DESIGN, FABRICATION AND PERFORMANCE EVALUATION OF BEANS DEHULLER

S.B. Adejuyigbe and B.O. Bolaji
Mechanical/Production Engineering Department
Federal University of Technology
P.M.B. 704
Akure, Nigeria

ABSTRACT

A beans dehulling machine was designed and fabricated using a locally available materials. The performance of the machine was evaluated and the results showed that the higher the feed regulator opening the higher the dehulling rate. The average capacity of the dehulling machine is found to be 3.67kg/h and the efficiency also is 75.7%.

Keywords: *Design, Fabrication, Performance Evaluation, Bean Dehuller.*

INTRODUCTION

Among the vegetarian population of the world, beans a family of legumes are an important part of our diet providing much of the essential proteins. Beans seed has been in cultivation in Nigeria, Latin America and Tropics for so many decades. It is worthwhile to note that the production and consumption of bean seeds have a great influence on the nutritional requirement of people and on the demand for industrial raw materials (Skerma et al, 1998).

Beans belong to the pea family "Leguminosae". Kidney, lima, mung and scarlet runner beans are genus "phaseolus". Soya beans are genus 'Glycine". The hyacinth bean is genus "dolichos" (Wittwer, 1980). The edible pods and the seed of these plants are also called beans. Beans seed is the inner part of bean pods, which is threshed after harvesting and it consists of endocarp and endosperm. The bean average diameter is 5 mm and its average height is 9.3 mm, the moisture content of bean seed for safe storage should be preferably below 12% (Wittwer, 1980).

Redhead (1989) and Erebor (1998), have both worked in the areas of planting and harvesting of beans, pest and diseases in beans production. The types of beans commonly found in Nigeria are brown beans, Sokoto whites etc. Research and development (R and D) has led to selected seeds from high yielding plants of different variety e.g. French Beans; lina, winged and sword. Others are common beans, which have different names in different regions of the world. They include the string beans, snap runner, French, salad, haricot, kidney and frijoles. These common beans are further subdivided according to their form, as dwarf "bush" cultivars, and climbing "pole" cultivars, and are also according to their culinary usage.

Mayhew and Penny (1998), described the following types of beans: red kidney beans, which can be used in soups stews, casseroles and salad;

navy beans which refer to several types of white beans are used in soups and casseroles; large and baby lima beans, the large limas have a butter flavour and are often called butter beans; purto bean is popular especially for Mexican dishes and black bean is popular for South American and Cuban dishes. Therefore, for health and ease of food production, there has been more demand for beans as part of our local balance diet in Nigeria. In recent years, medical experts have analysed and confirmed that beans provide us with valuable and necessary source of protein, which assists in the formation of muscle, hair and body tissue.

According to Skerman (1998), beans are not only a good source of protein but they are also important source of fiber, and they are naturally low in fat and cholesterol. Bean husk is used as livestock feed and supplement.

The traditional methods of dehulling has been practising for long in Nigeria, these methods involved soaking, after which the soft bean seed is then collected in the mortar and pounded using the pestle for a period of time. The mechanized method that can enhance dehulling is shelling/ threshing after which a blower winnows it. Also mechanically, beans can be dehulled by milling using a milling machine and a blower is used to separate the husk. The weight of seed allows it into the collector.

The factor in dehulling that has not been taken into consideration is the spliting of the bean seed into two equal halves, which require extra care in design. A visit to IITA (International Institute of Tropical Agriculture) at Ibadan, and Federal School of Agriculture, Akure both in Nigeria shows that the only machine near the dehuller developed so far was a sheller whose purpose is different from the beans dehuller. Dehulled beans production level in Nigeria is low because of the limitation of the widely employed traditional method of dehulling (pounding). Therefore, there is need to cater for the ever-increasing future demand for dehulled bea d its products. This paper presents the report of th design and fabrication of a beans dehuller using available local materials with the aim of increasing dehulled beans production on small-scale basis. The performance of the machine was also evaluated.

