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Construction and evaluation of soybeans thresher

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In order to resuscitate soybean production and post-harvest processing, especially in terms of threshing, there is a need to develop an affordable threshing machine, which will reduce drudgery associated with manual soybean threshing. Soybean thresher was fabricated and evaluated at the Institute of Agricultural Research and Training (IAR&T), Apata, Ibadan. The machine component parts includes: hopper, threshing unit, shaker, cleaning unit and the seed outlet; all working together to achieve the main objective of threshing and cleaning. TGX1835-10E variety was used for the evaluation because of its high resistance to pests, rust and pustules. The final moisture content of the sample used was about 15%. The sample was weighed and introduced to the machine. The parameters evaluated includes: Moisture content, threshing efficiency, cleaning efficiency, machine capacity and speed. The threshing efficiency and capacity are: 74% and 65.9 kg/h, respectively. All materials used were sourced locally, which makes the cost of production of the machine to be considerably cheaper than the imported soybean thresher.

Key words: Construction, efficiency, evaluation, soybean, threshing.

INTRODUCTION

Soybean (*Glycine max* (L.) merril) is an annual leguminous plant which belongs to the family of Papiliondea. Its origin can be traced back to China and it has spread all over the world. It is an erect branching plant, which produces pods. The pod may be straight or slightly curved and it is usually covered with hair. It ranges in color from very light to various shades of grey and brown to nearly black. Each pod measures about 2.5 to 5 cm long. As many as 300 to 400 pods can be produced by one plant and one pod may contain between 1 to 5 seeds. The seeds are round and sometimes oval in shape.

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Production of soybean has steadily increased around the world, it forms an integral part of both human and animal diets. Coalition of high yields per hectare in soybean farms (especially in the leading soybean producing areas) together with favorable soybean prices has made gross incomes per hectare for soybean producers to improve significantly (BFAP, 2013). For farmer to meet up with the demand of soybean in today's market, alternative and effective means of post-harvest handling must be developed which will increase production, reduce drudgery, maximize time of operation and less labor intensive. It must also be designed such that all steps involved will be combined in a single operation (Yang et al., 2016).

All soybean varieties examined by Beliavskaya (2017) were confirmed to have high economic value coefficient of agronomic stability higher than 70%. Animal agriculture is the largest consumer of soy protein and it is a growing industry around the world. Soybean is an excellent protein resource and also an efficient feed ingredient (NSRL, 2010). Soybean is the largest single source of edible oil and it accounts for roughly 50% of the total seed oil production, worldwide. Global production of soybean was approximately 219.8 million metric tons, in 2005 from which India produced about 9.3 million metric tons (FAO, 2007). This accounts for about 4% of the total world production. From this, less than 10% is consumed directly by human (Gandhi, 2006). In 2016, the Global Soybean Production was about 313.02 million tons, according to United States Department of Agriculture (USDA, 2017) global production will be about 345.96 million tons. This could account for an increase of 32.94 million tons or a 10.52% in soybean production around the globe from the previous year.

Deshpande et al. (1993) reported that soybean contains 35% total carbohydrate, 40% protein and 20% cholesterol-free oil. Soybean can be processed into varieties of products, such as vegetable oil, soy-milk and soy-cheese, soybeans cake for animal nutrition and also as "Soy-gari" (soybean fortified with gari). This is recommended for use in the fight against malnutrition in areas where cassava is consumed and protein intake is inadequate. As a legume crop, soybeans Improve yields by enhancing soil health, prevent soil erosion, conserve soil moisture and protect water quality. Merwe et al. (2013) reported that that the yield in production is connected to commercial farmers becoming aware of the importance of soybean in crop rotation systems with maize.

