DESIGN AND CONSTRUCTION OF A MACHINE FOR DECORTICATING BAMBARA NUT

I. M. Bashiri, M. Zubairu and E. S. Olorunaye
Department of Agricultural Engineering, Kaduna Polytechnic, Kaduna

Abstract
A Bambara nut decorticator was developed and it was tested for its performance in terms of its decorticating and cleaning efficiencies as well as percentage of broken seeds. The performance test which was conducted at a moisture content of 8.3% showed that the machine has a decorticating efficiency of 93% and cleaning efficiency of 85% which is an impressive performance. The 4.9% broken seeds and 2.7% undecorticated pods figures are low enough for the machine to be adjudged to have performed satisfactorily. It is recommended that the machine should be evaluated considering variables such as moisture content, cylinder speed feed rate and different varieties of the crop to establish the most suitable cylinder speed, moisture content and the feed rate for best performance of the machine.

Keywords: Bambara nut, development, decortications, cleaning

Introduction
Bambara groundnut (Vigna subterranea (L.) verdc.) according to Atiku et al 2009 is an indigenous African crop that is now grown across the continent in countries such as Nigeria, Senegal, Kenya, South Africa and many others. In Nigeria, it is grown in most of the northern states. Bambara nut is a seed which is contained in a pod. The pods are harvested by pulling or lifting the plant manually or by using a hoe. At times, a single furrow ox-drawn plough is used. The pods are then separated from the vines by hand. They are washed, used fresh or are dried and stored. The seed contains about 63% carbohydrate, 19% protein and 6.5% oil, (Goli 1997). The haul is used for livestock feed, (Tanimu and Aliyu, 1996).

Despite its economic importance, no commercial production and industrial use of the crop take place in Nigeria. Its production is usually undertaken by the small scale farmers. The seed which is usually covered by the haul is removed by the cracking the port and releasing the seed. The decorticating method in use is still the traditional method and varies from locality to locality depending on the quantity produced. Some communities use mortar and pestle to crush dry pods. Some beat the pods with sticks on the ground; others use stones to crush dry pods on flat ground. These methods have the disadvantages of damaging the seeds and are slow and laborious. These have resulted only small quantities of the crop being produced. To, therefore encourage increased production of this crop, a machine that is capable of decorticating the pod to produce clean seed was designed and fabricated. With increased production of this machine, Bambara nut can be decorticated more easily and quickly. It will also be readily available to different communities and draw large attention to the usefulness of the seed.

Operational principles
The operation of the machine is based on the principles of decorticating. The machine comprises of hoppers, frame, decorticating unit, cleaning unit and sieve. The hopper serves as the feeding chute to the decorticating chamber where Bambara nuts are decorticated. It was constructed with a 2mm thick metal sheet. As the Bambara nuts are fed into the hopper, they go down to the decorticating chamber where the pods are decorticated by the action of rotating spike teeth cylinder against the stationary concave. The decorticated seeds, undecorticated pods and the hauls all and pass down through the perforated concave unto a stream of air in the cleaning unit. The clean seeds are collected in a container at the clean seeds outlet. There
hulls from the decorticated pods are blown out through the second outlet. The machine is powered by a 1.9hp electric motor.

**Materials and method**
The materials used for the design and construction were sourced locally and Bambara nut used for testing the machine was bought at Kasuwan Magani market, Kaduna State.

**Design calculation**

**Design of the shaft**
The shaft carries the cylinder or drum on two bearings. Welded to the body of the cylinder are spikes that perform the decortications.

\[ d^3 = \frac{16}{\pi \delta_s} \sqrt{(K_1 M_1)^2 + (K_b M_b)^2} \]

(1)

Where, 
- \( d \) = Shaft diameter (mm)
- \( \delta_s \) = Allowable stress, (Nm-2) 40MN/m2 (ASME code)
- \( K_t \) = Combine shock and fatigue applied to tensional moment
- \( M_b \) = Maximum bending moment,
- \( M_t \) = Torsoional moment

\[
M_t (p.t.o) = \frac{KW x 9550}{rpm} \]

(2)

\[
KW = \text{Power transmission.} \\
K_b = \text{Combined shock fatigue applied to bending moment}
\]

