DEVELOPMENT OF A MEDIUM SCALE MOTORIZED DRY BEAN SEED DEHULLING MACHINE

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ABSTRACT
The need to dehull seeds such as maize, beans, etc for further processing for various food products has become imperative. Thus, this work aimed at developing and fabricating a dry bean seed de-hulling machine using abrasive disc design concept. The de-hulling mechanisms utilizes eight abrasive discs attached to the shaft in the de-hulling chamber of the machine. The de-hulling machine was specifically developed for dry bean seed processing however, could also work for other seed such as maize, soya beans and guinea corn. The chaffs leave the machine through a slot created under the polishing chamber while the de-hulled seed fall through the seed outlet under the action of gravity into a bowl or sack placed under the polishing chamber. Preliminary evaluation revealed that the machine had output capacity of 1.04 ton per hour with overall efficiency of 83.60 %.

KEYWORDS: Development, Machine, De-hulling, Dry Bean Seed

1. INTRODUCTION
De-hulled bean seed is a product that is used for various delicacies in Nigeria, such delicacies ranges from Akara in Igbo language, Kosai in Hausa language and English language is known as bean cake, Moimoi and cooked milled de-hulled bean without oil commonly referred to as *Ekuru* in Yoruba language. Another is bean soup known as Gbegiri soup which is a delicacy in the consumption of cooked yam flour commonly referred to as Amala. These food products mentioned are widely consumed across Nigeria and some other countries of the world mostly in Africa.

Thus, de-hulling of dry bean seed become a major challenge. However this has not been adequately addressed as bean is commonly been de-hulled by soaking in water and thereafter rubbing the seeds against each other manually by hand, leg or pestle and mortar. This method is wet de-hulling where the product is difficult to store because of the moisture level of the de-hulled.

The need to encourage motorising dry de-hulling becomes imperative because it will save time as preparation is without going through rudiment of soaking in water. It will also create job opportunities through small scale industry. None the less de-hulling of bean seed has been from time immemorial; however, this study is looked at creating an indigenous way of coming up with a technology that can de-hull dry bean seed in a cheap and efficient method using locally available materials.

De-hulling involves removal of the fibrous seed coat that tightly envelops the cotyledons. In other words, de-hulling may be described as the efficient and complete removal of the outer layers enveloping the cotyledons from the kernel leaving a seed coat free cotyledon. Mortar and pestle, hand rubbing and grinding stone are used in the olden days to de-hull seeds, thereby giving room for a better way of de-hulling. There some attempts to motorise seed de-hulling

resulting in the development of machines based on attrition and tangential abrasive de-hulling devices (Akintola, et al. 2018).

It has been suggested that as much as 33-5 0% of food grade protein will come from plant protein in the future (Bird, 1974). Dry edible beans provide an excellent source of protein and a balance of other essential nutrients to the diets of both developed and subsistent populations (Muggio, et al 1981). At the same time that consumption of vegetable proteins is expected to increase, U.S. per capita consumption of canned and packaged dry beans has continued to decline from 7.6 pounds per year in 1962 to 4.1 pounds per year in 1981. Whole beans require soaking and long cooking times. Canned beans, one of the first convenience foods, have become a staple but less promoted product on retail shelves.

A study by the National Science Foundation identified five potential areas for increasing the per capita consumption of dry beans, including the development of food products based on legumes (Adams et al., 1978). New technologies for altering the form of dry edible beans into specialty flours have been developed by the Protein Research Centre at Texas A&M University and tested at the Food Science and Human Nutrition Department at Michigan State University. Dry bean flour is a new product to the industry whose marketability and costs are not known. The aim of the study was to develop a motorized dry bean seed de-hulling machine to make dry bean seed product available with specific objective of reducing the drudgery in manual dry beans de hulling. This is towards enhancing commercial scale beans processing.

2. MATERIALS AND METHODS

2.1 Description of the Machine

The dry bean seed de-hulling machine can de-hull dry bean seed of different size. The machine consists of the following main parts: hopper, de-hulling chamber, drive shaft, polishing chamber, and frame as shown in Figure 3.

2.1.1 Hopper: The hopper of the machine has the length of 360 mm, 305 mm width and the height of 270 mm. It was made from a 2mm thick stainless steel sheet. The hopper unit is connected to polishing chamber as it accommodates the dry bean seed before gradually moving to the polishing chamber.

