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Original Article

Development of a hand operated maize sheller

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ABSTRACT

Maize shelling is the separation of maize grain from the cobs by initial impact or rubbing against a material. This study developed a hand operated maize sheller to improve on the processing aspect of maize production. The developed hand operated shelling machine was tested for performance and evaluated and compared to the performance of the "local hand shelling method." The parameters used in evaluation include shelling speed, shelling force, shelling power, throughput capacity, and efficiency. It had shelling force of 0.09 N, shelling speed of 0.26 m/s, required shelling power of 0.002 NMS^{-1}; it had an overall mean throughput value of 163 kg/h. While the hand method had a mean throughput capacity of 35.05 kg/h; this suggests that the developed sheller is 5 times faster than hand method. They have a relatively close efficiency values of 97.4 % and 98.6%.

Keywords: Efficiency, maize, shelling, throughput capacity

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INTRODUCTION

Maize (Zea mays) is one of the most important cereal crop grown in the world, it belongs to a grass family (Gramineae) and originated from Mexico and South America. In Nigeria, it is the most important cereal crop after sorghum and millet[1] and this crop is grown as one of the efficient species domesticated by man.[2] The period between planting and harvesting of maize depends on variety, but in general, the crop physiologically mature 7–8 weeks after flowering, at that time the kernel contains 35–40% moisture and has maximum content of dry matter.[3] Table 1 below shows some physical parameters of maize processed corn is used in manufacturing of many products ranging from breakfast foods, corn meal flower and grits, starch, corn syrup, corn-oil, spirits, acetone, chemical, absorbent, seed, and silage. The demand in maize in Nigeria is been fuelled by the continuous grown been witnessed in the poultry and beverage sectors where they are used as raw materials, as animal feeds and human consumption.[4] Maize is a stable food crop for most very sub-saharan Africans of which Nigeria is inclusive with per capital kg year of 40.[4] A large quantity of maize is needed to meet the need of the agro-allied industries in providing the afore-stated items for the use and survival of humanity. It is because of the importance of maize that it is processing and preservation to an optimum level must be analyzed. The major step involved in the processing of maize includes harvesting, drying, dehusking, shelling, storing, and milling. For rural farmer to minimize their profit from their maize, appropriate technology that suites their need must be used. The processing of agricultural product like maize into quality form not only prolongs the useful life these but also increases the net profit of the farmers make from mechanization technologies.

Maize Shelling

Maize shelling is the separation of maize grain from the cobs by initial impact or rubbing against a material. The difficulty of the process depends on the varieties grown, the moisture content, and the degree of maturity of the crop.[4] Maize shelling is difficult at a moisture level above 25% with the moisture content, grain stripping efficiency is very poor with the high operational energy and causing mechanical damage to the seed. The high cost of tractor operated maize sheller has made it unbearable for the use of peasant farmer for their maize processing, instead, traditional methods were used with time consuming and high energy requiring demand.

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Maize is shelled traditionally by hand; this is done by rubbing the maize against each other until the grains are removed from the cob. However, this traditional method of shelling is highly tedious, inefficient, and time consuming with low productivity as workers can only shell view kilometer per hour.[4] However, the modern way of shelling is by the use of mechanical means,[5] observed that manual shelled maize is time consuming and tedious and few existing mechanized sheller are imported and out of reach to small peasant farmers that are characterized by low income and small farm holding.

METHODOLOGY

Design Consideration

The design considerations include the design criteria and the functional requirement of the machine:

Design criteria

The design criteria consist of the following;

i. Improvement on the manual shelling process
ii. Ease of operation, control, and efficiency
iii. Simple design and ease of fabrication
iv. Use of locally sourced materials for fabrication.

Functional requirement

The functional requirements of the machine include:

i. It would be able to shell all varieties of dry maize
ii. It would save time when compared to other manual shelling methods
iii. It would increase the level of maize production among rural farmers
iv. It would be easy to operate for both skilled and unskilled farmers.