DESIGN THEORY

Hopper design

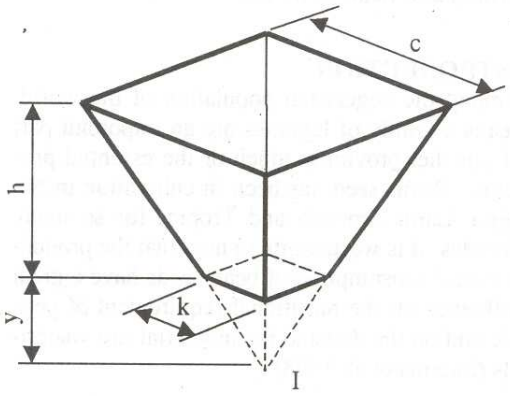
The hopper design is based on the volume of frustrum of a pyramid (Fig. 1). The volume of frustrum of a pyramid can be obtained as follow:

Volume of the big pyramid of base ABCD and vertex I = $^1/_3\, c^2(h + y)$

Volume of the small pyramid of base EFGH and vertex I = $^1/_3\, k^2 y$

Volume of frustrum $= {}^1/_3[c^2 (h + y) - k^2 y]$ (1)

Fig. 1: Hopper Design



Where:

h is the height of frustrum
y is the height of the small pyramid
c is the length of one side of the square base of the big pyramid
k is the length of one side of the square base of the small pyramid.

The height of the small pyramid (y) can be obtained by using similar triangular formulae as:

$$y = \frac{hk}{C-K} \text{ or } \frac{h}{\frac{c}{k}-1} \quad (2)$$

Dehulling chamber design

The dehulling chamber treated as a thin walled cylinder (Hall et al 1988), the targential stress perpendicular to the axis of the cylinder is

$$\sigma = \frac{pd_{dc}}{2t} \quad (3)$$

Where:

σ = perpendicular of hoop stress, assumed to be the maximum tensile stress the cylinder is subjected to at failure by yield.

p = Internal Pressure

t = thickness of dehulling chamber

d_{dc} = internal diameter of dehulling chamber

Also, $\sigma = S_{all} = (0.5\ S_y)/N$ (4)

Where:

S_{all} = allowable shear stress

N = factor of safety

S_y = yield stress

Volume of dehulling chamber (V_{dc})

This is given by

$$V_{dc} = \pi r_{dc}^2 l_{dc} \quad (5)$$

Where: r_{dc} = radius of dehulling chamber

l_{dc} = length of dehuling chamber

Volume of roller in dehulling chamber (V_r)

$$V_r = \pi r_r^2 l_r \quad (6)$$

Where r_r = radius of roller.

l_r = length of roller.

Volume of beans in dehulling chamber (V_b)

The volume of Beans (V_b) in the dehulling chamber is obtained by subtracting the volume of roller (V_r) in the dehulling chamber from the volume of the duhulling chamber (V_{dc}).

$$V_b = V_{dc} - V_r \quad (7)$$

Weight of beans in dehulling chamber

Weight of beans $W_b = mg$ (8)

Where:

m = *mass of beans*

g = acceleration due to gravity

Also, $m = \rho V_b$ (9)