2.1.2 De-hulling Chamber: It has the length of 290 mm, 285 mm width and the height of 250 mm, the de-hulling chamber is in between the hopper and the polishing chamber it accommodates de-hulling mechanism made of up four abrasive discs attached to the shaft at equidistance, the shaft is connected to the big pulley of the machine which transmit power from R175 diesel engine with the aid of belt to the de-hulling chamber. After de-hulling the de-hulled dry bean seeds gradually moves to the polishing chamber.

2.1.3 Polishing Chamber: The polishing chamber is attached to the through chute under the de-hulling chamber with length of 465 mm made from stainless steel sheet and diameter of 300 mm, it houses the polishing mechanism made of up brushes which rob dehulled beans against the drum wall thereby polishing the de-hulled dry bean seed. Thereafter the polished seed moves out of the machine through the seed outlet and collected using bowl or sack.

2.1.4 Drive Shaft: The shaft has the length of 670 mm with diameter 30 mm. It is held by two pillow bearings from both sides, the shaft transmits torque and motion generated by prime mover to turn the de-hulling and polishing mechanisms.

2.1.5 Frame: The frame of the dry bean seed de-huller is 985 mm long, 1000 mm high and 430 mm wide. It supports and allows the body to rest firmly. Itis made from 45 x 45 mm angle iron.

2.2 Working Principle of the Machine

The dry bean de-huller is operated and powered by a R175 diesel engine. It is operated by loading a dry bean into the hopper further dropping by gravity into the de-hulling chamber. The de-hulling chamber has four abrasive discs attached to the shaft which perform the task of removing the coat that cover the bean seed by robbing the bean seed against the discs arranged equidistance from each other. The de-hulled bean moves into the polishing chamber where the seed would be polished and discharged through the seed outlet into a bowl or sack.

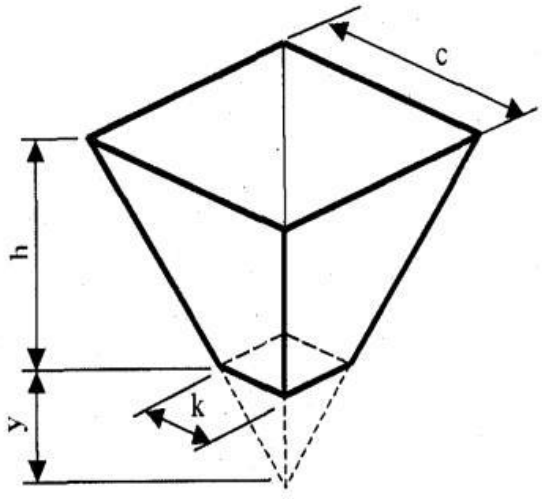
2.3 Design Considerations

In the design of the dry bean de-huller, many factors were considered to achieve an acceptable level of reliability and efficiency. These include: -

1. Physical properties of materials to be handle
2. Effective de-hulling, polishing and minimal loss of useful bean seed
3. Affordability, workability, availability and strength of materials used for fabrication
4. The quality of food to be handle, hence material that will not contaminate it.

2.4 Design Calculations

2.4.1 The hopper Design: The hopper was designed based on the volume of frustum of a pyramid. The volume of the frustum of a pyramid can be obtain as showed below:-



Volume of the big pyramid = $\frac{1}{3}c^2(h+y)$ (1)

Volume of the small pyramid = $\frac{1}{3}k^2y$ (2)

Volume of the frustrum = $\frac{1}{3}\left[c^2(h+y) - k^2y\right]$ (3)

where,

h is height of frustum {m}
y is height of small pyramid {m}
c is length of one side of the square base of the big pyramid {m}
k is length of one side of the square base of the small pyramid {m}

Capacity of Hopper= $\frac{Volume\ of Hopper}{Volume\ of}$ dried bean seed (4)

2.4.2 The pulley:To determine the speed of the driven pulley, the relationship given by Ghupta and Khumi (2004) was adopted.

$$nd = ND \quad (5)$$

where,

d is diameter of the small pulley {m}
n is speed of the small pulley {m/s}
N is desired speed of the big pulley {m/s}
D = desired diameter of the big pulley {m}