Description and Design of Machine Parts

The machine was designed to work on the principle of friction between the maize and the steel due to the sudden push from the weight of a falling shaft on the shelling cone. It is made up of six (6) major units as in Figure 1 below namely:

i. Pressing shaft … this is the portion of the machine where the operator holds and press to transmit shelling force through the shelling shaft. A shaft length of 370 mm was selected for this study
ii. Shelling shaft … This is a major part of the machine; it bears the shelling cap and conveys the shelling force from the pressing shaft to the shelling unit. The shaft does not undergo torsional stress during loading; therefore, the shaft diameter considered was subject to the maximum width of available maize width

Shaft length = 360 mm
Shaft diameter = 28 mm
Weight = mg
But $M = \rho v = \rho \pi r^2 l$ (ρ for steel = 8,050 kg/m^3)
$M = 8{,}050 \times 3.14 \times 0.014^2 \times 0.36 = 1.784$ kg.

iii. Shelling cap … this is the part of the machine that comes in contact with the maize and forces the cob to pass through the cone, while the grains are shelled into the shelling unit. A diameter considerably larger than any maize width was assumed. This is to ensure that the cap can conveniently cover the full width of any maize size to be shelled

Cap diameter = 70 mm

iv. Shelling cone … It is made of stainless steel pipe and welded at the centre of the shelling unit. The cone helps to hold the maize so that the maize cob can pass through it during shelling operations. The cone was designed based on the maximum width of matured maize cob; from literature, a maize cob ranges between 10 and 45 mm. It was therefore ensured that the cone can easily accommodate different sizes of maize to be shelled

Cone external diameter = 45 mm
Cone internal diameter = 43 mm
Cone length = 70 mm.

v. Shelling unit: This is the chamber where shelling takes place, it also accommodates the shelling cone and it is mounted on the stand. The slicing unit is made up of a steel material. It is oblong shaped and dimensioned 380 mm by 28 mm, with a height of 90 mm and has an outlet of width 8mm. It is inclined at an angle of 60 to ensure that shelled maize slid down into the collector through the outlet through the influence of gravity
vi. Outlet … This is the opening through which the shelled maize exits the shelling unit for collection or bagging
vii. The frame … it is made of low carbon iron; the stand forms a trapezoidal shape of 520 mm by 320 mm width and a height of 860 mm. It supports and holds the machine components and gives it a compact design and study outlook.

Mode of Operation

The machine is a simple design that requires little or no knowledge of engineering for utilization, the respective components and materials are shown in Table 2 below. To operate this machine, unshelled maize is placed carefully in the shelling cone. The operator takes hold of the pressing shaft and applies a downward pressure or force. This pushes the shelling shaft which also bears the shelling cap to press on the maize in the shelling cone. The force been applied pushes the maize cob into the cone, but the grains are shelled away. The shelled grains fall into the shelling unit where they are conveyed towards the outlet for collection.

Performance Test

A performance test was carried out on the hand operated machine and compared with hand shelling (HS) method; men and women that weighed 60–70 kg were given a known weight of unshelled cobs with <10% moisture content. The developed machine was used for shelling for 1 h, and the not well shelled cobs were weighed. This was replicated five (5) times. The same procedure was run through, using HS method and results were recorded.

Evaluation Parameters

This includes shelling speed, shelling force, required shelling power, throughput capacity, and the efficiency of the machine.

i. Shelling speed (V)… this is the rate at which a cob of maize is shelled

$$V = \frac{d}{t} \tag{1}$$

Where
d…maximum length of maize cob
t … time to shell a maize cob

ii. Shelling force (F)… this is the force to be exerted to shell a cob of maize in a single stroke

$$F = m \times a = m \times \frac{v}{t} \tag{2}$$

Where
m … maximum weight of maize cob
a … rate of speed of shelling a maize cob

iii. Shelling power (P)… this is the power required to shell a cob of maize in a single stroke.

