ANALYSIS

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Developments of a motorized maize shelling machine

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ABSTRACT
Maize shelling is an important step towards the processing of maize to its various finished products. Threshing or shelling operations of maize follow the harvest and whatever pre-drying of the crop is undertaken. In this studies, A maize shelling machine was designed, fabricated and its performance evaluated, During the design and fabrication of the machine, considerations were given to ease of assembling and disassembling of the machine, ease of loading the maize and offloading the cobs and easy mechanism of recovery the unshelled grains from the cobs. The performance evaluation of the machine was carried out by

considering the experiment as a regression experiment to determine the relationship between the feed rate and shelling and cleaning efficiency of the machine. The result of the statistical analysis generated from the regression models and R^2 value of $y = -0.017x + 106.9$, $R^2 = 0.283$ and $y = -0.007x + 103.5$, $R^2 = 0.258$ was obtained for shelling and cleaning efficiency respectively. Also, the result reveal that the feed rate has no significant effect on the shelling and cleaning efficiency of the machine at 95% confidence level. The maize sheller has a production cost of $265.

Keywords: Maize, Cobs, Shelling Efficiency, Cleaning Efficiency, Feed rate

1. INTRODUCTION

Maize (*zea mays*), the American Indian word for corn, means literally that which sustains life. It is, after wheat and rice, the most important cereal grain in the world, providing nutrients for humans and animals and serving as a basic raw material for the production of starch, oil and protein, alcoholic beverages, food sweeteners and, more recently, fuel. In Africa, maize has become a staple food crop that is known to the poorest family. It is used in various forms to alleviate hunger, and such forms include pap or ogi, maize flour, and etc. It is because of the importance place of maize that its processing and preservation to an optimum condition must be analyzed.

Shelling is the removal or separation of maize grain from the cob and it is an operation that follows the harvest. It can be carried out in the field or on the farm by hand or with the help of animals or machines. The grain is obtained by threshing, friction or by shaking the products. The difficulty of the process depends on the varieties grown, the moisture content and the degree of maturity of the crop FAO (1992). Maize shelling is difficult at a moisture level content above 25%, with this moisture content, grain stripping efficiency is very poor with high operational energy and causing mechanical damage to the seed. A more efficient shelling is achieved when the grain has been suitably dry to 13 to 14% moisture content (Danilo, 1991). There have been various means of shelling starting from the traditional pestle and mortar to the various mechanical and electro-mechanical devices. The use of 'cone' sheller was reported by Kaul and Egbo, (1985), the sheller consists of a cone with three to four lines of serrated ribs. The dehusked cob is rotated in the cone by one hand while the Sheller is held in the other hand rotating the cob against the internal rib of the Sheller to detach the grain from the cob. Adewale, *et al.,* (2002) and Adegbulugbe, (2000) established that shelling process is a function of moisture content. It is easier to shell maize dry than wet. Adewale *et al.,* (2002) also reported that the local techniques of shelling and winnowing of shelled maize is grossly inefficient judging by the serious bruises encountered by the crops. There are many types of maize shellers, but the motorized shellers are either imported or locally fabricated by local welders who have no knowledge of both the machine and crop parameters suitable for optimum performance of the shelling machines (Adewumi, 2004). Maize can also be dehusked and shelled but this is with a lot of kernel damage at the end of the processing operation (Adesuyi, 1983). Other types of devices used for shelling mechanism are cross flow rasp bar, axial flow rasp bar and spike tooth cylinder. A spike tooth cylinder is more positive in feeding than rasp bar cylinders with the added advantage that, it does not plug in easily. While rasp bars are easier to adjust and monitor and are relatively simple to operate and durable. The efficiency of shelling machines varies from one machine to the other as affected by some factors like the crop moisture content, feeding rate, shelling mechanism and the concave cylinder clearance (Adewale *et al*., 2002).

2. MATERIALS AND METHODS

2.1. Design Calculation

2.1.1. The hopper

The hopper is a trapezoid, which serve as the input unit calculation in meters.

$$\text{Volume} = \frac{1}{2}(A + B)HXL \quad (1)$$

Where
A = Top side of the hopper
B = Base side of the hopper
H = Height
L = Length
The volume capacity of the hopper is $0.046m^3$

2.1.2. The Shelling Drum Capacity

Volume of the shelling concave $= \frac{1}{3}\pi r^2$ (2)

$0.03926 m^3$

To know the shelling volume capacity we need to calculate the volume of concave and deduct it from volume of shelling drum. The Volume of the Shelling cylinder is determined as:

Height = 0.64m, diameter = 0.11m where r = $\frac{D}{2} = \frac{0.215}{2} = 0.108m$

Volume of the cylinder = $\pi^2 h$ (3)

The Volume of spikes attached to the cylinder as:
H = 50mm = 0.05m
D = 12mm = $\frac{D}{2}$ = r = 6mm = 0.006m

