Development and Testing of a Portable Hand-Operated Groundnut Sheller

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Abstract

This paper presents the design, fabrication and performance evaluation of a hand operated hand groundnut sheller using locally available materials of metal, wood and wire mesh. The sizing and fabrication of feeding hopper, shelling chamber, exit jute, blower, pulley system and main framework were done using standard engineering procedures. The machine was tested for shelling capacity and efficiency at five concave clearances, six operation speeds (in revolutions per minute) and three moisture contents. An optimum clearance was reached at 30 mm for runner and bush varieties of groundnuts from Western Kenya. At this clearance the average sheller efficiency was 79% when the groundnuts were at a moisture content of 13% and sheller operation speed of 15 revolutions per minute. The total amount of power requirement for the Sheller was approximated as 3.71 W.

Key Words: Groundnut, Sheller, Design, Efficiency, Capacity, Power, Solar Energy

Introduction

Groundnuts are a high value crop that can be marketed with little processing. There are two types of groundnuts, the bush and runner varieties and their various hybrids. The main difference between the varieties with reference to the design of post harvest machines is with respect to the number of seeds or kernels in the pods. The bush variety contains one or two kernels in a thin shell while the runner has one to three kernels in a thicker shelled pod.

The removal of the outer coat or shell of the groundnuts is termed shelling or decortication. In this paper, the former term is preferred. In Kenya, groundnut shelling is mainly done by use of bare hands. The process is tedious, slow, tiring and time consuming. One man can shell upto 14 kg of kernels of groundnuts in a day by hand (Ackali, 1996; Atiku, *et al.*, 2004).

A number of groundnut shelling machines have been designed and developed in many developing groundnut growing countries include Super Cayon, Sharpur and Malian groundnut shellers (Atiku *et al.*, 2004). These machines are operated by hand, foot or engine or electric power.

Akcali (1996) designed and tested a peanut sheller, comprising of a conical auger and a surrounding conical grate based on a mathematical model associating physico-mechanical properties of peanuts with design parameters. The sheller had a capacity of 80 kg/h and an efficiency of 86% kernel removal without breakage. Dash *et al.* (1994) developed a pedal-operated decorticator that was evaluated at different sieve clearances for four varieties and moisture contents of groundnuts. They reported the optimum shelling capacity as 72 kg/h at average nut diameters for the clearance and storage moisture contents for moisture content. The other details of the sheller development were not available.

The shelling efficiency of a reciprocating groundnut sheller at various operating conditions including rotational speeds, feed rates, air velocities and groundnut moisture contents in terms of mechanical damage and unshelled seeds (total losses), sheller productivity, unit energy consumption, seed recovery and degree of cleanliness have been reported by Helmy (2001). He reported the shelling efficiency of this sheller as being 3.45% higher than that of a drum-sheller at approximately the same operating conditions.

These machines, however have inherent shortfalls that include lack of (1) continuous feeding component leading to intermittent operation and production, (2) a blower to remove the shells after shelling, necessitating a separate winnowing operation, (3) automatic feeding and adjustment mechanisms, leading to high labour demand and need to sort pods and frequent adjustments for different pod sizes, (4) proper monitoring of the operation to reduce kernel bruising, and (5) high capacity and lifespan (Ackali, 1996; Atiku *et al.*, 2004). Most of all, these shellers are relatively expensive and unavailable in the Kenyan market.

Most hand-operated shellers can shell between 25 kg/h and 220 kg/h, depending on manpower capacity, operating conditions of the sheller, and nut characteristics with a shelling percentage of 65%-75% (Helmy, 2001; Atiku

et al., 2004). There is therefore need to design, fabricate and test locally assembled shellers, which can be driven by hand for rural low income groundnut producers. The development of such a machine must consider the power source and amount, groundnut characteristics, structural stability during operation, material and cost of machine, ergonomic suitability and other design parameters such as clearance, forces and efficiency.