2.4.3 Belt Length:The length of the belt will be determined using Equation (6).

$$L = 2C + \frac{\pi}{2}(D_1 + D_2) - \frac{(D_2 - D_1)^2}{4C} \quad (6)$$

where,

L is total length of the belt (mm)
D_1 is diameter of driven pulley (mm)
D_2 is diameter of driving pulley (mm)
C is distance between the centres of the two pulleys (mm)

2.4.4 The Belt Drive: Belts are used to transmit power in equipment. It requires close spacing and centre distance. It transmits power from motor to the shaft making the centre distance between motor and shaft to be adjustable. The twisting moment (T) was given as:

$$T = (T_1 - T_2)\ xR \quad (7)$$

where,

T_1 is Tension in the tight side
T_2 is slack side of the belt
R is Radius of the pulley
Tension ratio for an open belt was calculated using Equation (8)

Let 2.3 $log\frac{T_1}{T_2} = \mu\pi$ (8)

Where: μ is the coefficient of friction between rubber belt and mild steel pulley given by 0.3.

2.4.5 The Shaft: The shaft was made from mild steel taking into consideration the Yield strength of the material, *Y and* Ultimate tensile strength, S_{ut} (Akintola et al., 2018).

2.5 Fabrication of Dry Bean Seed De-huller

Fabrication of the dry bean seed de-huller was carried out at the fabrication workshop of the Nation Centre for Agricultural Mechanization (NCAM), Ilorin. Figure 2 shows the detailed and dimensioned diagram of the produced dry bean de-hulling machine.

2.5.1 Hopper: It was constructed with stainless steel sheet of 2mm thickness, the length of the hopper is 360 mm, 305 mm width and height of 250 mm which are welded together to form the hopper in trapezoid shape.

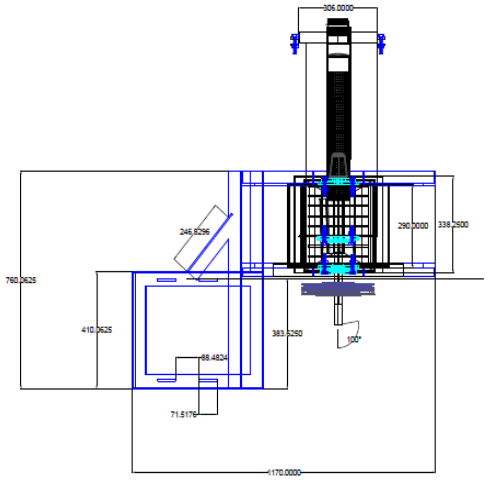
2.5.2 De-hulling chamber: The de-hulling chamber is one of the most important part of the machine. It is made from the same material as that of the hopper it has a length of 290 mm, 285 mm width and the height of 250 mm.

2.5.3 Polishing chamber: The polishing unit of the machine, was made from stainless steel sheet materials. It has a length of 465 mm and a diameter of 300 mm respectively. It is cylindrical in shape.

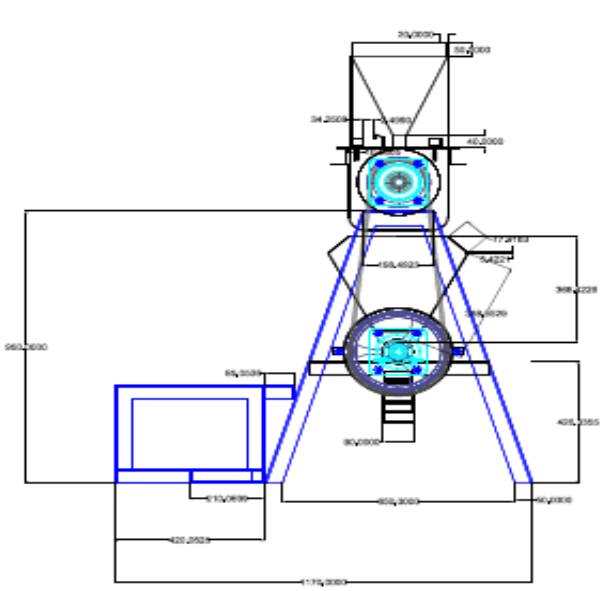
2.5.4 Shaft: The driving shaft is made from mild steel rod with the length of the shaft is 670 mm and the diameter is 30 mm.

2.5.5 Frame: This component part supports and hold other components of the machine, the frame is made of 45 x 45 mm mild steel angle iron. It has a length of 985 mm, width of 430 mm and height of 1000 mm.

