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DEVELOPMENT OF A LOCUST BEAN SEED DEHULLING CUM WASHING MACHINE

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ABSTRACT

A wet locust bean seeds (Parkia biglobosa) dehulling and washing machine was developed to reduce drudgery attached to traditional dehulling of the seeds which are processed for use as condiment and flavours' for food in many African countries. The machine consisted of dehulling and washing units, the dehulling mechanism obtains its drive from a 0.38 kW gear motor of 30 - 50 rpm. The dehulling shaft; has rods arranged concentrically to break seed coat and radial fan - like blades used as stirrer. The dehuller cum washer was evaluated based on boiling time of the seeds on an electric cooker. The result indicated that efficiency of the machine increased linearly with increase in boiling time. The throughput capacity decreased with increase in boiling time and moisture content decreased with increase in boiling time from the sixth hour. Dehulling efficiency ranged from 59.7 to 68 %, and cleaning efficiency ranged from 83.4 to 87.4 % while average throughput capacity was 108 kg/hr.

Keywords: Locust bean, dehulling, washing and boiling, separation, dehuller efficiency.

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1. INTRODUCTION

African locust bean (*Parkia biglobosa*) is a member of the Leguminosae family crop normally found around the tropics and several towns in the savannah territories of West Africa especially in the middle belt and south western area of Nigeria [1]. It is common in Nigeria particularly in the Northern and South-Western Nigeria [2]. African locust bean tree produce fruits from December to March. The fruits are ready for harvest in April and have many leguminous pods each with a tough pericarp. The matured locust bean fruit is shown in Figure 1. Although all the parts of the African locust bean are useful, the seed is used as a food condiment and is a good substitute for meat because it is high in protein, fat, and vitamins, tannin and mineral contents [3, 4]. The pods were harvested and processed into the fermented product known as *'iru', 'dawadawa', 'ogiri'* in the Yoruba, Hausa, and Igbo languages respectively. The pods also contain yellow powdery pulp in which seeds are embedded. The seeds have hard, black testa making them less vulnerable to insects and rodent infestation [5].

On a moisture-free basis, the fermented locust bean contains about 40 % protein, 32 % fat and 24 % carbohydrate [6]. Thus, apart from being a food condiment the fermented bean also contributes to human calorie and protein intake. According to Diawara *et al*. [7], it has essential acids and vitamins and serves as a protein supplement in the diet of the poor. Locust bean could be added to maize to produce fortified-pap with a better protein base, just as in the case of soy-ogi. *Dawadawa* is used in soups, sauces and stews to enhance or impart meatiness [8]. The African locust beans can only be safe for consumption after it has been processed i.e. when the toxins and the anti-nutrients have been removed [9]. The major processing procedures involves harvesting, decorticating, de-pulping, and drying to get the locust beans seed that represent the major raw material from this important crop [10]. There are mainly two locust beans processing methods namely: traditional and the improved (modern) method. Traditional method of locust bean processing is a rigorous, time consuming, and unhygienic one [9]. Traditional dehulling of locust beans is untimely, laborious and inefficient. The procedure had witnessed little or no substantial technological transformation and progress in the manufacturing techniques. Olaoye [10] postulated two major constraints involved in the production and processing of locust bean as bottleneck associated with the crop's seasonality and traditional technology with its attendant low quality and quantity of the derived products. Increased consumption of "i*ru"* as a condiment has attracted research interests in development of machines to take care of some of its unit process operations. Traditional "*iru"* processing is still being carried out at a domestic level. Sadiku, [5], considered in detail the different methods of processing locust bean in South West of Nigeria. The methods of processing locust bean that were assessed were: *Ajibode*, *Saki*, *FRIN* and improved methods as described by Sadiku, [5]. A control method in which there was no addition of chemical substances was included.

Mechanizing post-harvest processing of locust bean will reduce drudgery associated with its processing, improve the quality and acceptability of condiment, improve the shelf life of the condiment and enhance the rural economy [11]. There is a general awareness in developing countries that rapid development of agriculture depends largely on the successful introduction of modern and small-scale agricultural machinery [12].

Faleye *et al.,* [1] observed that decorticating by hand is labour intensive, grossly inefficient and consumes time. Therefore, a simple and relatively inexpensive decorticating machine must be developed to overcome these predicaments. Agricultural processing includes activities that maintains, raises the quality or changes the form or characteristics of an agricultural [13]. Processing activities are undertaken to provide a greater yield from a raw farm product by either increasing the amount of the finished product, the number of finished products or both and to improve the net economical value of a product. Many processes (unit operations) are involved in converting a raw product to a finished product that is consumable by the end users. Each of these processes is referred to as a unit operation. The major unit operations in processing of agricultural products includes; dehulling, cleaning, size reduction, grading, parboiling, blanching, drying, separation, mixing, packaging, etc. There are two basic methods of cleaning which can be dry and wet cleaning [14].