Where: ρ = density of beans

V_b = volume of beans

Power required to drive the shaft

The power required to drive the shaft is given by

$$P = T_s \varpi_s \quad (10)$$

Where T_s = torque on shaft

ω_s = angular speed of shaft

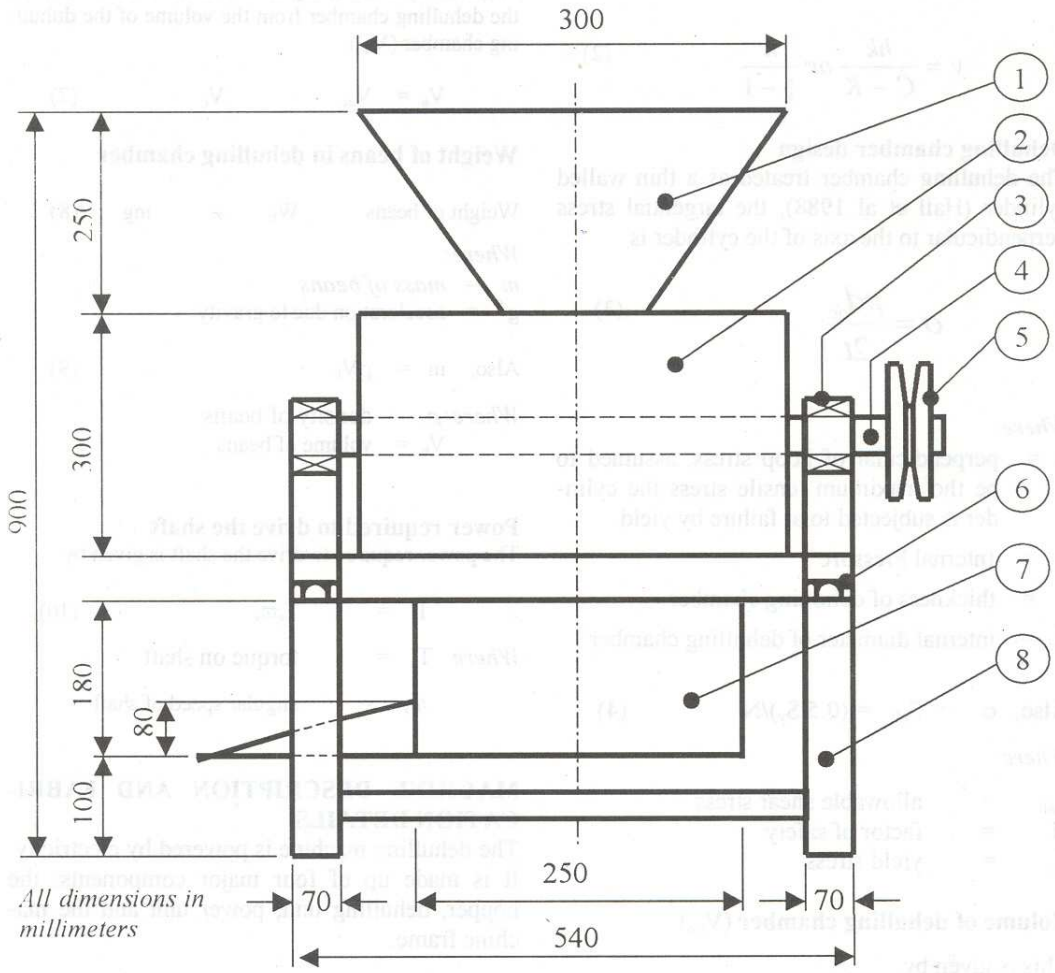
MACHINE DESCRIPTION AND FABRICATION DETAILS

The dehulling machine is powered by electricity. It is made up of four major components; the hopper, dehulling unit, power unit and the machine frame.

Hopper unit

The hopper unit is shown in Fig. 2. It is the device through which the machine is fed or charged with bean seeds. It has a square base on which an inverted hollow pyramidal frustrum is attached. It is constructed from 1.5mm thick galvanised metal sheet and the square base is constructed with mild steel angle bar of 3mm thick.

Fig. 2: Beans Dehulling Machine



1. Hopper 3. Bearing 5. Pulley 7. Collector
2. Dehulling chamber 4. Shaft 6. Bolt 8. Machine frame

Dehulling Unit

The dehulling unit consists of power shaft, bearing, dehulling chamber and collector.

***Power shaft*:** this is mild steel shaft, cylindrical in shape and of the same diametric sections. It is 20mm in diameter, 600mm length and the two ends are press fitted through the bore of the ball bearings to hold the shaft in place.

***Bearings*:** these are two ball bearings encased in a rigid housing and have internal bore of 20mm. The bearing supports the power shaft at both ends of the dehulling chamber. Each of the

bearing is held in position by M12 bolts and nuts on a channel welded on top of the machine frame (Fig. 2).

Dehulling chamber: The dehulling chamber is made from 1.5mm thick galvanised metal sheet. A square opening (45mm x 45mm) is provided at the upper half of the chamber at the centre. An angle bar is welded to the mouth of the square opening to form the hopper seat.

Collector: The collector collects the dehulled bean seeds as it husks which come from the machine through the outlet. It is made of 1.5mm thick galvanised metal sheet and is welded to the machine frame.

Power unit

The power unit consists of an electric motor, belt and pulleys.

Electric motor: The electric motor is the prime mover of the machine. It is a 3 phase 15kw motor with a speed of 750rpm.

Belt: a single belt type B is used for power transmission from the electric motor to the dehulling unit. The belts specification is B54 (Shingley, 1990).

