ABSTRACT

Groundnut shelling is one of the important operations in the peanut harvesting process. Indeed, one of the major constraints in the groundnut production process in developing countries is the tedious task of shelling. It is with the aim of removing this constraint that a prototype groundnut sheller was produced including the dimensioning and design of all the constituent parts. The main components of the stripper are: The frame, the threshing machine, the concave, the fan and the motor. The nominal production capacity of the machine is 378 tons per year and per season with an electric power of 1.6 HP. The cost of the machine is US$ 475, affordable for small local producers. Finally, an economic profitability study of the machine was carried out and presented. It reveals a minimum production of 2.2 tons per year and per season to pay back the initial investment cost of the acquisition.
Keywords: Groundnut; shelling; husker; economic return.

1. INTRODUCTION

Agriculture is the basis of Benin's economy. It contributes about 23% to Gross Domestic Product (GDP), provides about 75% of the State's export earnings and employs about 70% of the working population [1]. The agricultural sector is characterized by the predominance of family-type farms and is vulnerable to climatic variability. The production and transformation processes of some oilseeds such as groundnuts have not undergone major changes despite technological advances. Groundnut production in Benin faces many problems, especially during harvesting (de-seeding or threshing). Groundnut shelling is the operation of separating the groundnut pods from the hull. According to authors, it's the most difficult operation during harvest [2].

Over the past few years, a great deal of successful work has been done on the design and construction of groundnut shellers. On the Beninese market, there are Japanese pedal threshers that were originally designed for rice and have been adapted for groundnut. But they were not suitable because the pod must be presented to the threshing elements while holding the leaves in hand to facilitate hulling, which results in low yields compared to manual work [3]. A small pedal-type threshing machine has been designed specifically for groundnuts by the Agronomy Division of Dharwar College of Agriculture in India, but the pod is made of wood, which makes it difficult to use in its present form in tropical Africa [4]. In the Congo, a prototype of a small crank-driven threshing machine has been developed that quadruples the yield of manual threshing, but requires human power to turn it [5].

Now that the areas sown by producers are increasingly large, non-motorized equipment is less suitable for carrying out the necessary work. It is becoming imperative to consider motorized equipment to facilitate the work. Recently, small motorized threshing machines in models ranging from 0.7 to 1.4 kW and weighing about 100 kilograms have appeared on the markets. Tests with these threshing machines in the Congo have yielded conclusive results, but only the bunch has to be presented to the thrasher, which complicates operations. In addition, manual sorting is also essential after shelling [3]. The FAO threshing machine often requires several threshing stages, which increases space requirements. In addition, the machine is expensive and difficult to manufacture. The CEEMAT (Centre for the Study and Experimentation of Agricultural Machinery in the Tropics, in French) threshing machine, on the other hand, has the disadvantage of having an irregularity in the threshing all along the threshing unit and a very high price compared to the capacity of our producers, which would limit the purchase by the producers [6]. The threshing machine designed by Cissé, whose manufacture requires gears, is very cumbersome [7]. In addition, the peanut pods are shelled by the feeding system (the two drums), which alters the conservation of the peanut pod. It is also intended only for dry peanuts only.

Recent advances have been observed in the manufacture of peanut huskers or straw choppers in the local market, such as the groundnut shelling and separating machine made in India [8]. The design is very simple and eco-friendly which uses simple mechanism properties such as shelling system, automatic separating system and crushing chamber. But it has a major drawback which is labour intensive and also it consumes lots of time. Output is about 20-30 kg/hour. We can also cite the small scale Peanut shelling machine designed in Soudan which capacity was assumed to be 180 kg/hr [9]. The power system consists of the electric motor and belt and pulley drives by which it runs the shelling roller and the blower. The shelling is achieved by shelling beaters on the drum by both rubbing and beating against a stationary plate called concave. Clean seeds are obtained by the blower action which blows the chaff and other debris from seeds. On the same way, a power groundnut sheller was designed and fabricated in Farm Machinery and Postharvest Process Engineering (FMPE) Division, Bangladesh Agricultural Research Institute (BARI), Gazipur during 2011-13 [10]. The developed groundnut sheller was capable to work continuously and facilitate winnowing. Moreover, it can separate unshelled groundnut from the shelled groundnut with simple 0.37 kW electric motor. In Nigeria, a local groundnut sheller was modified to improved performance and incorporate cleaning unit [11]. The sheller was constructed from locally available materials with a compact and robust design that suit the local requirements.