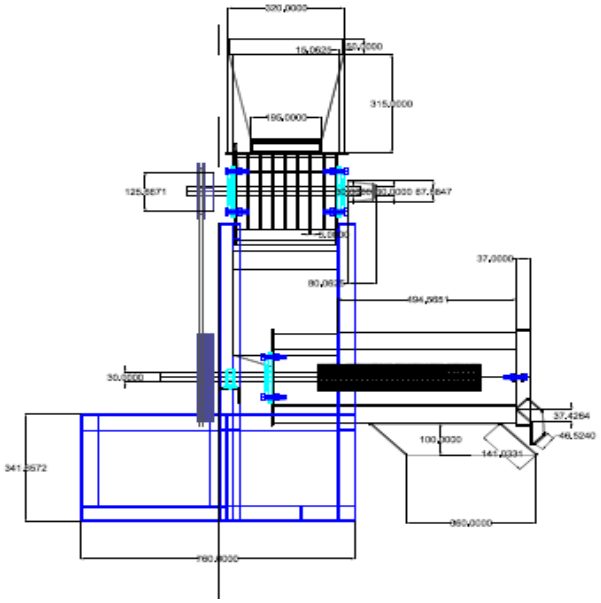
Fig. 1. The pictorial view of the machine



Plan



Front



End

Fig. 2. Third angle projection of the machine

S/No.	Components
1	Hopper
2	Dehulling Disc
3	Dehulling Chamber
4	Shaft Cap
5	Polishing Pulley
6	Bearing
7	Polishing Chamber
8	Through Chute
9	Dehulling Pulley
10	Belt
11	Shaft
12	Sieve
13	Frame

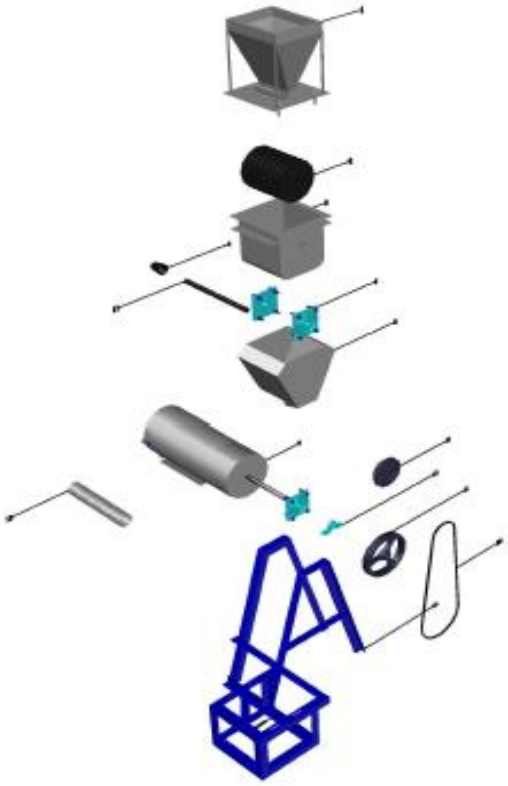


Fig. 3. Parts drawing of dry bean de-huller

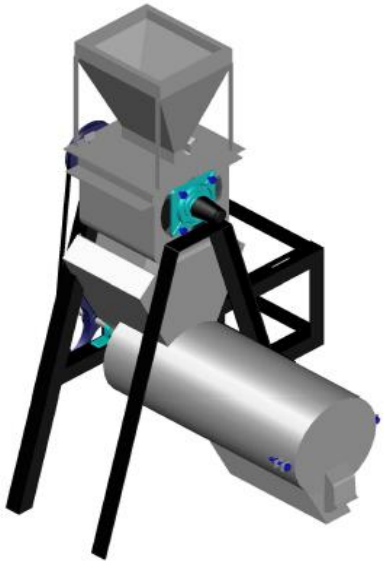


Fig. 4. Isometric view of dry bean de-huller

2.6 Performance indices

The dry beans de-hulling machine developed was subjected to a preliminary performance evaluation test. The beans variety used for the performance evaluation is black eyed peas (*Phaseolus vulgaris*) with a moisture content of 5.96 %. The test was carried out with 6kg, 4kg and 3kg of the test sample in three different batches. The performance indices that were used for the performance evaluation of the machine are; De-hulling efficiency (%) and Output capacity (kg/hr).