Table 1: Physical parameters of maize grain

Properties	Remark
Diameter	5.0–9.0 mm
Length	5.57–12 mm
Width	6–11 mm
Mass	0.1–0.3 kg
Density	700 – 760kg/mm

$$P = f \times v \tag{3}$$

iv. Throughput capacity (kg/h): Throughput is the rate of shelling; it is the quantity of shelled maize divided by the time taken

$$\text{Throughput} = \text{weight}/t \text{ (Kg/h)} \tag{4}$$

Where
Weight … weight of shelled maize
t …total time taken to shell

v. Efficiency (%): The efficiency of the machine was calculated using the equation below:

$$\text{Efficiency} = \left[\frac{\{W1 - W2\}}{W1}\right] \times 100 \tag{5}$$

Where W1 ------ weight of unshelled cobs
W2 ------ weight of not well shelled cobs

RESULTS AND DISCUSSION

Maximum Shelling Speed

V = d/t = 0.26/1 = 0.26 m/s

Maximum Shelling Force

$$F = m \times a = m \times \frac{v}{t} = 0.34 \times 0.26 = 0.09N$$

Maximum Shelling Power

$$P = f \times v = 0.09 \times 0.26 = 0.002NMS^{-1}$$

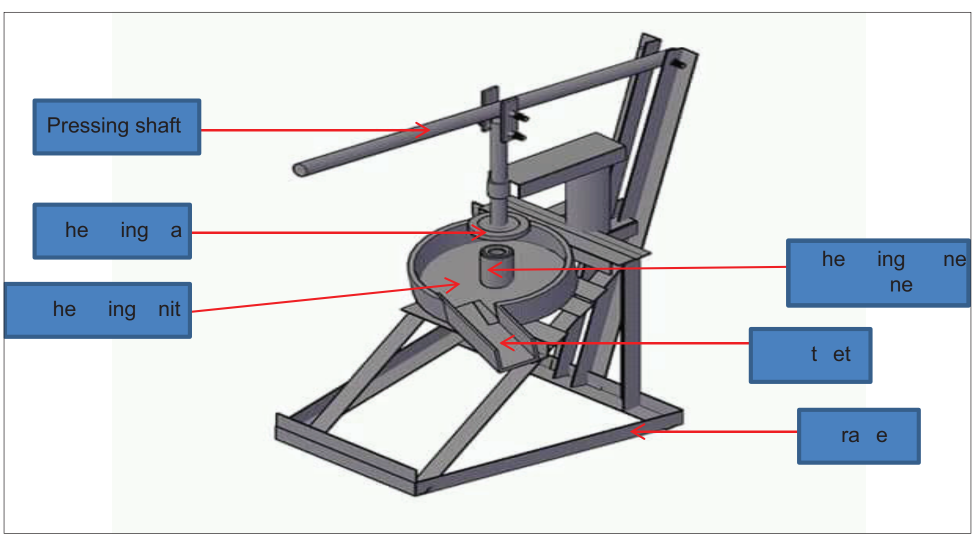

Figure 1: Assembly of developed machine

Table 3 gives the efficiency and throughput capacity of the developed maize sheller, while Figure 2 is the graphical illustration of the same. The highest throughput value was obtained at the second replicate and had an overall average throughput value of 163 kg/h. The overall mean efficiency was 97.4%.

Table 2: Summary of materials for respective components of the machine

Component	Material
Frame	Angle iron rod
Pressing shaft	Carbon steel
Shelling shaft	Carbon steel
Shelling cone	Stainless steel
Shelling unit	Carbon steel

Table 4 gives the efficiency and throughput capacity of HS method. The highest throughput value was at the third and fifth replicates, while the overall mean throughput value was 35.05 kg/h. This method had a mean efficiency of 98.6%.

Figure 3 shows the comparison of the throughput values of both shelling methods. The result suggests that the developed maize sheller with a means throughput capacity of 163 kg/h performs approximately 5 times faster than HS with a mean throughput capacity of 35.05 kg/h.

Figure 4 is the graphical illustration of the efficiency of the developed hand operated maize sheller and HS method. It shows that their efficiencies were relatively close; the former had a mean efficiency of 97.4% while the latter had a mean efficiency of 98.6%.

