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Development and Performance Evaluation of a Motorized Groundnut Threshing Machine

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ABSTRACT
Manual threshing of groundnut is labor-intensive, time-consuming, and inefficient for small to medium-scale farmers. This study presents the design, fabrication, and performance evaluation of a motorized groundnut threshing machine aimed at reducing post-harvest losses and improving processing efficiency. The machine comprises a threshing drum, concave sieve, cleaning system, and a power source. Laboratory and field tests were conducted to evaluate threshing efficiency, cleaning efficiency, throughput capacity, and mechanical damage. The machine achieved a maximum threshing efficiency of 86 %, cleaning efficiency of 58 %, and throughput capacity of 169 kg/h at an optimum drum speed of 750 rpm. The results demonstrate the potential of the developed machine to enhance groundnut processing at the smallholder level, contributing to food security and rural development.
Keywords: groundnut, threshing machine, agricultural mechanization, design and fabrication, post-harvest losses

I. INTRODUCTION

Groundnut (Arachis hypogaea L.) is a major legume crop widely cultivated in sub-Saharan Africa, Asia, and parts of South America for its edible oil and protein-rich seeds. In Nigeria and similar regions, groundnut farming is predominantly carried out by smallholder farmers who rely on traditional methods for harvesting and processing. One of the major bottlenecks in the groundnut value chain is threshing, typically done manually by beating the pods with sticks or trampling underfoot. This practice is inefficient, labor-intensive, and often results in high levels of seed breakage and contamination.

With increasing demand for agricultural mechanization, the development of efficient, low-cost threshing machines tailored to local needs is critical. This study aims to design, develop, and test a prototype groundnut threshing machine capable of improving threshing performance while maintaining seed integrity and minimizing losses.

II. MATERIALS AND METHODS

Material Selection Consideration.

For the purpose of this design, mild steel was used for most of the component and this is because of the environmental condition in which the material will function, physical and mechanical properties (shear strength, hardness, toughness, ductility, yield strength, fatigue etc.), its availability, machinability and ease of forming and joining by welding.

2.2 Machine Components

The groundnut shelling machine was designed to operate based on mechanical food size reduction by shearing (crushing) action. The following components make up the machine;

The Frame: The frame gives supports to the entire machine and it carries the prime mover, the shelling unit, the hopper and the blower. It is a rectangular shaped structure, 1220 mm by 350 mm by 430mm, constructed from 2mm mild steel plate

The Feed Hopper: This structure holds the groundnut seeds in place prior to been shelled. The hopper is mounted on the shelling unit at an inclination of the pod angle of repose. The pods to be shelled fall into the shelling unit by gravity and the feeding rate is controlled by a flow rate control device called the control gate.

The Shelling Unit: The shelling unit performs the function of breaking the nut and releasing the kernel from the pod. It consists of open ended fanglike rotary shelling blades with attached detachable rubber paddles, carried by a shaft fixed across the centre of the semi-cylinder. The unit also

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consists of an adjustable semi cylinder-like concave sieve which in tandem with the rotary blades enables shelling by shearing action. The clearance between the drum and the concave is adjustable.

The Separating Unit: It comprises of the separating sieve and the blower (which separates the seed and shell by air current) driven by a belt and pulley arrangement. The separating sieve is a 2-level rectangular 630 by 160mm light metal frame with attached sieves of desirable pore sizes.

The Power Source: A 1.5Hp motor which serve as source of power for machine operation based on design analysis and considerations. For manual operation, human efforts will be required by cycling

2.1 **Design Considerations**

2.1.1 Determination of size of the hopper:

The hopper was designed to accommodate more groundnuts using the relation below [1]

$V=\frac{Ab+aB+2(ab+AB)h}{6}$ …………………[1]

Where, A = Length of the upper base, = 350mm

B = Width of the upper base= 430mm and

h = height and

a = 290mm Length of the lower base, = 150mm

b = Width of the lower base=160mm Substituting the value in the above equation hence we get the volume of the hopper as

$V = 0.04333m^3$

2.1.2 Shaft Design

Torque T = $\frac{\pi\tau d^3}{16}$

Allowable stress τ = 40N/ mm2,

34= 3.14×40× d^3/16

d = 1.62 m = 16mm (approx.)

The obtained shaft diameter is 16.11 mm.

In order to do weld attachment on the shaft, diameter of the shaft is chosen to 40 mm.