**Shaft analysis**
The shaft used for this machine is subjected to two types of forces namely twisting moment and bending moment.

\[
f = \frac{T}{r} = \frac{C \phi}{l}
\]

(3)

Where,
- \( f \) = torsional shear stress,
- \( r \) = distance from neutral axis to outermost fibre,
- \( T \) = twisting moment (or torque) setting on shaft
- \( J \) = polar moment of inertia
- \( C \) = modulus of rigidity of shaft material,
- \( \phi \) = angle of twist in radius on a length, (ASME 1995)

Polar moment for round solid shaft, \( J = \pi/32 \times d^4 \) .................

\[
\frac{T}{\pi} \frac{32 \times d^4}{d} = \frac{f_t}{d^2}
\]

\[
T = \frac{\pi}{16} x ft x d^3
\]

Twisting moment, \( T \) can be obtained from

\[
P = \frac{2\pi NT}{60}
\]

(5)

Where, \( N \) = speed of shaft in rpm

Since it is operated by a belt drive,

\[
T = (T_1 - T_2)R
\]

(6)

Where \( T_1 \) and \( T_2 \) are tensions on the tight and slack side of the belt respectively

\( R \) = radius of pulley

**ii. Shaft subjected to bending moment only**

Bending equation can be derived from

\[
\frac{M}{I} = \frac{f_b}{y}
\]

(7)

Where,
- \( M \) = bending moment
- \( I \) = moment of merits of cross-sectional area of the shaft about axis of rotation
- \( f_b \) = bending stress,
- \( y \) = distance from neutral axis to outermost fibre.

\[
I = \frac{\pi d^4}{64}
\]

\[
M = \frac{\pi f_b d^3}{32}
\]

**Determination of power**

Power required for decorticating is given by:

\[
P = T \omega
\]

(8)
Power transmission by belt

Driving force is given by \( F = T_1 - T_2 \)

Power transmitted is given by: \( P = Fv = (T_1 - T_2)v \)

Where, \( T_1 = \) Tension in the tight side in N
\( T_2 = \) Tension in the slack side in N
\( v = \) Velocity of belt in m/s

Torque exerted on driving pulley, is given by \( (T_1 - T_2)r^2 \)

Centrifugal Tension \( T_c \), is given by, \( T_c = m\nu^2 \)

Where, \( m = \) mass of belt per length,
\( \nu = \) velocity of belt,
Tension on tight side of belt, \( T_1 = T - T_c \)

**Determination of the length of belts**

The length of belt of any machine is calculated from the formula below

\[
L = 2C + \pi \left( \frac{PD_1 + PD_2}{2} + \frac{PD_1 + PD_2}{4C} \right)
\]

Where \( L = \) Length of belt
\( PD_1 = \) Pitch diameter of big pulley
\( PD_2 = \) Pitch diameter of small pulley
\( C = \) Center distance between the pulleys

**Spikes on shaft of cylinder**

Ahuja and Sharma (1989) established spikes spacing for manually operated bambara nut decorticator at 40-45mm. In this design work, one legged spike teeth of 80mm x 120mm spacing was used. The spikes is made up of mild steel with height \( h = 47.63\text{mm} \).

Diameter of spikes = 2.5mm
Length = 40mm

**Moisture content**

Moisture content of Bambara nut was obtained using the oven dry method at a temperature of 1350 and was calculated using the expression below:

\[
M_c = \frac{(M_1 - M_2) \times 100\%}{M_1} \quad (ASAE 1983)
\]

Where \( M_c = \) Moisture content of Bambara nut
\( M_1 = \) Mass of wet Bambara nut
\( M_2 = \) Mass of oven dried Bambara nut
Table 1: Average moisture content of Bambara nut

<table>
<thead>
<tr>
<th>S/N</th>
<th>Moisture Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8.5</td>
</tr>
<tr>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>3</td>
<td>7.5</td>
</tr>
<tr>
<td>Average</td>
<td>8.3</td>
</tr>
</tbody>
</table>

The moisture content was used to determine the level of dryness of the sample.