In some, several groundnut shelling equipment was reported in the literature. But threshing or husking of groundnuts with combustion engine
threshers remains marginal in Benin. In fact, Beninese farmers face many constraints in terms of tool supply: Support, insufficient advice on choosing their equipment; low purchasing power, which does not allow them to have access to quality equipment; difficulties in obtaining credit, and spare parts are difficult to obtain for most imported equipment. It is in response to these constraints that this study aimed to design and build a locally manufactured husking machine that is innovative in terms of its robustness, low cost and adaptation to the capacity of the users.

2. MATERIALS AND METHODS

2.1 Presentation of a Peanut Plant

Groundnut (Arachis hypogea) is an oilseed plant of the legume family, belonging to the Papilionaceae subgroup, which is widely distributed in all tropical regions of the world. It is a legume 30 to 70 cm high, erect or creeping. The aerial part is carried by a main stem in the form of roots and two primary lateral branches coming from the crown of the plant. The leaves are made up of two pairs of opposing elliptical leaflets at the end of a petiole inserted on sequential alternate branches. The yellow or orange flowers, Papilionaceous take birth in the axils of the leaves, they wriggle quickly. The base of the fertilized ovary elongates to form a peduncle called a gynophore which sinks into the soil where the fruit (pod) forms, consisting of an indehiscent shell containing 1 to 4 seeds.

The plant will have limited vegetative development until the start of flowering which begins 25 to 30 days after sowing. Under optimal conditions and in rainfed cultivation, the peanut completes its cycle in 90 days (early variety), 120 days (semi late) or 140 days (late variety).

2.2 Description of the Husker

Fig. 2 shows a perspective view of the designed prototype.

Within the framework of this work some materials were used. These include welding stations, generator, drill, grinding wheel, tools such as saw blades, files, wrenches, forging and other technical tools. The main components of the stripper are: the frame, the threshing machine, the concave, the fan and the motor. Of all these components, only the fan and motor are purchased and the others have been made by us.
2.2.1 Chassis

The chassis is the support for the whole machine. It is used to stabilize and secure the machine components. In the model of the chassis shown, both types of motors, internal combustion engine or electric motor, can be used indifferently. It is mainly made of angle iron.

2.2.2 Threshing drum

The threshing drum is one of the most important parts of the machine. It consists of the tips or fingers attached to flat irons around hoops and an axle. It is driven by a rotating movement.

2.2.3 Counter thresher

It is also an important part of the machine. It consists of the beater fingers or points fixed on flat irons and quarter hoops. The counter threshing drum is fixed to the frame; it is not in motion. It is the rotational movement between the thresher and the counter thresher that enables the peanuts to be husked.

2.2.4 Ventilator

The rotating fan produces a flow of air that separates the peanut pods from the straw. It consists of blades.

2.2.5 Motor

The motor is the driving unit of the machine. It transmits its rotary motion to the machine components. On the proposed peanut thresher, an electric or combustion engine can be used.

2.3 Operating Principle of the Groundnut Sheller

When the motor (8) is switched on, the pulley (10) of the beater shaft rotates via the belt (11). The dry peanut straw is poured into the machine through the hopper (1), but the wet peanut straw is held by the user and introduced into the machine through the same hopper. As a result of the beater's rotating movement, an impact occurs between the straw or vine and the beating elements, which allows the pods to be separated from the straw or vine. The pod-straw assembly arrives in the winnowing channel (blower) (9) where, under the effect of the air flow, the pods are separated from the straw. The pods are collected in the tank (7) through the chute (6), while the straw is pushed back to the outlet. The following Fig. 3 shows a schematic diagram of the operating principle.

