

Development and Performance Analysis of a Dehulling Machine for Enhanced Efficiency and Quality Processing of Soybean

¹Olajide O. G., ²Fawohunre A. J. and ³Fasoyin S. A.

^{1,2,3} Department of Agricultural and Bio-Environmental Engineering Technology, Rufus Giwa Polytechnic, Owo, Ondo State, Nigeria.

Abstract

The study focused on the design and fabrication of a soybean dehulling machine aimed at improving processing efficiency and reducing the labour associated with manual dehulling. The machine was powered by one horsepower (1HP) electric motor operating at a rotational speed of 600 rpm. It was designed to effectively separate the seed coat from the cotyledon while minimizing mechanical damage. The performance evaluation was carried out at three different levels of moisture content 10%, 12%, and 14% to determine the effect of seed moisture on dehulling efficiency and seed breakage. The performance of the machine was affected by the seed moisture level. An optimum performance occurred at 12% moisture content, with a dehulling efficiency of 90.4% and a minimal breakage rate of 0.3%. These findings indicate that moderate moisture enhances the frictional interaction between the seeds and the dehulling surface, leading to efficient shell removal. The developed machine demonstrated a reliable operation, ease of maintenance, and suitability for small and medium scale soybean processors.

Keywords: Soybean; Dehulling machine; Moisture content; Machine performance; Breakage rate

1. Introduction

Soybean is usually grown as a food crop and also, one of the major industrial crops grown in every part of the world (Gaguan and Nagal, 2025). In Nigeria, the crop can be cultivated successfully in many states using low agricultural input (Sunday *et al.*, 2024). It is also requiring a far lower use of fertilizers and in fact provides a huge benefit due to its nitrogen-fixing properties to the soil. This makes soybean an excellent rotational crop (with corn, sorghum or cotton) for Nigeria, as the availability and cost of chemical fertilizers is a major constraint.

Due to the production level, Nigeria has recorded largest production of the crop for human and livestock feeds in West and Central Africa. This made the country to have an enormous prospect for producing the oil instead of imported vegetable oils (Abhadionmhen *et al.*, 2025). The current domestic demand and home consumption have made the crop a versatile and multi-purpose agricultural product that could be processed in almost three hundred and sixty methods for human, livestock and industrial goals. The demand and consumption of the crop made the indigenous mills working earnestly for producing edible oils from soybean to reverse the hardship encountered by the people due to the effect of the current ban of imported vegetable oils as well as to meet the demand of the oil.

Soybean has an average of forty and twenty percent protein and oil contents respectively, it is free from cholesterol and more protein-rich than any of the common vegetable of animal food (Olajide *et al.*, 2019). The rapid growth in the poultry sector in the past ten years has also increased demand for soybean meal in Nigeria (Oluwadele *et al.*, 2024).

Some of the operations carried out on soybean after its production include harvest, pre-drying, threshing, pre-cleaning, drying, cleaning and sorting, packaging, storage and processing (dehulling, milling and so on) (Agbokou *et al.*, 2025). The primary production of soybean is mainly for their meal. Meal and oil are the primary and secondary products of soybean respectively (Liu *et al.*, 2024).

The unit operation which involves taking off of the fibrous soy seed coat that compactly enclose the cotyledons describe the term dehulling. Mortar and pestle, hand rubbing and grinding stone are used in the

ancient days to dehull the seed which thereby give room for a better way of dehulling which brings about the mechanical way (Akintola *et al.*, 2018; Mounika *et al.*, 2025).

2. Materials and Methods

2.1 Operation of the machine

The soybean dehulling machine used abrasion force. Dehulling take place in the annular space between rotating shaft and stationary cylinder. The dehulled soybeans pass out through an outlet of the dehulling chamber while the chaff pass through another outlet. The fabricated machine is shown in **figure 1**.



Figure 1: The fabricate soybean dehulling machine

2.2 Design Calculations

The Hopper Design: The hopper was designed based on the volume of frustum of a pyramid. The volume of the frustum of a pyramid was obtained as given by (Fawohunre and Olajide, 2020; Akintola *et al.*, 2018).

$$\text{Volume of the first pyramid} = \frac{1}{3}a^2(h + y) \quad (1)$$

$$\text{Volume of the second pyramid} = \frac{1}{3}b^2y \quad (2)$$

$$\text{Volume of the frustum} = \frac{1}{3}\{a^2(h + y) - b^2y\} \quad (3)$$

where: h = height of frustum (mm), y = height of small pyramid (mm), a = length of one side of the square base of the first pyramid (mm) and b = length of one side of the square base of the second pyramid (mm).