Threshing is the removal of grain from pod. It is also a post-harvest operation that must be given adequate concentration. It must be carefully carried out in order to ensure that the seeds are not damaged. A bad threshing operation will reduce the quality of the seeds or render them completely useless. The primitive system of threshing, which is usually done by beating soybeans with a flail or trampling on it by animal hooves, is usually energy-intensive (Shannon, 1984), that is, drudgery, increase in loss and wastes time. This has been replaced by modern day thresher, which is able to combine the processes together in a single operation. Mechanical threshing is expensive because it requires high technology; however, it helps to improve the quality of final product and removes all the problems associated with the old method of threshing (Olaoye, 2011). An effective threshing operation depends on type of crop, condition of crop in terms of available moisture content, maturity, rate at which materials are fed into the cylinder, speed of the threshing drum and the number of rows of concave clearance, amongst others (Bainer et al., 1960).

MACHINE COMPONENT PARTS AND THEIR FUNCTIONS

Each of the machine member parts was measured according to the working diagram specification. They were cut and joined together to form the complete machine. The machine was fabricated in order to serve as a soybean thresher for small- and medium-scale industries. It is designed to be powered by electric motor. It consists of the following parts: the hopper, shelling unit, blower, grain outlet, shaft, the spout, frame and base, pulley and bearing.

The hopper

This is the receptive part of the machine for onward transportation into the shelling compartment. It is a trapezoid in shape in order to allow easy flow of materials (soybeans) into the machine.

Shelling unit

This comprises the sieve spiels and it carries the hopper at the top. This unit is cylindrical in shape and it is divided into two equal parts, with the sieve/screen at the bottom. The sieve aids the transportation of the threshed soybeans to the sieve. It also reduces the amount of chaff that passes through the fan housing.

Spout

The sieve is embedded inside the spout. It is hollow and opens to the fan housing, which is the cleaning unit. The spout transfers the thresher compartment into the cleaning unit.

Grain outlet

The grain outlet is an opening which collects the clean grain as they drag from the concave into the collecting tray.

Blower

This is an enclosure of the cleaning unit, where the cleaning operation is carried out. It also helps to remove dust and high thrash materials from the desired grain.

Frame

The frame is a structural member of the thresher into which fittings

Figure 1. Soybeans threshing machine.

of the new component is directly attached on. The frame is very strong because of the distortion and its flexibility will affect the stability of the machine, which can lead to personal hazards.

Pulley

This transmits power from the source (electric motor) to other moving parts of the machine through the use of a belt.

CONSTRUCTIONAL DETAILS

The hopper was formed from metal sheet of gauge, 16 cm. It measured 460 by 250 mm at the top and 365 by 260 mm at the base. These were mulled into a concave shape in order to form the feeding tray of the machine. The hopper is trapezoidal in shape to enhance easy feeding of materials.

Threshing drum

Gauge 12 (3 mm thick) metal sheet was cut into a length of 4 and breadth of the sheet was rolled into a cylindrical shape of 750 mm diameter. Two 3 mm diameter and circumference 62 cm to cover the open ends were then welded to form a closed end cylindrical shape. The two ends of the drum were perforated at the center in order to allow the shaft pass through it. At both ends, the shaft was welded to the drum, such that when the shaft rotates the drum equally rotates. The cylinder was then divided into 5 equal parts (12 cm long each) and the spikes of 4 cm long were welded to the drum at a spacing of 5 cm apart.

Cylinder housing

Two gauge 14 mm metal sheets were measured, cut and labeled A and B; each of them was folded into a semi-circle shape of 25 mm diameter. The edges were then bent square to each other. At the bottom of B, a hole of 50 by 50 mm was cut as an outlet for the threshed materials to come out of the threshing unit. The circle rods, each of 1.5 mm diameter and 7 mm long were welded to the inner side. They were arranged in four rows and covered one third (⅓) of the semicircular circumference of the cylinder. The spacing between each rod was 0.65 cm.

Cleaning unit

Gauge 16 sheet metal were measured 42 × 364 mm and another two were measured (260 × 108 mm) and cut. The four were welded together to form a rectangular box having two point ends. The shaft is allowed to pass through the blower and 3 pieces meter sheet of 18 x 140 mm welded to the shaft to form the fan blade of the blower. The parts were joined together to form a complete soybeans threshing machine as seen in Figure 1.

Machine specifications

Machine specifications are as shown in Table 1.