Pulleys: The electric motor and shaft pulleys serve as means through which the belt transmits the power from the electric motor to the shaft. The diameter of the electric and shaft pulleys are 84mm and 104mm respectively.

Machine frame

The machine frame carries every other component of the machine. It is fabricated from 70mm x 70mm x 5mm thick and 50mm x 50mm x 4mm thick angle bars. The four legs of the frame form the machine stand.

Operation of the machine

The machine requires only one operator since it is easy and simple to operate. Before the operation of the machine it must be ensured that all the parts are properly set and fixed or bolted together. A charge of beans is fed into the machine when switched on through the hopper. As the shaft rotates, it carries along the roller and the charge of beans travels radically along with the roller, which presses the beans from their husks. The dehulled beans and their husks come out through the machine outlet in the lower half of the dehulling chamber.

Machine maintenance

In order to prevent unnecessary breakdown of the machine, the following preventive maintenance tips and precautions should be followed so as to prolong the service life of the machine.

a) Oiling of the bearing should be carried out regularly

b) All bolts and nuts should be properly tightened at all times, especially the ones securing the two halves of the dehulling chamber.

c) The machine should not be fed above its capacity at a time. This is to prevent clogging of the dehulling chamber.

d) The belt should be well tensioned and guarded together with the pulleys.

e) The hopper should be covered when the machine is not in operation, to prevent foreign materials such as nails, bolts, nuts, etc from getting into the dehulling chamber, as these could affect the roller when the machine is later operated.

f) There should be constant flow of water into the dehulling machine via the upper opening above to enhance passage of beans through the sieve gauze and minimize pressure on the bean seed.

RESULTS, DISCUSSION AND PERFORMANCE EVALUATION

To evaluate the performance of the machine, it was run without load for 5 minutes with a 3 – phase, 750 rpm, 15kW kubota electric motor. At the end of the 5 minutes, the machine was

loaded with 1000g of well soaked beans through the feed hopper. The dehulling of the 1000g of beans was noted. The result of the test carried out are shown in Tables 1 and 2.

From the test results, it was observed that an increase in clearance between the feed regulator and the dehulling chamber, results in corresponding increase in the dehulling rate of the machine and vice versa (Figs 3). The decreased in regulator opening restricts the flow of the bean seeds into the dehulling chamber, thereby reducing the dehulling rate. It was also deduced from Fig. 4 that the smaller the clearance, the higher the dehulling time needed for the beans. This was due to the fact that at smaller clearance, much time and pressure was required to force the bean through the small clearance.

Fig. 5 shows the relationship between the weight of dehulled beans, the weight of bean husks and the feed regulator opening. At reduced opening,

Table 1: Dehulling rate and time for different feed regulator opening

Trial	Feed Regulator Opening (mm)	Dehulling Time (min)	Weight of Dehulled Beans (g)	Dehulling Rate (g/min)
1st	15	20.0	860	43.00
2nd	20	19.0	913	48.05
3rd	25	18.5	945	51.08
4th	30	17.0	947	55.71
5th	35	16.0	953	59.56
6th	40	14.5	980	67.59
7th	45	12.5	977	78.16
8th	50	11.0	950	86.36

Table 2: Weights of dehulled beans and husks for different regulator opening

Trial	Feed Regulator Opening (mm)	Weight of Undehulled Beans (g)	Weight of Dehulled Beans (g)	Weight of Husks (g)
1st	15	1000	860	140
2nd	20	1000	913	87
3rd	25	1000	945	55
4th	30	1000	947	53
5th	35	1000	953	47
6th	40	1000	980	20
7th	45	1000	977	23
8th	50	1000	950	50

much pressure is built up in the chamber than at large opening, which aids the grinding and compression of the bean seeds and part of the beans is mixed with the husks. Initially, in Figs. 5 and 6, as the feed regulator opening is increasing the weight of dehulled beans is increasing and the weight of the bean husks is reducing. Later, as the opening is increased beyond 40mm, the weight of dehulled beans start to decrease and the weight of bean husks start to increase. This shows that the regulator opening must not be too small and must not be too large for better performance of the machine.