Dehulling of locust beans is basically a wet cleaning process vital in the removal of foreign materials from crops and guarantees less damage to the crop. Effectiveness of dehulling is determined by the availability of water as the cleaning liquid, which helps in the removal of dirt, dust and other light particles from the locust beans. They are usually in a pulpy media after they have been soaked or fermented in water and must be separated from their pulpy media before they can be further processed into consumable products. The separation is accomplished by washing with water. This work develops and evaluates a machine that performs wet dehulling cum washing with a view to obtain an insight on the best processing parameters that should be met to have efficient processing of the locust beans seed thereby reducing wastage, improving product quality, reducing drudgery and fatigue. The parameters to be considered for evaluation of machine's performance include parboiling time, weight of seeds, moisture content and its effect on dehulling efficiency and throughput capacity.

2. MATERIALS AND METHODS

2.1. Materials Selection

The factors considered in the development of the wet locust beans seeds dehulling machine includes: cost of the materials, construction technique, availability of materials, durability of materials, cost of maintenance and effect of the material used on the food material. Galvanized steel was used for the dehulling and washing chambers, while angular mild steel was used for the frame of the machine for rigidity and stability.

2.1.1. Machine operation

The wet locust bean seeds dehulling machine dehulls and separates locust beans from its coat. These beans are first dehulled in the dehulling chamber. The dehulling shaft is powered by a 0.5hp electric motor which is connected to a gear reduction device to further reduce the dehulling and washing speed. As the dehulling shaft rotates, it provides drive to the dehulling stirrer mechanism inside the dehulling unit and the washing unit respectively. As the locust beans are fed into the dehulling cylinder through the feeding chute (hopper), they are dehulled by abrasive action and then conveyed to the washing unit under the dehulling unit. The stirrer in the inner concentrate cylinder of the washing unit gently stirs the dehulling beans solution to dislodge the coats from the seeds. Due to the variation in the density of the coat and the seed from the density of water, the coat floats on the water which is collected by lowering the outer concentrate of the washing unit with hand operated handle.

2.2. Machined Design Analysis

2.2.1. Design of the dehulling unit

Capacity of dehulling unit was designed to be portable and to avoid over feeding the machine by using eqn.1

$$V = \pi r^2 h \tag{1}$$

Where; V = volume of the dehulling cylinder, m^3

$$V = \pi \times 0.1935^2 \times 0.15 = 0.0176\, m3$$

2.2.2. Washing unit capacity

Volume of inner cylinder, V

$$V = \pi r^2 h \tag{2}$$

$$V = \pi \times 0.135^2 \times 0.21$$

$$V = 0.012 m^3$$

$$p = \frac{m}{v} \quad (3)$$

$$551.66 = \frac{m}{0.012}$$

Capacity, m = 6.62 kg

2.2.3. Determination of shaft torque

$$T_S = \frac{P_S}{\omega_S} \quad (4)$$

Where T_s = torque of shaft, p_s = power delivered from the motor to drive the shaft
ω_s = angular speed of shaft

$$\omega_S = \frac{2\pi N}{60} \quad (5)$$

Where N = speed of gear motor, which is 30 rpm
Therefore,

$$\omega_S = \frac{2\times\pi\times30}{60} = 3.142 \text{ rad/s}$$

Power generated from the gear motor = 0.5 hp (0.375 kW.
Assume 5% of power is lost during transmission;

$$5\% \text{ of } 0.375 \text{ kw} = \frac{5}{100} \times 0.375 = 0.019 \text{ Kw}$$