RESULTS

Performance evaluation of the machine was carried out on mass basis. A known mass of the sample (soybean) at a moisture content of 15% was fed through the hopper and was conveyed into the threshing drum, where threshing takes place, by gravitational force. Threshed sample from seed outlet, chaff outlet and other outlets, were collected and mainly separated into: threshed, unthreshed, chaff and losses. The samples were weighed using an electronic weighting machine. The performance data and analysis of results are shown in Table 3.

Analysis

Performance data were analyzed by using the following equations

$$w_{te} = 100 - \left(\frac{w_2}{w_1}\right) \bullet 100 \quad (1)$$

$$w_{ce} = 100 - \left(\frac{w_2}{w_1}\right) \bullet 100 \quad (2)$$

$$w_{le} = 100 - \left(\frac{w_2}{w_1}\right) \bullet 100 \quad (3)$$

Where, w_1 = weight of threshed grain (g); w_2 = weight of unthreshed grain (g); w_{te} = threshing efficiency (%); w_{ce} = cleaning efficiency (%); w_{le} = loss efficiency (%).

Table 2 indicates parts of the machine, material used and specification used for construction of the soybean thresher. Figure 2 shows the front and side views of the

Table 1. Machine specifications.

Power	5 hp electric motor
Length	650 mm
Width	580 mm
Height	10.15 mm
Material for construction	All steel
Drum speed	Between 154 to 222 rpm

Table 2. Materials specification details.

Item no.	Name	Material	Specification
1	Hopper	MS	250 × 450 Top, 75 × 450 Bottom
2	Concave	MS	⌖ 300 500 Long, 3 thick
3	Cylinder/drum	MS	⌖ 200, 460 Long, 3 thick
4	Cylinder shaft Veering house	MS	⌖82 5 Thick (6308)
5	Cylinder shaft 1	MS	⌖ 42, 700 Long
6	Reciprocator shaft Bearing housing	MS	⌖72 5 Thick (6308)
7	Reciprocator	MS	⌖ 32 650 long
8	Frame	MS	550 × 400 × 650 (main); 550 × 185x (Engine seat)
9	Seed	MS	550 × 165 × 240
10	Fan	MS	032, 670 long (shaft); 485 x 115, 2 thick (blade)
11	Fan pulley	MS	⌖45
12	Fab belt	Rubber and Tread	A-60
13	Driving cylinder pulley	MS	⌖ 140
14	Fan driving cylinder pulley	MS	⌖200
15	Sieve	MS	490 × 170 15 thick
16	Sieve guard	MS	490 × 170 15 thick
17	Bolt and nut	MS	M 8 × 20 (18)
18	Bolt and nut	MS	M 10 × 70 (52)
19	Reciprocator belt	MS	A-33
20	Reciprocator pulley	MS	⌖162
21	Reciprocator	MS	⌖ 82 5 thick (6308) 80 long (arm); ⌖ 20, 5 thick (head)
22	Fab housing	MS	⌖260 × 495 12 thick; 490 × 75 (air exit)

threshing machine, while Figure 3 shows its orthographic view.

Moisture content

From the material, 2 samples were taken. The first sample was weighed and the mass recorded. Water was added to the second sample and it was oven dried for 3 h and then reweighed and the mass recorded. The final moisture content was determined from Equation 4.

$$\text{Moisture content} = \left(\frac{weightofwetsample - weightofdrysample}{weightofdrysample}\right) \bullet 100 \quad (4)$$

Weight of wet sample = 98 g;
Weight of dry sample = 85g

$$\text{Moisture content} = \left(\frac{98-85}{85}\right) \bullet 100$$

= 15%

DISCUSSION

From Tables 3 and 4 and Figure 4, it was observed that the threshing efficiency increased, cleaning efficiency increased, losses were at minimum, machine capacity increased as the speed of the machine increased. The

Table 3. Machine performance data.