The pressure exerted in shelling is given by Equation (1) (Akcali, 1996).

$$P = a_o + a_1 \frac{R_o}{R_2}(1 - KY)\rho_{gdt} \quad \ldots\ldots(1)$$

Where: P is the pressure exerted (units),

a_o is the pressure strain coefficient at the surface of the beater (i.e. 2.40),

a_1 is the pressure strain coefficient (10.1),

Ro is the radius of the beater,

R_2 is the radius of the concave from the centre of the beater, and approximated as:

$$R_2 = R_o + \beta_s \quad \ldots\ldots(2)$$

where: β_s is the average pod size,

ρ_g is the bulk density of groundnuts, and

KY is the shelled ratio, given by:

$$K_y = \frac{\textit{Shelled groundnut weight}}{\textit{input groundnut.pods.}} \quad \ldots\ldots(3)$$

These relationships were developed with the following assumptions: first, that the length of the beater was adequate for proper testing of the model; secondly, that there existed negligible friction between the machine model's moving member(s); thirdly, the speed of rotation of the beater was uniform; and finally the angle of repose of the groundnuts was 20^0.

The purpose of this research was to develop and evaluate a machine for low-income small-scale groundnut growers, that has a higher capacity than hand shelling, and is efficient, affordable, portable, hand operated, easily repaired, serviced and cheaply maintained for the shelling of groundnuts. Consequently, the objectives of this study were to design, develop, test and evaluate a groundnut sheller that can save resources of time and labour spend when using manual shelling techniques.

Materials and Methods

Design and Fabrication

The development of the hand-operated sheller involved the selection and sizing of material for the following components using both theoretical and established relationships as described by many designs and researchers including Ackali (1996), Atiku et al (2004) and Helmi (2001). The materials, functional components and features are described hereunder and shown in Figures 1 to 4.

The grate and concave shelling chamber is easier to load in the vertical plane. The 300 mm wooden grate with a roughened surface was further covered with a wire grid to increase its ability to shell off the pods from the kernels. The lower half was fitted with a wire grid giving an adjustable clearance varying from 20 mm to 40 mm making the pod inlet wider and broken shells outlet small. These material selections and dimensions were based on the groundnut pod and kernel characteristics of size, hardness at y storage temperatures, construction material durability and relative costs.

Drive mechanism – a manually activated crank and handle in order to develop a cheap machine that can be locally reproduced. The diameter and length of the wooden shaft were chosen to be 25 mm and 700 mm respectively. To reduce the cost of the hand-operated machine, wood was found suitable for the crank and handle.

The sheller, ergonomically fit for an average adult; that is, the height of the handle and feeding hopper (and the machine) above floor being 1150 mm and 1500 mm respectively; a handle diameter of 27 mm. These dimensions are within the ergonomic limits of an average worker and enabling ease of operation of the sheller and comfortable to man. The feeding hopper was sized using the amount and inherent characteristics of groundnuts especially the 20° angle of repose suggesting an incline of the same amount to reduce friction forces onto the walls enhance material flow. Soft wood planks were chosen for the hopper to reduce cost. The sheller was designed to handle 5 kg of unshelled groundnut pods (bulk density 218 kg m^{-3} giving a volume of 0.02 m^3) at any given load and trial. Receiving (concentrating) hopper and

discharge chute were made plain iron sheet shaped and joined to give the required slopes and capacities.