2.4 Modeling

2.4.1 Threshing and winnowing system

2.4.1.1 Determining the power absorbed by the mixer

The power consumption is the electrical power required to turn each functional element of the threshing machine. The estimation of these consumptions is based on the theory of
similarities. Thus, Vaschy Buckingham's theorem is written \[7\]:

\[ P_b = \pi_1 \times Q \times N^2 \times D^2 \]  

(1)

With \(\pi_1\): A dimensionless constant, \(Q\): The gross output of threshed material in kg/h, \(N\): The beater speed in rpm, \(D\): The beater diameter mm, \(P_b\) The beater power in kW.

2.4.1.2 Determining the blower power consumption

The blower power consumption writes:

\[ P_v = F \times V \]  

(2)

\(P_v\): The blower power in kW, \(F\): Air resistance force in N, \(V\): The blade speed in m/s.

2.4.1.3 Sizing of the motor

The power of the motor to be installed is the sum of the powers of all the components increased by 30% as service coefficient [12]:

\[ P_m = 1.3(P_v + P_b) \]  

(3)

Where \(P_v\): The fan power in kW; \(P_b\): The beater power in kW and \(P_m\): The motor power in kW.

2.4.2 Belt and shaft

2.4.2.1 Characteristic parameters of the belt

The transmission of the engine's movement to the other components will be done by V-belts. A belt is characterised by its pitch length, centre distance, winding angle, permissible power, the tension of the soft strand and the tension of the taut strand.

2.4.2.2 Theoretical centre-to-centre distance

The centre distance is the distance between the axes of the two pulleys. To determine the centre distance \(a\), its minimum \(a_{\text{min}}\) and maximum \(a_{\text{max}}\) values have to be determined first. In order to calculate the belt centre distance, the ratio \(D_p/d_p\) must be determined first [12], where \(D_p\) is the diameter of the large pulley and \(d_p\) the diameter of the small pulley.

\[ \frac{D_p}{d_p} \]

Fig 3. Diagram of the operating principle of the de-duster

When the ratio $D_p/d_p$ is between 1 and 3, $a_{\text{min}}$ and $a_{\text{max}}$ are determined using the following relationships:

$$a_{\text{min}} \geq \frac{d_p+d_p}{2} + d_p$$  \hspace{1cm} (4)

$$a_{\text{max}} < 3(D_p + d_p)$$  \hspace{1cm} (5)

After calculation, an approximate value of the theoretical centre-to-centre distance is chosen such as:

$$a_{\text{min}} \leq a < a_{\text{max}}$$  \hspace{1cm} (6)

### 2.4.2.3 Determining the pitch length

The pitch length calculated here is the reference length given by expression (7) [12].

$$L_p = 2a + 1.57(D_p + d_p) + \frac{(d_p-d_p)^2}{4a}$$  \hspace{1cm} (7)

After calculating $L_p$ (mm), refer to the table showing the excerpts of the guide pitch lengths of V-belts to select a suitable standard length [12]. From the standard pitch length, the actual centre-to-centre distance (mm) of the belt is then determined by the expression (8):

$$a_r = \frac{L_p-2a(d_p+d_p)}{2} - \frac{(d_p-d_p)^2}{4[L_p-2a(d_p+d_p)]}$$  \hspace{1cm} (8)

### 2.4.2.4 Determining the wrap angle

The wrap angle is the angular deviation between the belt direction and the horizontal. It is determined by the following formula [12]:

$$\theta = 180 - 2\sin^{-1}\left[\frac{d_p-d_p}{2a}\right].$$  \hspace{1cm} (9)

---

**Fig. 4. Diagram of a belt transmission [12]**

---

$D_p$ meaning the diameter of the large pulley in mm, while $d_p$ is the diameter of the small pulley in mm.

### 2.4.2.5 Determining the permissible power $P_s$

$$P_a = P_b \cdot K_\beta \cdot K_{\theta}$$  \hspace{1cm} (10)

$P_b$, base power (kW); $K_\beta$, the pitch length correction coefficient; $K_{\theta}$, wrap angle correction coefficient [12].