Therefore, power delivered from the motor to the shaft, p_s

$$p_s = 0.375 - 0.019 = 0.356\, kw$$

Finally, torque of shaft, T_s

$$T_s = \frac{0.356 \times 10^3}{3.142}$$

$$T_s = 113.3\, Nm$$

2.2.4. Determination of minimum shaft diameter

Eqn. 6 was used to design minimum shaft diameter

$$d^3 = \frac{16T_s}{\sigma\pi} \quad (6)$$

Where, $T_s = torque\ of\ shaft, 113.3\ Nm$

d = minimum shaft diameter (Factor of safety for steel materials = 4, Maximum allowable working stress = 112MN/m^2) [15]

$$\text{Factor of safety F. S} = \frac{allowable\ stress}{Working\ stress}$$

$$d = \sqrt[3]{\frac{16 * (113.3 * 10^{3)}}{\pi * 28}} = 27.4mm, d = 2.7cm$$

Therefore, in the design we used 3cm shaft

2.2.5. Determination of torsional deflection of the shaft

Khurmi and Gupta [15] gave an equation to evaluate the torsional deflection of a shaft. Below is the equation

$$\sigma = \frac{584TL}{D^4G} \tag{7}$$

Where G = torsional modulus of elasticity, 8000 N/mm, D = shaft diameter, 25 mm and L= length of shaft, 510 mm

$$\text{Hence, } T = (\frac{D}{2.26})^4$$

$$T = 31 \times 10^3 \text{ N-mm}$$

Finally,

$$\sigma = \frac{584 \times (31 \times 10^3) \times 510}{30^4 \times 8000}$$

$$\sigma = 1.43°$$

2.2.6. Determination of the power requirement of the machine

a) Determination of the power requirement to dehull the boiled locust bean

$$P_h = T_s\omega$$

Where $P_h = Power\ required\ to\ dehull$, $T_s =$ torque of shaft, $\omega = angular\ speed$

$$P_h = 113.3\ Nm \times 3.142$$

$$P_h = 0.36\ kw$$

b) Determination of power required to drive the dehulling and washing shaft.

$$P_{c1} = W_{c1}r_c \tag{8}$$

Where $P_c = Power\ required\ to\ drive\ the\ shaft$, $W_c = weight\ of\ the\ conveyor$

$$r_c = radius\ of\ the\ conveyor = 0.1m$$

$$mass = 1.5\ kg$$

$$W_c1 = 1.5 \times 9.81 = 4.72\ N$$

$$P_{c1} = 19.62 \times 0.1 = 0.001472 \text{ kW}$$

$$P_{c2} = 4.905 \times 0.05 = 0.00025 \text{ kW}$$

Total power required by the machine

$$\text{P} = P_h + P_c1 + P_{c2}$$

$$= 0.36+0.001472+0.00025 = 0.326 \text{ Kw}$$

P = 0.48hp. Hence, 0.5hp motor was selected

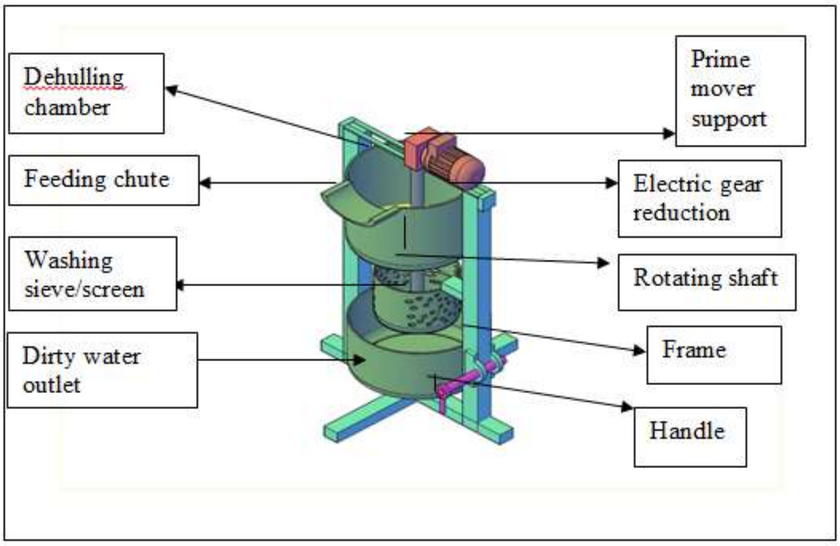

Figure 2 AUTOCAD representation of the machine

2.3. Preparation of Samples

The locust bean seeds were obtained from the teaching and research farm of Landmark University. The locust bean seeds were weighed using a digital weighing balance (CAMRY ACS-30-ZE41, CAMRY), and each was sorted out for material other than the bean after which it was divided into four (4), each of 1.5 kg before parboiling. The locust bean seeds were boiled in a stainless cooking pot with lid before dehulling at different boiling time (6, 8, 10 and 12 hours). Moisture content (dry basis) was determined using the digital moisture analyser. Weight of the boiled beans was determined using the weighing balance. The boiled beans were then dehulled and washed using the fabricated wet locust bean seed dehuller and washer at desired operating speed. After the dehulling and washing process, the samples were collected. The mass of undehulled beans, whole beans, broken beans in the final product and the mass of the coat were determined respectively. The dehuller efficiency, coefficient of wholeness of beans defining the quality of beans recovered, the throughput capacity, coefficient defining the quantity of beans dehulled, cleaning efficiency were calculated respectively and at different boiling time.