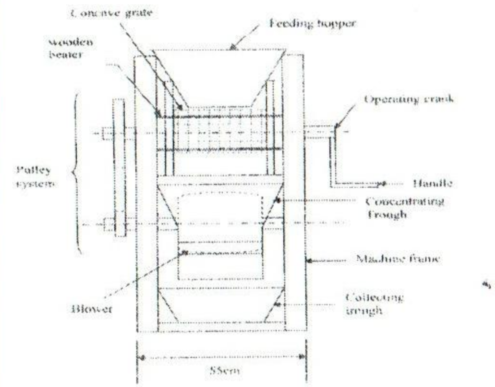

Figure 1. Front view of the groundnut sheller

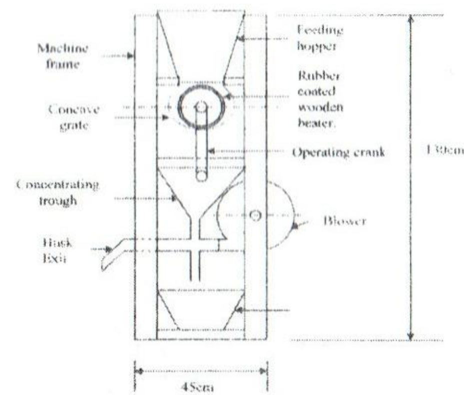

Figure 2. Side view of the groundnut sheller

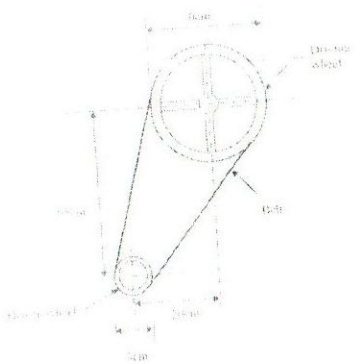

Figure 3. Pulley system

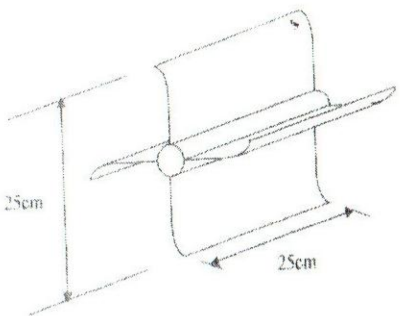

Figure 4. Rotating blower blades

The pulley system (Figure 3) consists of two pulleys, flat belt and a 6.25 mm round metal rod to transit the power. The blower (Figure 4) was made of flat sheet metal (gauge 30) joined to the power transmission shaft (6.25 mm pipe 3). The shape of the blades and dimensions are as shown. The framework to hold all the other components was found to be sufficient using locally available 75 mm by 50 mm soft wood pieces, glue and nails. The necessary computations of forces, torques, strains and stresses and detailed drawings for various components are not included in this paper.

The 28 kg portable hand operated groundnut sheller is made of a cypress wooden frame, a wooden beater wrapped with wire mesh to roughen it, a concave grate made of wire mesh, a collecting trough, a feeding hopper, a wooden shelling chamber cover and a hand operated crank. The feeding hopper is to be placed over the shelling chamber and suitably constructed with its walls inclined at 20° to allow all the unshelled groundnut pods to fall into the shelling chamber by gravity. The beater was directly coupled to a hand operated crank on one side. A sheet metal collecting trough, with its walls inclined at 20°, is constructed under the concave. The overall dimensions and weight of the sheller were 1400 mm high, 700 mm long, 500 mm width and 28 kg (making it portable).

Operation

The unshelled groundnuts are loaded onto the hopper and then the handle is rotated by hand. The rotating grate (also termed the beater) pulls the unshelled groundnuts into a shelling chamber with a tapering/reducing clearance between the grate and the wire grid concave. The beater applies shelling pressure on the groundnut pods through compression, impact and fatigue through the friction of the three surfaces (grate, pod and concave). As the beater rotates inside the chamber, it exerts pressure along its axis of rotation, which causes the breakage of pods resulting in a mixture of hulls (shells) and kernels. The shredded and small shells drop through the smaller openings of the wire grid (at lower side concave) being followed by the bigger shells and kernels as the shelling proceeds and the mixture moves forward. This partially sorted mixture collects in trough under the concave. The mixture is then sorted into unshelled groundnuts, pods and broken and whole kernels. Chaff and finer particles are separated from whole kernels by the use of the blower whose effect acts on the mixture as it falls through the concentrating trough. The shelled groundnuts then drop under the influence of force of gravity, into the collecting trough.

Performance Testing

The capacity and efficiency of the sheller was determined at different operating conditions including the speed of beater rotation and feed rates, different clearance settings, groundnut sizes and moisture contents. The study assumed the effects due to chance and untested factors were normally distributed and their variance was constant throughout the experiment. It was also assumed that the different observations were the independent, that is, the results of one observation did not affect the results of the other observations.