Capacity of hopper: The capacity of hopper was determined using equation (4) as given by Olajide *et al.*, 2019.

$$c_h = \frac{v_{cp}}{v_s} \quad (4)$$

where: c_h = capacity of hopper, v_{cp} = volume of hopper and v_s = volume of soyabean

The belt design: The following equations will be used for the determination of length of belt as given by Khurmi and Gupta (2014) as:

$$L = 2c + \frac{\pi}{2}(d_2 + d_1) + \frac{(d_2 - d_1)^2}{4c} \quad (5)$$

where, L = length of belt (mm), d_1 = diameter of driver pulley (mm), d_2 = diameter of driven pulley (mm), c = distance between center of the two puller (mm) and $\pi = \frac{22}{7}$

The pulley design: The machine pulley diameter will be determined using equation (6) as given by Fawohunre and Olajide, 2020.

$$n_2d_2 = n_1d_1 \quad (6)$$

where, d_2 = diameter of the motor pulley (mm), n_2 = speed of the motor (rpm), d_1 = desired diameter of the machine pulley (mm) and n_1 = desired speed of the machine (rpm)

The Shaft design: The determination of shaft diameter was suggested by Khurmi and Gupta (2012).

$$d^3 = \frac{16n}{\pi S_s} \sqrt{(kb \times cbm)^2 + (kt \times ctm)^2} \quad (7)$$

where, d = diameter of shaft (mm), π = Constant (3.142), cbm = combine bending moment, ctm = combine torsional moment, S_s = 8000 psi for shaft without keyway, n = factor of safety, k_b = combine shock and fatigue factor for bending moment and k_t = combine shock and fatigue factor for torsional.

Dehulling chamber design: The dehulling chamber was a thin-walled cylinder, the tangential stress perpendicular to the axis of the cylinder is given in equation (8) as:

$$\sigma = \frac{pd_{dc}}{2t} \quad (8)$$

where: σ = perpendicular of hoop stress, assumed to be the maximum tensile stress the cylinder is subjected to failure by yield, p = internal pressure, t = thickness of dehulling chamber and d_{dc} = internal diameter of dehulling chamber

Also,
$$\sigma = s_{ass} = \frac{0.5 s_y}{n} \quad (9)$$

where: s_{ass} = allowable shear stress, n = factor of safety and s_y = yield stress

Volume of dehulling chamber: The volume of dehulling chamber was given as:

$$v_{dc} = \pi r_{dc}^2 l_{dc} \quad (10)$$

where: r_{dc} = radius of dehulling chamber (mm) and l_{dc} = length of dehulling chamber (mm)

Power requirement: The power required to turn the shaft of the machine for effective dehulling was suggested by Khurmi and Gupta (2012).

$$p_d = T_d \omega_2 \quad (11)$$

$$\frac{T_m}{T_d} = \frac{\omega_2}{\omega_1} \quad (12)$$

where, p_d = power required for dehulling (watt), T_d = dehulling torque for feed rate, ω_2 = dehulling speed (rad/s), T_m = motor torque and ω_1 = speed of the motor (rad/s).

3. Results and Discussion

3.1 Results

The dehuller is designed for soybean and operates capably at a speed of 600 rpm. A test usage of the machine was carried out; it was run without load for 5 minutes with 1 hp electric motor. Thereafter it was loaded with 750g of soybeans through the hopper. The performance of the soybeans dehuller was evaluated at different moisture contents (10%, 12%, and 14%) to determine how moisture level affects its operating efficiency and rate of breakage. The beans were conditioned to the required moisture levels before dehulling to maintain uniform testing conditions. The result is presented in **Table 1**.

Table 1: The results of the performance test

Moisture Content (%)	Weight of dehulled soybean (g)	Weight of dehulled soybean (g)	Dehulling efficiency (%)	Breakage rate (%)
10	750	609	81.2	0.5
12	750	678	90.4	0.3
14	750	635	84.7	0.9

3.2 Discussions

Figure 1 illustrates how moisture content affected the rate of kernel breakage while **Figure 2** presents the variation of dehulling efficiency with moisture content. The two **Figures** clearly show that the performance of the dehulling machine is strongly influenced by the moisture content of the soybeans. At low moisture level (10%), the grains were too dry and brittle, leading to poor hull separation and frequent cracking. As the moisture content increased to 12%, the dehulling efficiency reached its peak while both the breakage rate dropped to its lowest values. This condition therefore represents the optimum moisture level for effective dehulling. Beyond this point (at 14% moisture), the performance declined again. The beans became overly soft, and the hull started to adhere to the seed surface. This reduced the impact effectiveness of the hulling mechanism and caused more incomplete separations and minor surface damage.

