 176.2 kg h^{-1} for 425 rpm operating speed and 127 kg h^{-1} for 225 rpm speed.

However, the reverse was the case for the dehulling efficiency which decreased with speed having the highest value of 86% for 225 rpm speed and lowest value of 74.4% at 425 rpm (Fig. 4).

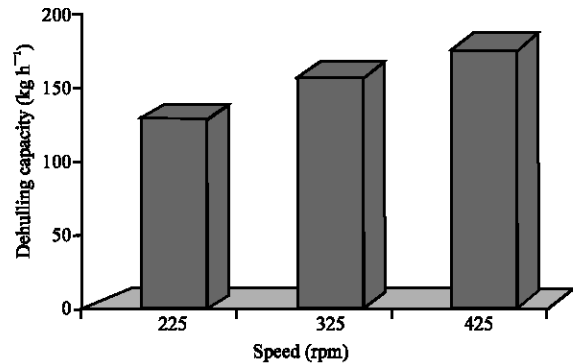


Fig. 3: Effects of speed on the dehulling capacity of a breadfruit dehuller

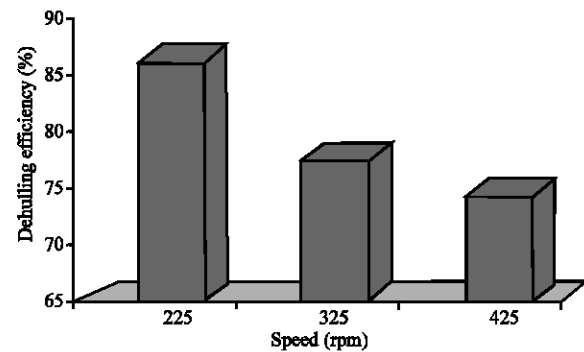


Fig. 4: Effects of speed on the dehulling efficiency of a breadfruit dehuller

Table 1: Analysis of variance for speed vs dehulling capacity

Sources	Degrees of freedom	Sum of squares	Mean squares	F _{Cal}	F _{TAB(5%)}
CFM	1	351747.27	-	-	-
Factors	2	6122.13	3061.07	57.25***	3.88
Error	12	641.60	53.47	-	-
Total	14	6763.73	483.12	-	-

Table 2: Analysis of variance for speed vs dehulling capacity

Sources	Degrees of freedom	Sum of squares	Mean squares	F _{Cal}	F _{TAB(5%)}
CFM	1	94248.07	-	-	-
Factors	2	362.53	181.270	36.01***	3.88
Error	12	60.40	5.033	-	-
Total	14	422.93	-	-	-

The effect of speed on the dehulling capacity of the machine was highly significant at 5% probability (Table 1).

This shows that at higher speeds the machine was able to process more breadfruit seeds than at lower speeds because of increased processing action at higher speeds. Also there was a high significance of the effect of speed on dehulling efficiency at 5% probability (Table 2).

This is due to the fact that at higher speeds the breadfruit seeds were discharged so quickly from the dehulling chamber without properly dehulling them, thereby causing lower dehulling efficiencies at higher operating speeds.

CONCLUSION

The breadfruit dehulling machine was developed and had satisfactory performance. It has a maximum dehulling efficiency of 86% at 225 rpm speed and a dehulling capacity of 127 kg h⁻¹.

RECOMMENDATION

It is recommended for use by food processors to reduce the drudgery involved in the use of laborious traditional methods.

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