The capacity (throughput) of sheller was determined by the amount of groundnuts shelled by the machine per unit time under different operating conditions. The shelling efficiency was computed as the percentage of shelled clean kernels to the total amount of unshelled groundnuts for each trial. Sheller efficiency can also be expressed as the ratio of shelled unsorted (including bruised and broken) kernels to input or clean kernels to unsorted kernels. The former definition is used in this paper.

Results and Discussion

The results of the capacity and efficiency of the sheller at different operating speeds of revolutions per minute, different clearance settings/sizes and moisture contents are presented and discussed in the following subsections.

Sheller Capacity

The capacity (throughput) of sheller was expressed as the amount of unshelled groundnuts (kg/h). Results are presented in Table 1 and Figure 5.

Table 1. Effect of concave clearance on the sheller capacity and efficiency

Concave clearance (mm)	Input groundnut pods (g)	Shelled kernels (g)	Unshelled groundnuts (g)	Broken kernels, dust (g)	Shelling time (minutes)	Sheller capacity (kg/hr)	Shelling efficiency (%)
20	5000	3680	760	560	15	20	73.6
25	5000	3890	700	410	14	21.4	77.8
30	5000	3990	650	360	13.5	22.2	79.8
35	5000	3880	790	330	12.5	24	77.6
40	5000	3660	990	350	12	25	73.2
Average	5000	3820	778	402	13.4	22.5	76.4

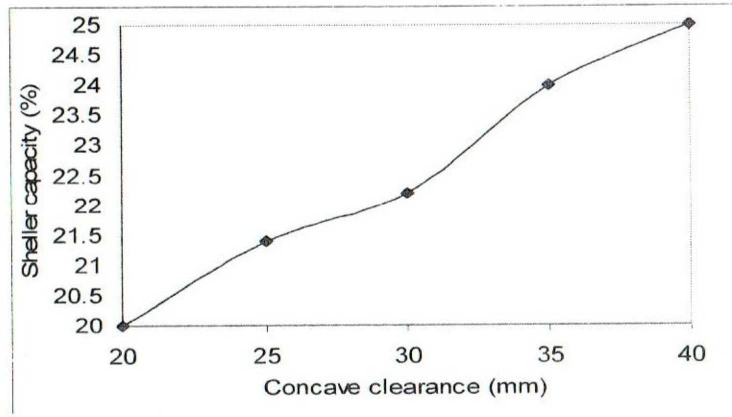

Figure 5. The effect of concave clearance on sheller capacity

The capacity increased from 20 kg/h to 25 kg/h as the concave clearance increased from 20 mm to 40 mm as would be expected since the bigger the opening in the chamber the more pods that can be handled per unit revolution and time and indirectly this defines the feed rate. However, the matching of the concave clearance with the pod size (an inherent property of a given groundnut variety) must be proper otherwise the ratio of shelled and broken groundnuts will be unacceptably high. Taking these factors in consideration, the optimal capacity is 22.2 kg/h at a concave clearance of 30 mm when the sheller efficiency is highest (79.8%). Since these are results from trial runs, it is expected that the throughput (per day) will reduce in actual operation.

Sheller Efficiency

The efficiency of the sheller is presented in Tables 1 to 3 and Figures 5 to 7. Generally, the efficiency of the shelling process of this machine varied with concave clearance, speed of operation and moisture content.

Figure 6 shows that the efficiency of the sheller increases asymptotically from 73.6% at the concave clearance of 20 mm to a peak of 79.8% at 30 mm concave clearance and the similarly decreases to 73.2% at 40 mm clearance. The optimal clearance setting for the machine is therefore recommended to be 30 mm concave clearance.