Fig. 3: Variation of Dehulling Rate with Regulator Opening

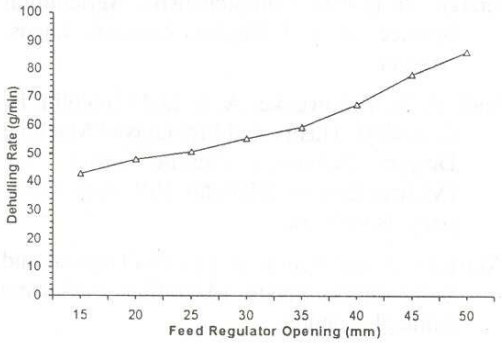


Fig. 4: Variation of Dehulling Time with Regulator Opening

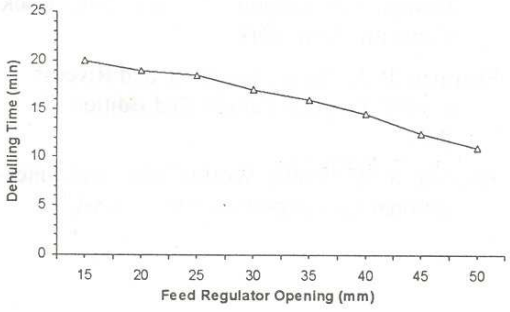


Fig. 5: Variation of Weight of Dehulled Beans with Regulator Opening

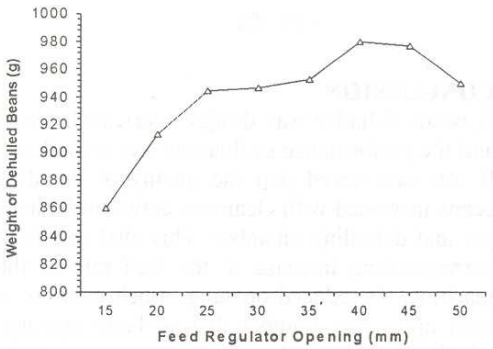
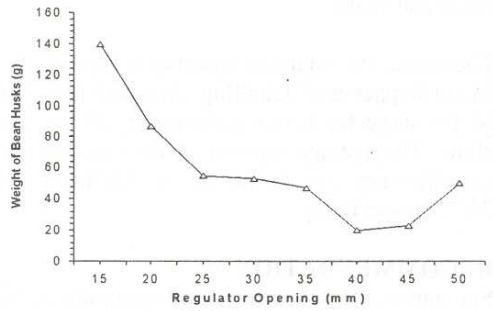


Fig. 6: Variation of Weight of Bean Husks with Regulator Opening



Performance Evaluation of the Machine

The actual capacity of the machine and the efficiency can be calculated using Table 1.

Average Capacity = $\Sigma R_i / N$

Where:

R_i = dehulling rate at 'i' trial (i = 1, 2, ... 8)

N = total number of trials

Average Capacity = 61.19g/min or 3.67kg/h

The design capacity of the machine from design calculation is 4.85kg/h

Therefore, $\eta = \frac{\text{Actual capacity}}{\text{Design capacity}} \times 100\%$

$= 75.7\%$

CONCLUSION

A beans dehuller was design, fabricated, tested and the performance evaluation was carried out. It was discovered that the quality of dehulled beans increased with clearance between the hopper and dehulling chamber. This also results in corresponding increase in the feed rate of the machine. At reduced opening, much pressure is built up in the chamber than at large opening, which aids the grinding and compression of the bean seeds and part of the beans is mixed with the husks. Over feeding of the machine leads to eventual stalling of the machine (clogging of the roller and shaft).

Therefore, the regulator opening (clearance between hopper and dehulling chamber) must not be too large for better performance of the machine. The average capacity of the machine and its efficiency are found to be 3.67kg/h and 75.7% respectively.

RECOMMENDATION

For improved performance and operation of the machine, the following are recommended:

(i) Stainless steel should be used in the fabrication of the shaft and dehulling chamber because of its high strength and corrosion resistance properties, which would help to increase the hygienic condition of the dehulled beans.

(ii) The machine should not be fed above its capacity at a time as this would also lead to stalling of the machine.

(iii) The selection of power unit (electric motor) should be directly based on the power requirement of the shaft.

(iv) The output capacity of this machine can be increased so that larger quantities of beans can be handled per unit time.

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