Diameter of shaft, d = 40 mm.

Shaft length used, L = 1368 mm

2.1.3 Determination of size of the concave:

The concave radius was determined based on Nalado [2] given as:

$Rc = RD + HP + Cc$ … (2)

Where, Rc = Concave radius (mm),

RD = Radius of drum;

Recall D2 = 280 mm

Therefore $RD = \frac{D2}{2} = \frac{280}{2} = 140mm$

HP = 14 mm; Height of rasp bar (10 mm rod was used),

Cc = 14 mm; concave clearance was obtained based on the geometric mean diameter of groundnut kernels from our previous study (Muhammad et al., 2015b).

Rc= 140 + 14 + 10 = 164 mm

2.1.4 Determination of the capacity of shelling chamber:

The capacity of the shelling chamber was computed based on its cylindrical geometry as:

$vsc=\frac{\pi\times Dsc\times Ls}{4}$ …………………………………[3]

Where, vsc = volume of shelling chamber (mm3), Lsc = Length of shelling chamber (630 mm), Dsc = Diameter of shelling chamber = 280 mm

$vsc = \frac{\pi\times280\times630}{4}$ = 138544.345$mm3$

2.1.5 Determination of air flow rate:

Air discharge by a centrifugal blower (Q) can be easily estimated based on air velocity required for cleaning, depth of air stream through the duct, and width of the duct. Q was obtained from the relation given by Joshi (1981) in equation 4:

$Q = AV$ ……………………………….[.4]

Where, Q = air flow rate (m3 /s), V = velocity of air required for cleaning obtained from literature (m/s) = 9.8 m/s (Ghanem and Shetawy, 2009),

A = Area of air duct (m2) = 0.329

Q= 32.9 × 9.8 = 3.6086 m3 /s

2.1.6 Determination of pulley sizes

The pulley diameter was determined using equation 3 as recommended by [5].

$d_1 = \frac{N_m D_m}{N_1}$ …………………………………[5]

Where Nm is the speed of motor pulley in rpm,

dm is the diameter of motor pulley in mm and

N_1 is the speed of shaft Pulley in mm.

Substituting Nm= 170 rpm, dm = 70 mm and N_1= 68 rpm, therefore d_1 is 175 mm.

The corresponding pulley size for the blower was calculated as:

$Dp3 = \frac{N1\times DP2}{N3} = \frac{300\times375}{680}$ = 165.44mm

The standard nearest pulley size was selected as 160 mm (Karwa, 2010)

2.1.7Determination of belt length:

The length of belt required for the shelling drum and blower was computed from equation 18 (Mohammed and Hassan, 2012):

$L = 2C + \frac{\pi(DP2+DP1)}{2} + \frac{(DP2+DP1)2}{2c}$ ……………..[6]

Where, L = belt length (mm),

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C = distance between the driving and the driven pulleys (600 mm).

$L = 2 \times 700 + \frac{\pi\,(375+75)}{2} + \frac{(375+75)^2}{2\times 700} = 2251.501$ mm

≈ 2252 mm

The nearest standard pitch length was selected as 2286 mm (Khurmi and Gupta, 2005).

The machine was designed based on the physical and mechanical properties of groundnut pods, including size, shell hardness, and moisture content. The key components include a threshing drum, concave sieve, cleaning unit, and power system. Design calculations were conducted for optimal drum diameter, peripheral speed, number of beaters, and clearance using standard engineering equations.

2.2 Fabrication Process

The machine frame was constructed from mild steel angle iron. Beaters were made from flat bar steel and welded onto the rotating drum. A mild steel sheet was perforated to serve as the concave. Bearings, pulleys, and V-belts were used for power transmission. The machine was painted to prevent corrosion and tested for mechanical stability