Table 3: Performance of hand operated maize sheller

Replicates	Unshelled cobs (kg)	Not well shelled (kg)	Efficiency (%)	Throughput capacity (kg/h)
1	168	4.15	98	163
2	170	4.16	97	165
3	168	4.11	98	163
4	167	4.21	97	162
5	167	4.20	97	162
Mean	168	4.17	97.4	163

Table 4: Performance of hand shelling method

Replicates	Unshelled cobs (kg)	Not well shelled (kg)	Efficiency (%)	Throughput capacity (kg/h)
1	35	0.70	98	34.10
2	35	0.80	98	34.05
3	37	1.09	97	36.00
4	36	0.85	98	35.10
5	37	0.81	98	36.00
Mean	36	0.11	98.6	35.05

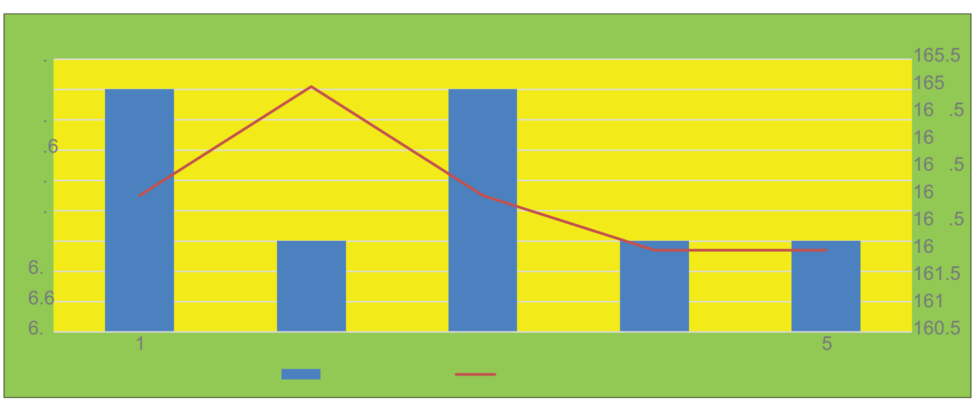

Figure 2: A graph of efficiency and throughout capacity of the developed maize sheller

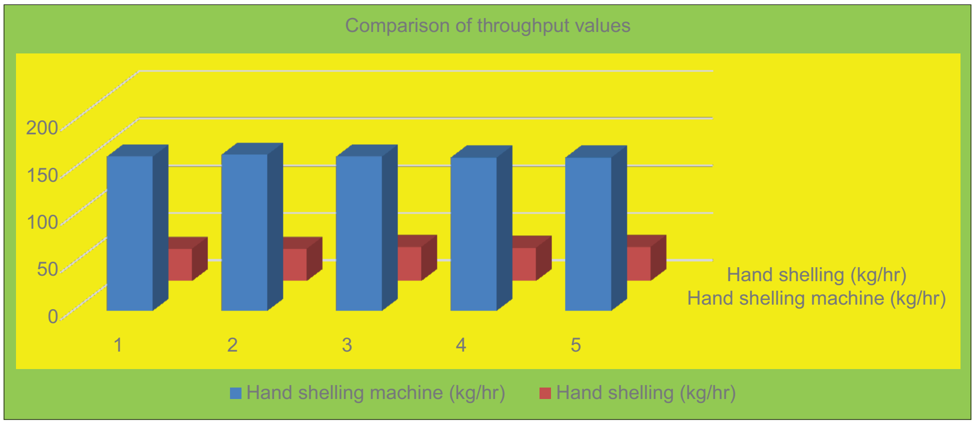

Figure 3: A graph showing comparison of throughout values

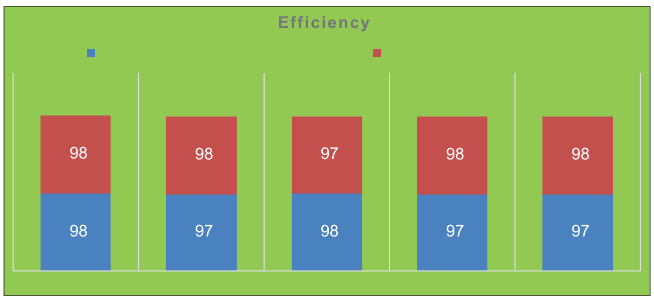

Figure 4: A graph showing the efficiencies of the two methods

CONCLUSION

The developed hand operated shelling machine was tested for performance and evaluated; the result was compared to a HS method. It had an overall mean throughput value of 163 kg/h, while the hand method had a mean throughput capacity of 35.05 kg/h. This suggests that the developed sheller is 5 times faster than hand method. They have a relatively close efficiency values of 97.4% and 98.6%; this suggests that they both would reduce losses.

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