Speed (rpm)	W_1 (g)	W_2 (g)	W_3 (g)	W_4 (g)	W_5 (g)	Time taken (sec)
42	1079	280	89	440	83	42
86	1190	420	98	565	92	78
78	1205	428	93	583	67	86

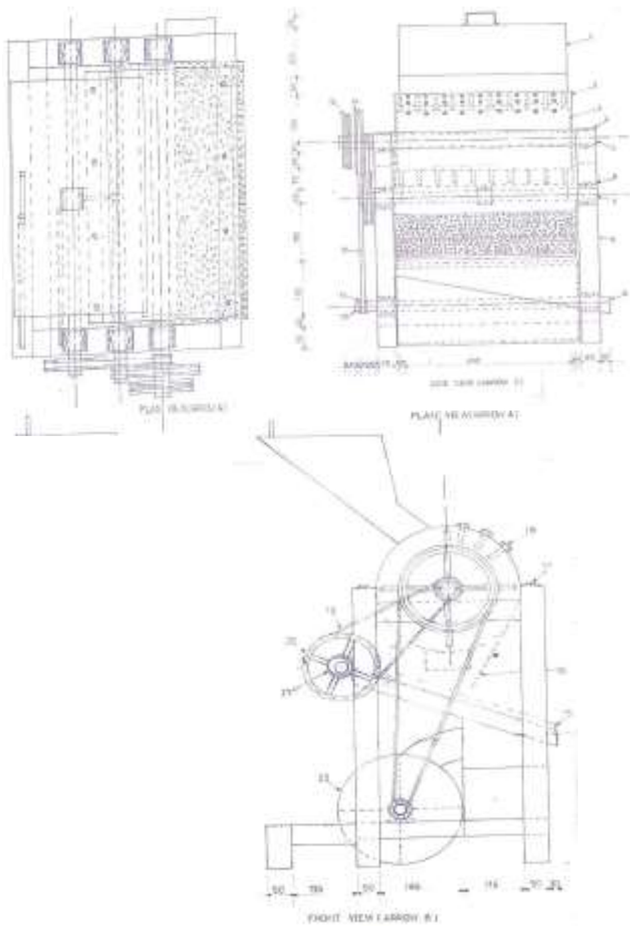

Figure 2. Machine front and side views.

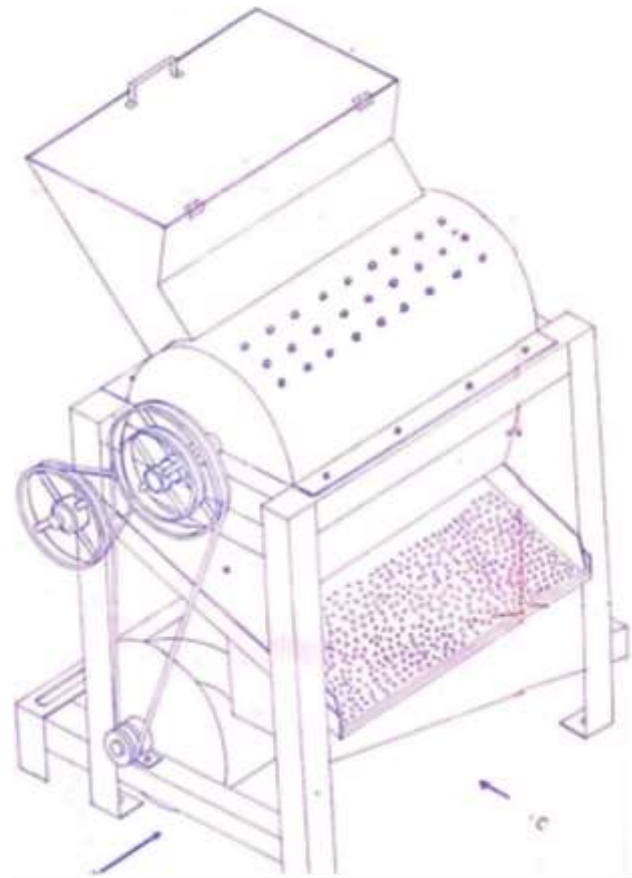

Figure 3. Orthographic view of the thresher.