### 2.4.2.6 Determining the tension of the slack strand

The tension of the slack strand is calculated as followed:

$$t = \frac{P \cdot \beta}{\sin(\theta/2)} + m \times v^2$$  \hspace{1cm} (11)

Where $P$ is the operating power, W; $\beta$ is the correction coefficient; $\theta$ is the wrap angle, C; $m$ is the linear mass of the belt, kg/m$^3$ and $v$ is the linear speed of the belt in mm/s [12].

### 2.4.2.7 Calculation of the tension of the stretched strand

Equation (12) gives the appropriate expression to compute the tension of the stretched strand:

$$T = t + \frac{P}{v}$$  \hspace{1cm} (12)

### 2.4.2.8 Calculation of the required number of belts

The required number is [10]:

---

71
2.4.3 Calculation of shaft parameters

To calculate the diameter of the shafts, the Westinghouse code was used [7].

\[
d = \left[ \frac{32 \times F_s}{\pi} \sqrt{\left( \frac{C}{R_e} \right)^2 + \left( \frac{M_t}{\sigma_D} \right)^2} \right]^{1/3} \quad (N)
\]

With C: The transmissible torque N.mm; M_t: The total bending moment N.mm; Re: The elastic strength MPa; \( \sigma_D \): the endurance limit MPa and F_s the safety factor.

After the shaft diameter has been calculated, its safety is checked according to the Von Mises-Hencky theorem [7]:

\[
n = \frac{\sigma'_p}{\sigma'}
\]

Where \( \sigma'_p \) is the plastic strength and \( \sigma' \) the bending strength.

2.4.4 Estimated cost of the machine

The estimated global cost \( C_g \) of the machine depends on the parameters listed below [13]:

- Raw material costs \( C_m \);
- Design office cost \( C_d \);
- Machining cost of \( C_u \) parts;
- Manufacturing cost \( C_f \).

Thus,

\[
C_g = C_m + C_d + C_u + C_f
\]

2.4.5 Calculating the economic viability of the machine

The calculation of the economic profitability of the groundnut thresher is made starting from a minimum threshold of 200 Kg of groundnut (leaves and pods). For this calculation, the income, variable and fixed expenses, gross margin, net margin and the threshold quantity of groundnut to be threshed per year are taken into account [1].

2.4.5.1 Calculation of income

With this peanut thresher 200 Kg of processed peanuts (tops + pod) provide 50 kg of peanut pods, i.e. 25% of peanut pods. Currently the price per kilogram of groundnut is 225 XOF. Thus the recipes are as follows:

\[
\text{Total recipe} = P \times Q
\]

With Q the quantity of groundnut processed per 200 Kg of raw groundnut (hull + pod) and P the price of one kilogram of groundnut pod.

2.4.5.2 Calculation of the variable charges

There are two types of expenses. The purchase of the 200 Kg of raw groundnut (leaves + pod) and all other expenses that go into the threshing of the groundnut (fuel, labour, repair and maintenance of equipment). Variable charges (costs) are equal to the sum of all expenses directly involved in threshing.

2.4.5.3 Calculation of the fix charges

Fixed costs correspond to expenditure incurred regardless of the quantity produced. They include expenditure on replacement of equipment after five years of use and costs that must be engaged even before production begins (workshop, purchase of machinery, etc.).

\[
\text{Fix cost} = \frac{A_t \times Q}{Q_a}
\]

With At: The total annuity; Q: The base quantity; Qa: The annual quantity that can be shelled.

2.4.5.4 Calculation of gross and net margin

The producer's gain after threshing the peanut is assessed by calculating gross and net margins.

\[
\text{Gross margin} = \text{Revenue} - \text{Variable costs}
\]

The difference between gross margin and depreciation and amortization expense is the net margin. It is this margin that takes fixed costs into account.

\[
\text{Net margin} = \text{Gross margin} - \text{depreciation expense}
\]

2.4.5.5 Break-even Quantity Calculation

The break-even point is calculated \( \langle \text{SR}_{CA} \rangle [1] \):

\[
\text{SR}_{CA} = \frac{\text{Annual fixed cost} \times \text{Income}}{\text{Gross margin}}
\]