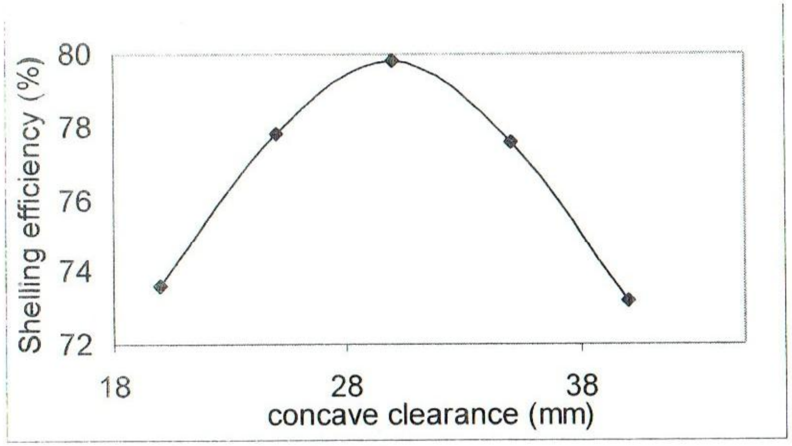

Figure 6: The effect of concave clearance on shelling efficiency

The effect of speed of operation of the sheller is presented in Table 2 and Figure 7 for the 12 to 17 revolutions per minute (rpm). The efficiency increased slightly from 77% to a maximum of 78.4% at 15 rpm but decreasing rather steeply to 75% as the speed increased to 17 rpm. The 15 revolutions per minute can thus be taken as the optimal point of operation.

Table 2: Effect of sheller speed on shelling efficiency

Shelling speed (rpm)	Input groundnut pods (g)	Shelled kernels (g)	Unshelled kernels (g)	Broken kernels, dust (g)	Shelling efficiency (%)
12	5000	3850	1040	110	77.0
13	5000	3880	1000	120	77.6
14	5000	3890	990	120	77.8
15	5000	3920	980	100	78.4
16	5000	3800	995	205	76.0
17	5000	3780	990	230	75.6

Table 3: The effect of moisture content on shelling efficiency

Moisture content (%)	Input groundnut pods (g)	Shelled kernels (g)	Unshelled pods (g)	Bruised and dust (g)	Shelling efficiency (%)
10	5000	3730	990	280	74.6
13	5000	3950	890	160	79.0
15	5000	3850	910	240	77.0
19	5000	3590	1300	110	71.8

The effect of the moisture content (mc) of the groundnuts on the shelling efficiency is presented in Table 3 and Figures 7 and 8

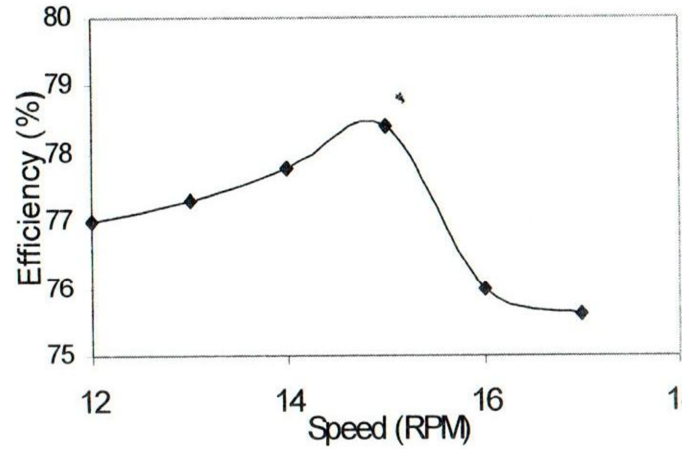

Figure 7. Effect of sheller operating speed on efficiency

Very dry groundnuts (at 10% mc) have a lower efficiency of 74.6% due to a higher percentage of broken kernels due to increased friction within the shelling chamber and sharp broken pods. The highest shelling efficiency was attained at a moderate moisture content of 13%. However, as the moisture content increases, the efficiency decreases since the pods are friable, tending to flex instead of cracking and breaking hence leading to a higher percentage of unshelled groundnuts.