2.4. Performance Evaluation of the Machine

The machine operational parameters such as throughput capacity, dehulling efficiency, cleaning efficiency and quality performance efficiency were determined using eqn. 9 – 13;

Throughput capacity

$$T_P(Kg/h) \tag{9}$$

$$T_P = \frac{3.6M_t}{t_D}\left(\frac{Kg}{h}\right)$$

Where, M_t = Mass of sample before dehullin, t_D = Time used in dehulling in secs

Dehuller efficiency,

$$DE = 100(C_h \times C_w) \tag{10}$$

Where, C_h = coefficient defining the quantity of beans dehulled

$$C_h = 1 - \left(\frac{M_u}{M_t}\right) \tag{11}$$

where M_u = mass of undehulled beans in the final product(Kg)

M_t = mass of sample before dehulling(Kg), C_w, *coefficient of wholeness of beans*

$$C_w = \frac{K}{K+b} \quad (12)$$

Where; k = mass of whole beans in the final product, kg

b = mass of broken beans in the final product, kg.

Cleaning efficiency,

$$CE = \frac{W_C}{W_{O+}W_S} \quad (13)$$

Where W_c = weight of clean beans, kg, Wo = weight of coat, kg, Ws = weight of un-dehulled bean, kg.

3. RESULTS AND DISCUSSION

3.1. Effect of Moisture Content

Fig. 3 shows the variation of moisture content (MC_{db}) of the locust bean with different boiling time. From figure 4 it can be seen that the moisture content decreased with duration of boiling. The maximum was 102.51 %, at the sixth hour of boiling, and the minimum moisture content was 53.68 %, at the twelfth hour. After the sixth hour of boiling the coat is already very soft and further boiling cause's reduction in the water holding capacity of the coat. This confirming to Audu *et al.*, [16], where it was stated that moisture content increases and get to it maximum at the sixth hour.

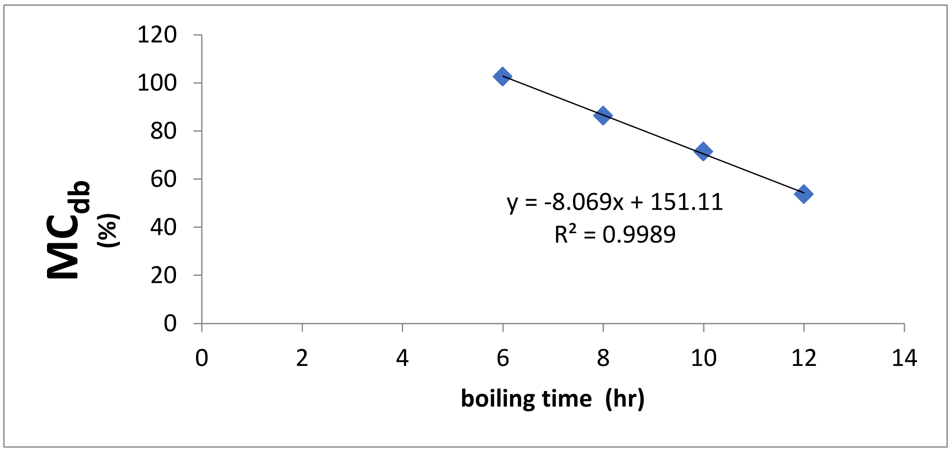

Figure 3: Variation of locust beans moisture content with boiling time

3.2. Effect of Duration of Boiling on Dehulling Efficiency (DE)

The effects of boiling time on Dehulling efficiency (DE) is shown in fig. 4 DE increased with the boiling time. Minimum and maximum efficiencies of 44.13 and 59.72% were obtained at 6 and 12 hours respectively. The low efficiency obtained initially was probably due to hard seed coats which were difficult to remove, thereby leaving many undehulled locust beans and a larger part of few cotyledons obtained were broken. At a higher boiling time, the coat were softened, therefore making dehulling easier with less breakage, since it elasticity increases with boiling time, this is in agreement with Faleye *et al.*, and Gbabo *et. al.*, [1, 17].