2.4.6 Calculation of the percentage of equipment used

The percentage of the capacity of the equipment used is the percentage of production for which
the gross margin covers the fixed costs. This percentage is calculated by the following formula:

\[
\% \text{Capacity used} = \frac{\text{SRCA} \times 10^{-0.0}}{\text{Income}}
\]  
(22)

### 2.4.7 Calculation of technical capacity

\[\text{Capacité technique} = Q \times Nm \times Hj \times Dv \]  
(23)

With Q: Hourly output; Nm: Number of working months; Hj: Daily working hour; Dv: Lifetime

### 2.4.8 Calculation of the threshold quantity

Threshold quantity = Useful capacity x Technical capacity  
(24)

### 3. RESULTS AND DISCUSSION

#### 3.1 Results

The results obtained from the application of the mathematical models of each part of the threshing machine are shown in Tables 1 to 3.

#### Table 1. Value the characteristic parameter of the threshing, winnowing system and typical motor

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threshing diameter</td>
<td></td>
</tr>
<tr>
<td>Rotation frequency (tr/min)</td>
<td>600</td>
</tr>
<tr>
<td>Hourly flow rate Q (kg/h)</td>
<td>700</td>
</tr>
<tr>
<td>Threshing drum diameter D (mm)</td>
<td>300</td>
</tr>
<tr>
<td>Power consumption Pb (W)</td>
<td>593.64</td>
</tr>
<tr>
<td>Winnowing system</td>
<td></td>
</tr>
<tr>
<td>Drag force F (N)</td>
<td>11.2</td>
</tr>
<tr>
<td>Blade speed V (m/s)</td>
<td>5.86</td>
</tr>
<tr>
<td>Power consumption Pv (W)</td>
<td>262.67</td>
</tr>
<tr>
<td>Motor</td>
<td></td>
</tr>
<tr>
<td>Driving power Prm (W)</td>
<td>1113</td>
</tr>
<tr>
<td>Engine speed N (tr/mn)</td>
<td>1600</td>
</tr>
</tbody>
</table>

#### Table 2. Value of the characteristic parameter of the belt drive system between motor and blower, threshing and blower and parameter of the shafts

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drive system between motor and blower</td>
<td></td>
</tr>
<tr>
<td>Operating power Ps (W)</td>
<td>1113</td>
</tr>
<tr>
<td>Belt linear speed V (m/s)</td>
<td>5.94</td>
</tr>
<tr>
<td>Centre distance a (mm)</td>
<td>407</td>
</tr>
<tr>
<td>Winding angle θ (°)</td>
<td>161.44</td>
</tr>
<tr>
<td>Belt pitch length Lp (mm)</td>
<td>12.5</td>
</tr>
<tr>
<td>Basic power Pb (kW)</td>
<td>0.83</td>
</tr>
<tr>
<td>Permissible power Pa (kW)</td>
<td>0.737</td>
</tr>
<tr>
<td>Number of belts n</td>
<td>2</td>
</tr>
<tr>
<td>Soft strand strength t (N)</td>
<td>204.88</td>
</tr>
<tr>
<td>Strand strength T (N)</td>
<td>392.28</td>
</tr>
<tr>
<td>Drive system between threshing and blower</td>
<td></td>
</tr>
<tr>
<td>Operating power Ps (W)</td>
<td>771.7</td>
</tr>
<tr>
<td>Belt linear speed V (m/s)</td>
<td>9.92</td>
</tr>
<tr>
<td>Centre distance a (mm)</td>
<td>214.13</td>
</tr>
<tr>
<td>Winding angle θ (°)</td>
<td>175.7</td>
</tr>
<tr>
<td>Belt pitch length Lp (mm)</td>
<td>719</td>
</tr>
<tr>
<td>Basic power Pb (kW)</td>
<td>2</td>
</tr>
<tr>
<td>Permissible power Pa (kW)</td>
<td>1.49</td>
</tr>
<tr>
<td>Number of belts n</td>
<td>1</td>
</tr>
<tr>
<td>Soft strand strength t (N)</td>
<td>91.17</td>
</tr>
<tr>
<td>Strand strength T (N)</td>
<td>168.96</td>
</tr>
<tr>
<td>Parameters of the shafts</td>
<td></td>
</tr>
<tr>
<td>Diameter d (mm)</td>
<td>35.2</td>
</tr>
<tr>
<td>Safety factor according to Von Mises-Hencky</td>
<td>7.31</td>
</tr>
<tr>
<td>Diameter d (mm)</td>
<td>20</td>
</tr>
<tr>
<td>Safety factor according to Von Mises-Hencky</td>
<td>3</td>
</tr>
</tbody>
</table>
Table 3. Cost and economic efficiency of the threshing machine