De-hulling efficiency - DE (%): This shows how efficiently the machine is de-hulling the sample. It was expressed as:

$$D_E = \frac{W_1}{W_1 + W_2} 100 \qquad (9)$$

where,

W_1 is Weight of de-hulled seeds (kg)
W_2 is Weight of un-de hulled seeds (kg)

Output capacity-$O_{c(kg/hr)}$: This is the total quantity of seeds collected at the machine outlet per batch per unit time. It was expressed as:

$$O_c = \frac{W}{T}\left(\frac{kg}{hr}\right) \times 3600 \qquad (10)$$

where,

W is the total mass of seeds fed into the machine (kg)
T is time taken to de-hull the seeds (hr.)

3. RESULTS AND DISCUSSION

The developed machine was able to effectively de-hull dry bean seed and results of a performance test are shown in Table 1. This results revealed that the machine was able to deliver 1.04 ton of de-hulled dry beans in an hour with an average of 83.37 % recovery after dry de-hulling using the machine. It was also observed that the machine dry has a percentage recovered whole grain de-hulled beans of 22.61 % as shown in Fig. 5, while the percentage split de-hulled beans is 62.02 %. The percentage broken beans after de-hulling is 10.40%.

It was however observed that the chaff hulled from the beans contained some bean powder which was not in significant quantity. The breakages observed after de-hulling did not in any way affect the product quality because the beans whether whole, split or broken would be eventually milled into powder. The efficiency of the machine was 83.60%. The dry bean seed de-hulling machine is adjudged to save time and energy removing the drudgery in manual de-hulling methods. The components are suitable and are readily available in the market for effective maintenance.

Table 1. Data obtained from the evaluation of the dry bean seed de-hulling machine

Specimen	Initial weight (kg)	Final weight (kg)	Dehulling Time (min)	Speed (rpm)	Whole (%)	Split (%)	Broken (%)	Chaff (%)	D_{Eff} (%)	Oc (kg/hr)
A	6.00	4.91	15.00	14.00	19.82	68.30	9.05	2.83	81.70	1440.00
B	4.00	3.41	15.00	14.00	19.49	67.33	6.62	6.56	85.50	960.00
C	3.00	2.51	15.00	14.00	30.83	57.26	5.91	6.01	83.70	720.00
Mean	4.33	3.61	15.00	14.00	22.61	62.02	10.40	4.97	83.60	1040.00

(D_{Eff} - De-hulling efficiency; O_c - Output capacity)

Fig. 5. Sample of the whole De-hulled dry bean seed

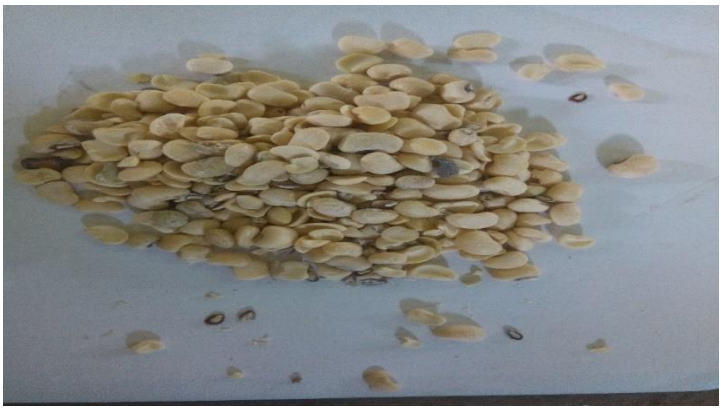


Fig. 6. Sample of broken dry bean seed

Fig. 7. Sample of the split dry bean seed

Fig. 8. Sample of the chaff of De-hulled dry bean seed

4. CONCLUSION

From the results of the performance evaluation of the developed dry bean seeds de-hulling machine, effective seed processing by coat removal from the dry bean seed as well as chaff separation chaffs was achieved effectively. The machine was designed such that it can be easily fabricated and maintained by local fabricators and end users respectively. The developed dry bean seeds de-huller can be used by farmers in rural and urban areas to add value to beans production and processing and subsequently attract better pricing. This is also in addition to the fact that the de-hulled beans can be stored whole or milled for a long time. The Output capacity of the machine is 1.04 ton/hr with an efficiency of 83.60 %.

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