threshing efficiency increased with increase in the speed of the cylinder. This is because at high speed, more kinetic force is impacted on the material. This is in line with what was stated by Bainer el al. (1960) and Sharma and Devnanl (1980). Lose efficiency increased from 42 to 43% when the speed was increased from 154 to 170 rpm, therefore increase in speed led to loss as reported by Sinha et al. (2014). The increase in cleaning efficiency at high speed might be due to the fact that the blower blows-off the chaff adequately, thereby improving the cleaning efficiency. At high speed, the machine was able to thresh more material, hence, increasing the machine capacity per hour. The loss efficiency is at minimum and increases thereafter. This may be due to the excess vibration from the machine. Therefore, threshing at high speed is advised in order to improve the threshing and cleaning efficiencies, and reduce losses.

Conclusion

From the result obtained, the following conclusions were made:

(i) A designed soybean thresher was constructed and evaluated. The main parts of the machine are: feeding unit, threshing unit, cleaning and grain outlet units. Machine performance evaluation was carried out with TGX1835-10E soybean variety.

Table 4. Soybean thresher analysis result.

Speed (rpm)	Threshing efficiency (%)	Cleaning efficiency (%)	Loss efficiency (%)	Machine capacity (kg/hr
154	68	26	42	92.5
170	76	36	43	54.9
222	78	37	33	50.4

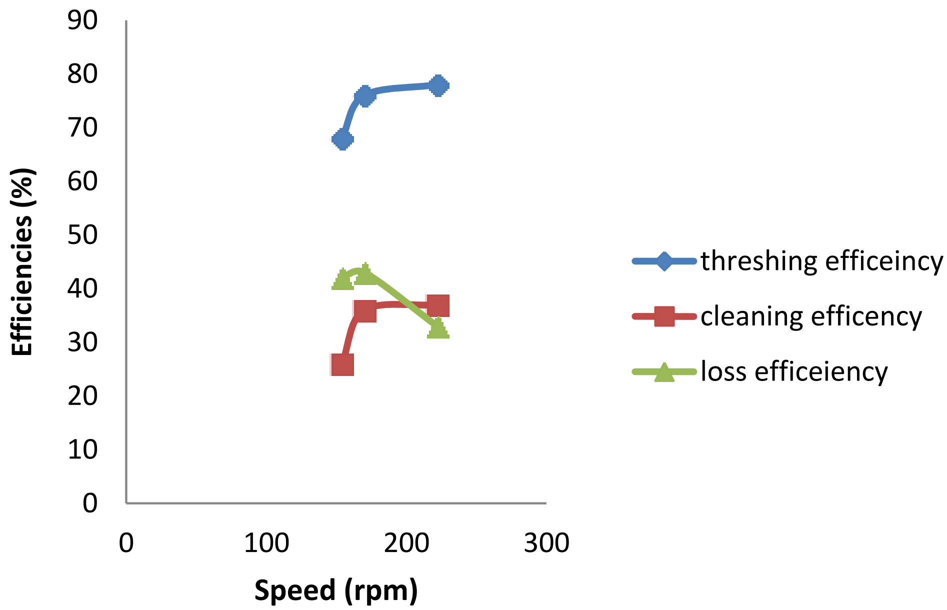

Figure 4. Machine efficiencies against speed.

(ii) The machine was developed in order to replace manual labor associated with soybean threshing.

Evaluation of the machine gave threshing efficiency as 74%, cleaning efficiency was 33% and the machine capacity was determined to be 65.9 kg/h. Feed rate affects threshing efficiency; this is due to inability of the machine to run effectively because of excess of materials within the cylinder and the spikes, this is in line with results obtained by Abdel-wahab et al. (2007). Machine capacity increased as the speed increased. Processing soybean with threshing machine increases market price as compared to manual threshing because loses and damages to seeds will be at minimum.

In order to obtain an optimum threshing and cleaning efficiencies, soybean should be threshed with low moisture content because moisture content state during threshing is an important measure in determining mechanical damage of crop (Allen et al., 1997; Dauda, 2001).

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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