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of the threshing machine</td>
<td></td>
</tr>
<tr>
<td>Cost of raw materials Cm ($)</td>
<td>307</td>
</tr>
<tr>
<td>Design office costs Ce ($)</td>
<td>62</td>
</tr>
<tr>
<td>Cost of machining parts Cu ($)</td>
<td>22</td>
</tr>
<tr>
<td>Manufacturing cost Cf ($)</td>
<td>84</td>
</tr>
<tr>
<td>Total Cost Cg ($)</td>
<td>475</td>
</tr>
<tr>
<td>Economic efficiency of the threshing machine</td>
<td></td>
</tr>
<tr>
<td>Income ($)</td>
<td>19</td>
</tr>
<tr>
<td>Percentage of equipment used (%)</td>
<td>3.52</td>
</tr>
<tr>
<td>Variable cost ($)</td>
<td>12</td>
</tr>
<tr>
<td>Fix charge ($)</td>
<td>0.2</td>
</tr>
<tr>
<td>Gross margin ($)</td>
<td>7</td>
</tr>
<tr>
<td>Net margin ($)</td>
<td>7</td>
</tr>
<tr>
<td>Break-even point in terms of turnover ($)</td>
<td>1</td>
</tr>
<tr>
<td>Technical capacity (kg)</td>
<td>63000</td>
</tr>
<tr>
<td>Break-even Quantity of Raw Peanuts (kg)</td>
<td>2217.6</td>
</tr>
</tbody>
</table>

3.2 Discussion

3.2.1 The engine

The engine's power output is 1113 W, which corresponds to 1.51 horsepower (hp). A 1.6 hp engine with a rotational speed of 1600 rpm is selected.

3.2.2 Drive shafts

The diameters of the threshing drum shaft and the calculated blower shaft are d = 35.2 mm and 19.34 mm respectively. Thus, the respective standard values of d = 35mm and d' = 20mm have been adopted [14]. With these values, the safety condition of the shafts according to Von MISES-HENCKY has been checked [7] and we consider them to be suitable.

3.2.3 The cost of the design office

The engineering department cost represents 15% of the cost of the machine or the cost of raw materials, standard parts, accessories and machined parts [13].

3.2.4 Calculating the economic viability of the threshing machine

According to the results in Table 3, the minimum amount of groundnuts to be threshed to make the machine profitable is 2.2 tons of raw groundnuts. Above this threshold, the net profit margin is 4250 XOF ($7) per 200 kg of processed product.

4. CONCLUSION

The objective of this work is to provide groundnut producers with a low-cost machine capable of assisting them in groundnut harvesting activities. In order to achieve this objective, an inventory of the groundnut production equipment found in the literature was carried out, with an analysis of their inadequacies. Then a model of the groundnut sheller adapted to the local conditions was studied and the prototype produced, together with an analysis of its performance and economic profitability.

The nominal production capacity of the dimensioned machine amounts to 252 tons per year with an electrical power of about 1.6 HP. The economic profitability analysis reveals a minimum production of 2.2 tons per year and per season in order to make the initial investment cost of the acquisition profitable.

The industrial realization of this equipment will be of great use to groundnut producers. It will help eliminate the major constraints that are disrupting groundnut producers in Benin. Thus, the State could support the manufacture of the wet and dry groundnut strainer with subsidies to enable its extension and promotion in local production in Benin.

However, much remains to be done to introduce a heavy mechanization on the farms and free Beninese farmers from the ergonomically crippling hard work of hand-tool-dominated agriculture. In this way, productivity can be increased by removing bottlenecks that limit agricultural production and rural income growth, as well as improving the reputation of agribusiness with young people and other professions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.
REFERENCES


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