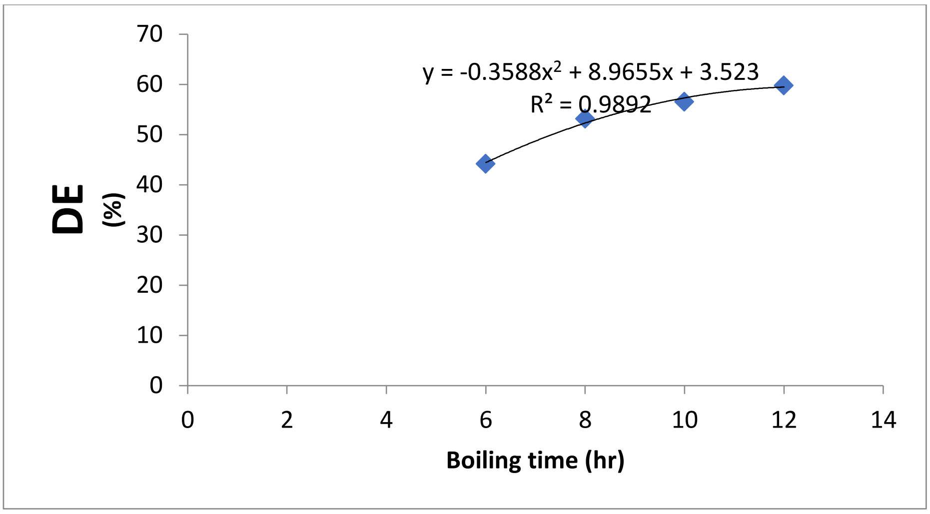

Figure 4: Effect of locust beans boiling time on dehulling efficiency

3.3. Effect of duration of boiling on cleaning efficiency, CE

Figure. 5 shows that the cleaning or separation efficiency increased with boiling time. This is probably because as the dehulling efficiency increase, the quantity of whole dehulled beans also increase weight of undehulled bean reduces, making the separation efficiency to be on a positive increase. It also shows it is highly correlated and linear. This is in relation with the study carried out by Gbabo *et. al*., [17].

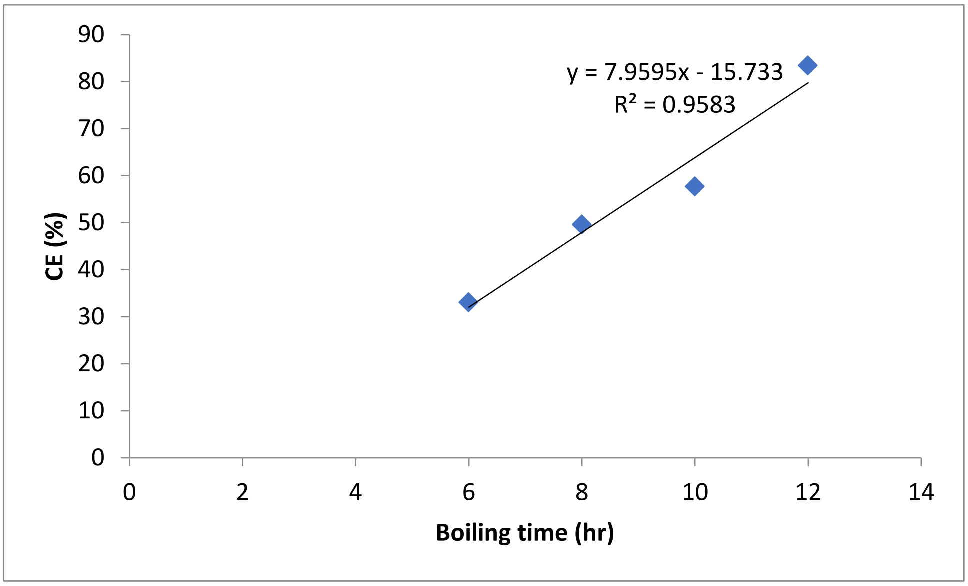

Figure 5: Effect of boiling time on cleaning efficiency

4. CONCLUSIONS

The wet locust bean seed dehuller washer was developed. Below are the following conclusions:

a) The bean dehuller cum washer works more efficiently as the boiling time increases. The machine attained a dehulling efficiency of 59.72 % and separation or cleaning efficiency of 83.39 % when the boiling time was 12 hours as compared to the value of 6 hours.

b) The best set of conditions under which the dehuller operates is a boiling time of 12 hours, moisture content of 53.7 %, at which maximum dehulling efficiency of 59.72 % and cleaning efficiency of 83.4 %.

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