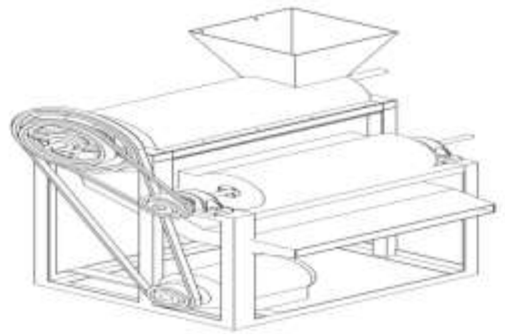

Figure 1.0 Schematic diagram of the machine

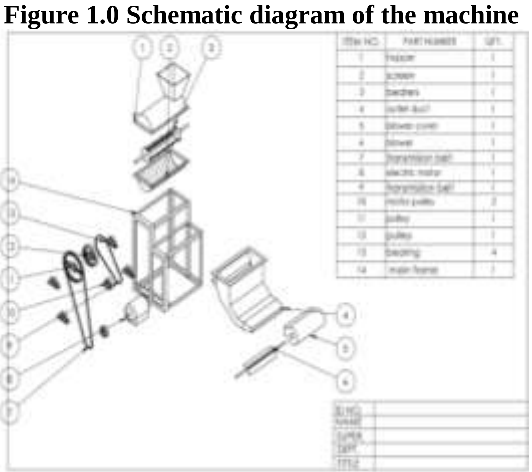

Figure 2.0 Exploded view

2.3 Testing Procedure

Tests were carried out under controlled and field conditions using freshly harvested groundnut pods. Performance indicators included threshing efficiency, cleaning efficiency, throughput capacity, and mechanical damage. Three different drum speeds (600, 750, 900 rpm) and feed rates (10, 15, 20 kg) were evaluated in a randomized design.

III. RESULTS AND DISCUSSION

The shelling machine performance evaluation parameters

S/N	SE (%)	MD (%)	ME (%)	SC (%)	CE (%)
1	86	18.7	80	168.0	56.8
2	88	22.3	79.2	169.0	55.2
3	87	17.3	81.0	168.9	60.0
4	87	20.1	80.2	170.0	57.1
5	85	17.1	79.6	168.9	58.0
MEAN	86	19	80	169	58

Key: SE - shelling efficiency; MD - mechanical damage, ME - material efficiency, SC - shelling capacity

Shelling efficiency, mechanical damage; material efficiency and shelling capacity were determined using equations 7 to 11 as recommended by [34]. Cleaning efficiency involves the separation of the seeds from the pod/chaff. [35] Recommends using equation 30 to estimate the cleaning efficiency.

$$Shelling efficiency\ (\%) = \left(\frac{Qs}{Qt}\right) \times \frac{100}{1} \quad \ldots\ldots [7]$$

$$Mechanical damage\ (\%) = \left(\frac{Qd}{Qu+Qd}\right) \times \frac{100}{1} \quad \ldots\ldots [8]$$

$$Material efficiency\ (\%) = \left(\frac{Qu}{Qu+Qd}\right) \times \frac{100}{1} \quad \ldots\ldots [9]$$

$$Throughput capacity\ (g\ \ h) = \left(\frac{Qs}{Tm}\right) \times \frac{100}{1} \quad \ldots\ldots [10]$$

$$Cleaning efficiency\ (\%) = \frac{Wd}{Wwp} \times \frac{100}{1} \quad \ldots\ldots [11]$$

Where Qs is the total weight of shelled groundnut, Qt is the total weight of groundnut, Qu is the total weight of undamaged groundnut, Qd is the total weight of damaged groundnut, and Tm is the time to shell the groundnuts, Wd is the weight of dirt included in kernels and Wwp is weight of total dirt from shelled groundnut

3.1 Threshing Efficiency

Threshing efficiency increased with drum speed, peaking at 86% at 750 rpm. At 900 rpm, a slight drop was observed due to increased seed damage and re-threshing.

3.2 Cleaning Efficiency

Cleaning efficiency reached 58% at the optimal speed. At lower speeds, chaff removal was incomplete, while higher speeds caused seeds to be blown away.

3.3 Throughput Capacity

The highest throughput capacity of 169 kg/h was recorded at 20 kg feed rate and 750 rpm. At 600 rpm, capacity was significantly lower.

3.4 Mechanical Damage

Seed damage was minimized (19%) at 750 rpm but increased sharply at 900 rpm (24%).

3.5 Comparative Performance

Compared to manual threshing (average 40–50 kg/day), the machine demonstrated improved productivity and reduced labor.

IV. CONCLUSION

A groundnut threshing machine was successfully developed and evaluated. It demonstrated high threshing and cleaning efficiency, reduced seed damage, and enhanced throughput. The machine is suitable for small to medium-scale farmers and can be powered by electric or petrol engines.

V. RECOMMENDATIONS

Further improvements including adjustable sieve openings for different pod sizes, solar power integration and field trials across diverse zones could be applied for possible upgrade of the machine.

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