Volume of spikes = $\pi^2 h$
= π x $(0.006)^2$ x 0.05
= 5.7 x $10^{-6}m^3$

If 129 spikes attached
= 5.7 x 10^{-6} x 129
= 7.353 x $10^{-4}m^3$

Total volume of shelling cylinder = Vol. of cylinder +volume of spikes (4)
= 5.7 x 10-^{6} + 7.353 x 10^{-4}
= 7.41 X 10^{-4}m

Therefore, the volume of shelling drums capacity of the maize Sheller
= Volume of concave-Volume of shelling cylinder
= 3.926x 10^{-2} – 3.33 x 10^{-2}
= 5.96 x $10^{-3}m^3$
The shelling drum capacity is 5.96 x $10\text{-}^{3}m^3$

2.1.3. The Main Frame

The design factors considered in determining the material required for the frame are weight and strength. In this work, angle steel bar of 11/2" by 11/2" and 2mm thickness is used to give the required rigidity.
The volume and total area:

Area = length x width
Volume = area x height (5)

Where length (L) = 1120mm = 1.12m, Width (w) = 468mm = 0.468m, Height = 1200mm = 1.2m

Area = 1.12 x 0.468
= $0.1748m^2$
Volume = Area x H
= 0.5242 x 1.2
= $0.6290m^3$

The total volume capacity for the frame work is $0.6290m^3$ (source Ranger Hope @2008, extraction courtesy of A.N.T.A publications) www. Splashmentime.com.au/macrops/data

2.1.4. Power requirement of the machine

According to spots (1985), for a 5 horse power motor and a speed of 1440rpm, the recommended minimum sheave pitch diameter is 3.8" which is equivalent to 96.52mm or 180mm diameter of pulley. For this range of V-belt was selected for this work. According to Williams (1953) a grove angle of 38^0 was chosen for a pulley of 100mm diameter using class B V-belt. Then the power requirement of the machine is determined as follows:

$$N_1 = \frac{N_2 D_2}{D_1} \qquad (6)$$

Where D_1 = 100mm = 0.1m

D_2 = 105mm = 0.105m

N_2 = 1440rpm

$$N_1 = \frac{1440 \text{ x} 0.105}{0.1} = 151.2\text{rpm}$$

The velocity ratio of the two pulleys is expressed as

$$\frac{N_1}{N_2} = \frac{151.2}{1440} = 1.05$$

V.R = 1.1:1

2.1.5. Motor power output design

Power is expressed as $P = \frac{\text{work−done}}{\text{Time}} = \frac{\text{Fforce x distance=FV}}{\text{Time}}$ (7)

But F = Ma, a = $\omega^2 r$

Where

F = rotational force acting on Rotor (μ)

a = Linear velocity or rotor (m/s)

M = mass of rotating rotor (kg)

Also

$V = \omega r$ (8)

$\omega = \frac{2\pi N}{60}$ (9)

let

Mass = 1kg (the material to be used)

$N_1 = 1440$ rev/min

$r = \frac{D_1}{2} = \frac{0.1}{2} = 0.05$ Smaller radius of pulley rotor

Power = mav (10)

$= \text{M x } \omega^2 \text{r x} \omega \text{r}$

$= \text{M}\omega^3 \text{r}^2$ (11)

$= \text{MX} \left(\frac{2\pi}{60}\right)^2 \text{Xr}^2$

$= 1 \text{ x } \left(\frac{2 \text{ x } \pi \text{ x } 1440}{60}\right)^3 \text{ x } (0.05)^2$

= 1 x 3430380.179 x0.0025

= 8575.95kgm^2/s^2

P = 8575.95watts

Recall

0.746hp = 1kw

P = 6.4hp

Comment: an AC-electric motor at 6hp output and 1440rpm is recommended for use.

2.2. Description of Components of the machine

The maize Sheller (Figure 1) consists of the hopper, the shelling units, the fan (blower) and the transmission unit. The hopper is trapezoidal in shape and made of mild steel of gauge 4mm to withstand vibration. The height is 200mm and widths of 300mm. During operation of the machine, the maize to be shelled was fed into the shelling unit through the action of gravity. The shelling unit consists of series of beaters arranged on the cylindrical shaft. The beater is made of flat bar, the maize cobs are being shelled by the action of beater on the maize cob against the concave sieve. The lengthy of the cylinder shaft is 920mm with 20 beaters attached at 64mm apart and the length of the concave is 700mm. the fan consists of blower which removes the chaffs and other dirt from the grain. A 1.5KW electric motor is used to transmit power to the machine through belt and pulley arrangement.

Figure 1 Pictorial View of the Maize Shelling Machine

3. RESULT AND DISCUSSION

3.1. Statistical Analysis

The data obtained for the calculated average value of the effects of feed rate on shelling and cleaning efficiency is as represented on Table 1.