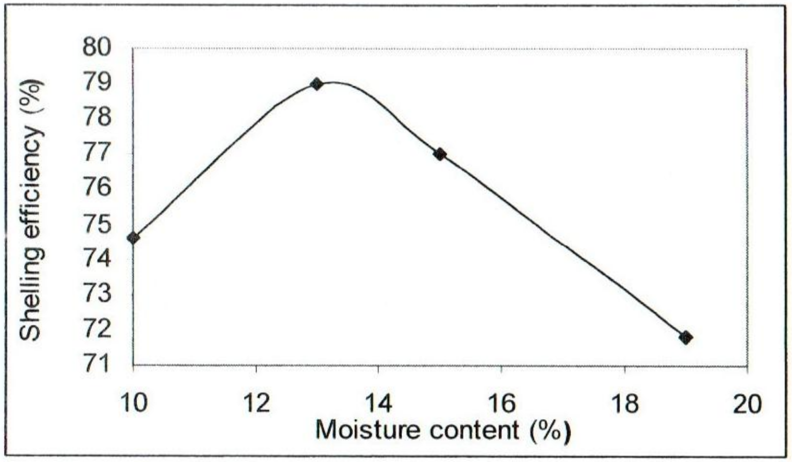

Figure 8. The effect of groundnut moisture content on sheller efficiency

Determination of Energy Requirement

The pressure exerted on the groundnuts is computed from equation (1), R_o is the radius of the beater (10 cm), $\beta_s = 5.6$, $\rho_g = 2.14$ KNm^{-3} (the measured density was 218 kgm^{-3}) and $K_y = 0.76$ (Table 1). Thus:

$$P = 2.40 + 10.1 * 2138.6(1-0.76)\frac{10}{13.5} = 7.1\,Nm^{-2}$$

The force applied is computed from:

$$F = P * Area \text{ ....} (4)$$

The area is the product of the length of the beater and its circumference $Area = 0.3*3.142*0.2 = 0.19\,m^2$. Hence,

$$F = 7.1 * 0.19 = 1.3\ m^2$$

The energy E_s spent in shelling is given by the product of the force applied per revolution and the distance covered by the rotating beater in one second.

This is computed as:

$$E_s = 1.5\left(\frac{40*3.142*0.2}{60}\right) = 0.55W$$

The kinetic energy (KE) is a function of the velocity (v) of the blower and mass (m) of the beater as defined in equation (5). The mass of the beater is approximated as 1 kg and the velocity ratio of the pulley system is 6. Therefore,

$$KE = \frac{1}{2} m\, v^2 \text{ ....} (5)$$

$$KE = 0.5 * 1 * \left(\frac{40*63.142*0.2}{60}\right)^2 = 3.16W$$

The total amount of energy (E_T) spent in operating the machine is the sum of energy spent in shelling and the energy spent in operating the blower. Its value is

$$E_T = (0.55 + 3.16)W = 3.71\,W$$

Conclusions and Recommendations

A groundnut sheller was designed and fabricated using locally available materials. It was tested for capacity and shelling efficiency at different concave clearances, operation speeds and moisture contents and found to give varied results. An optimum clearance was reached at 30 mm for runner and bush varieties of groundnuts from Western Kenya. At this clearance the average sheller efficiency was 79% when the groundnuts had 13% moisture content and sheller operation speed was 15 revolutions per minute.

A higher prime mover and winnower some should be incorporated to operate the machine and remove chaff and dust thus increase recoverable kernels. Further and finer adjustments of the clearance should be added to reduce the bruising effect of the machine and thus improve its efficiency. The lifespan and costing of the machine could be established based on long-term operation. The equipment should be redesigned and tested on the use of solar energy as the source of power.

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References

Akcali, I.D. (1996). An approach to developing a peanut sheller. Agricultural Mechanization in Asia, Africa and Latin America 27(3):44–50.

Atiku, A., Aviora, N. and Haque, M. (2004). Performance and evaluation of a bambara groundnut sheller. Journal of CIGR Agricultural Engineering 4:12-18.

Helmy, M.A. (2001). Evaluation of a reciprocating peanut sheller. Agricultural Mechanization in Asia, Africa and Latin America. 32(4):35-42, 27.

Dash, A.K., Dash, D.K. and Dash, S.K. (1994). Development and performance evaluation of a pedal-operated groundnut decorticator. Agricultural Mechanization in Asia, Africa and Latin America 25(2):61-65.

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