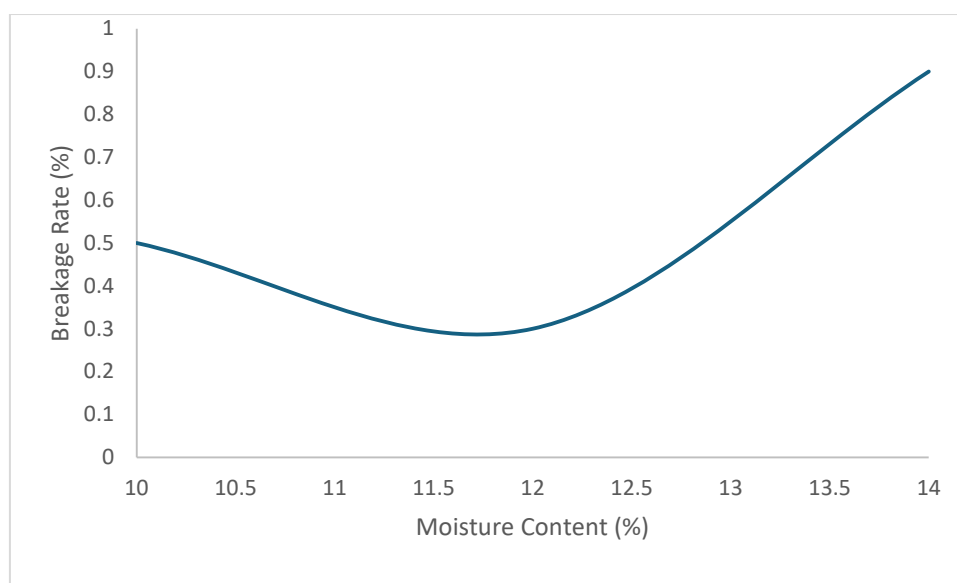


Figure 1: Relationship between moisture content and breakage rate

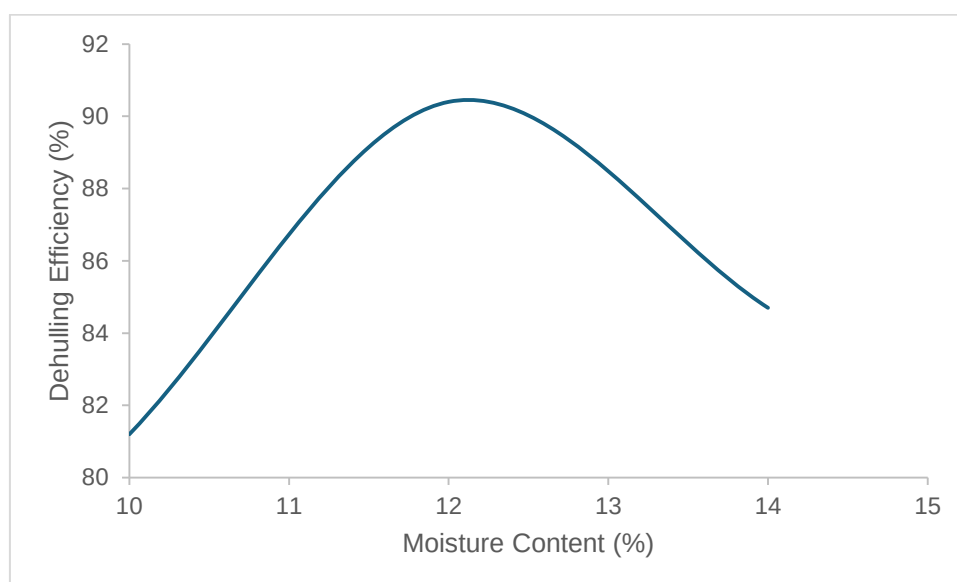


Figure 2: Relationship between moisture content and dehulling efficiency

4. Conclusion and Recommendation

4.1 Conclusion

The study examined the performance of a locally fabricated soybeans dehulling machine with particular attention to how moisture content affects its operation. The experimental results revealed that the moisture level of the beans is a critical factor determining the overall efficiency of the dehulling process. When the soybeans were too dry, the hulls resisted separation and the kernels fractured easily. On the other hand, excessive moisture caused the hulls to soften and stick to the cotyledon, reducing the effectiveness of shell removal. Among the conditions tested, a moisture content of 12% gave the most satisfactory performance, producing the highest dehulling efficiency with minimal breakage.

4.2 Recommendations

Even though the findings are satisfactory, continued development could expand the machine's range of use and boost operational performance:

- i. **Moisture Conditioning:** Beans should be
- ii. e conditioned to about 12% moisture content before dehulling to ensure maximum efficiency and reduce kernel damage.

- ii. **Speed Optimization:** Further tests should be conducted at different shaft speeds to determine the best combination of rotational speed and feed rate for various bean varieties.
- iii. **Material Selection:** The use of mild steel or stainless steel for the contact surfaces is encouraged to improve durability and minimize contamination of the product.
- iv. **Further Research:** Future studies can focus on evaluating the machine's performance with other legumes and on developing a moisture-control unit that automatically conditions the grains before dehulling.

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