Table 1 Effects of Feed rate Shelling and Cleaning Efficiency of the machine

Feed rate (kg/hr)	Shelling efficiency (%)	Cleaning efficiency (%)
529.41	98.04 ± 0.0808	99.34 ± 0.0808
600.00	95.52 ± 0.1617	99.52 ± 0.1617
606.74	97.72 ± 0.3453	98.35 ± 0.0519

3.2. Analysis of Variance (ANOVA)

The ANOVA for the effects of feed rate on the shelling and cleaning efficiency is as shown on the Tables 2 and 3 respectively.

Table 2 ANOVA for the Effects of Feed rate on the Shelling Efficiency of the Machine

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.009	1	.009	.005	.944[b]
	Residual	11.582	7	1.655		
	Total	11.591	8			

3.3. Effects of Feed rate on the Shelling and Cleaning Efficiency of the Machine

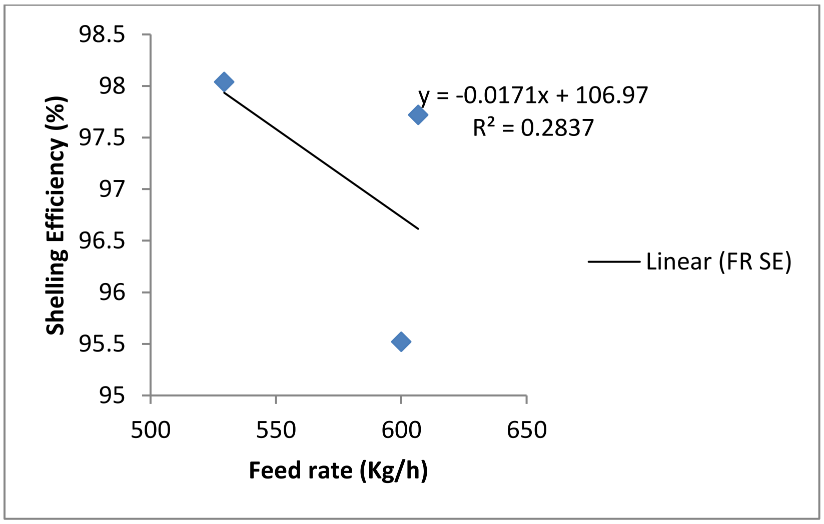

Figure 2 Effects of Feed rate on the Shelling Efficiency of the Machine

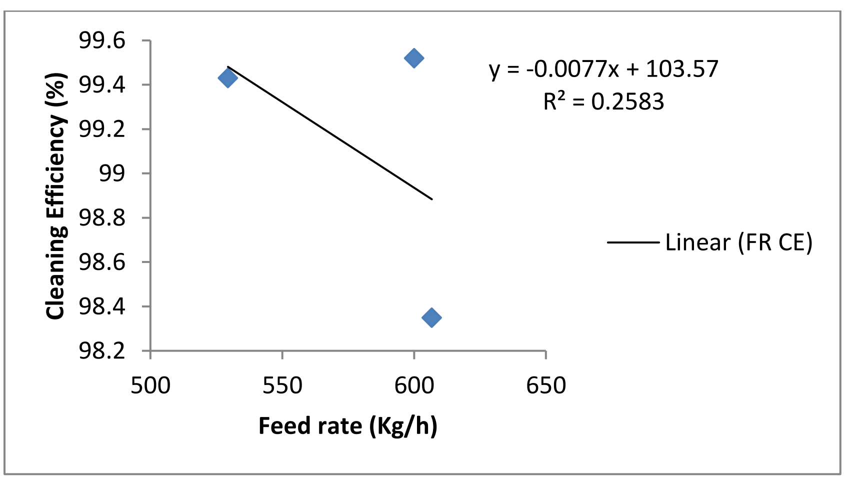

Figure 3 Effects of Feed rate on the Cleaning Efficiency of the Machine

Table 3 ANOVA for the Effects of Feed rate on the Cleaning Efficiency of the Machine

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.000	1	.000	.001	.973[b]
	Residual	2.455	7	.351		
	Total	2.456	8			

The tables reflect that the feed rate has no significant effects on the shelling and cleaning efficiency of the machine.

Figures 2 and 3 shows the relationship between the feed rate and shelling and cleaning efficiency of the machine.

4. CONCLUSION

The maize Sheller was design, fabricated and tested. The sheller consist of a rotating shaft with grain de-cobbing spike which are arrange in a spiral form on the shaft, the sieving screen, the blower as it major component for its efficient operation. The performance evaluation of the sheller was carried out to know the relationship between the feed rate, shelling and cleaning efficiency of the machine. The result of the evaluation shows that the feed rate does not have significant difference on the shelling and cleaning efficiency of the machine.

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Conflicts of Interest: The authors declare no conflict of interest.

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