**Determination of machine performance**

a) The performance of the machine was determined at only one moisture content level of 8.3% wet basis
b) Only one variety of bambara nut (White eyed) was used for the test.
C) The machine is operated by a 1.9 horsepower electric motor was switched-on and one hundred kilogram of the Bambara nut sample was weighed and fed into the machine through the hopper. The decorticated nut passes through the holes of the concave unto a stream of air generated by the fan. The air blows the decorticated shells of the nuts while the decorticated seeds and undecorticated nut are collected at the seed outlet. The decortications was completed in thirty minutes. The procedure was repeated seven times and the following weights were taken and recorded in Table 2

<table>
<thead>
<tr>
<th>S/N</th>
<th>Duration of operation (min)</th>
<th>Number of Sampled Feed rate (kg/30min)</th>
<th>Fully Decorticated (Kg)</th>
<th>Decorticated broken seeds (Kg)</th>
<th>Undecorticated seeds (Kg)</th>
<th>Weight of winnowed shells (Wt)</th>
<th>Weight of Shells with seeds (Wts)</th>
<th>Total weight of shells (Wts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30min</td>
<td>1</td>
<td>87.0</td>
<td>5.0</td>
<td>2.0</td>
<td>4.5</td>
<td>1.0</td>
<td>6.0</td>
</tr>
<tr>
<td>2</td>
<td>30min</td>
<td>2</td>
<td>89.0</td>
<td>4.5</td>
<td>2.0</td>
<td>4.0</td>
<td>1.0</td>
<td>5.0</td>
</tr>
<tr>
<td>3</td>
<td>30min</td>
<td>3</td>
<td>90.0</td>
<td>3.9</td>
<td>3.1</td>
<td>3.0</td>
<td>1.0</td>
<td>4.0</td>
</tr>
<tr>
<td>4</td>
<td>30min</td>
<td>4</td>
<td>88.0</td>
<td>5.5</td>
<td>3.5</td>
<td>2.0</td>
<td>1.0</td>
<td>3.0</td>
</tr>
<tr>
<td>5</td>
<td>30min</td>
<td>5</td>
<td>88.0</td>
<td>6.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>4.0</td>
</tr>
<tr>
<td>6</td>
<td>30min</td>
<td>6</td>
<td>89.0</td>
<td>4.5</td>
<td>3.0</td>
<td>2.5</td>
<td>1.5</td>
<td>4.0</td>
</tr>
<tr>
<td>7</td>
<td>30min</td>
<td>8</td>
<td>87.0</td>
<td>5.0</td>
<td>3.0</td>
<td>3.5</td>
<td>2.5</td>
<td>6.0</td>
</tr>
</tbody>
</table>

i) weight of sample feed into the machine (WT)
ii) weight of fully decorticated seeds (W1)
iii) weight of fully shelled broken seeds (W2),
vi) Weight of undecorticated pods (W3)
vii) Weight of winnowed shells (Wws)
(viii) Total weight of shells (Wts)

The performance was calculated on the basis of the following indices:

Decorticating efficiency, $\eta_d = \left(\frac{W_1 + W_2}{W_T}\right) \times 100\%$ (Atiku, 2004) (14)

Percentage Undecorticated $P_u = \left(\frac{W_4}{W_T}\right) \times 100\%$ (15)

Percentage damage $P_d = \left(\frac{W_2}{W_T}\right) \times 100\%$ (16)

Winnowing (cleaning) efficiency, $\eta_c = \left(\frac{W_{Wws}}{W_{Wts}}\right) \times 100\%$ (17)
Avec 30min 100 88.25 4.9 2.7 3.0 1.5 4.57

Decorticating efficiency, \( \eta_d = \left( \frac{W_1 + W_2}{W_T} \right) \times 100\% = \left( \frac{88.25 + 4.9}{100} \right) \times 100\% = 93.15\% \)

Percentage Undecorticated \( \text{Pu} = \frac{W_3}{W_T} \times 100\% = \left( \frac{2.7}{100} \right) \times 100\% = 2.7\% \)

Percentage of broken seed \( \text{Pd} = \frac{W_2}{W_T} \times 100\% = \left( \frac{4.9}{100} \right) \times 100\% = 4.9\% \)

Winnowing efficiency, \( = \left( \frac{W_{WS}}{W_{TS}} \right) \times 100\% = \left( \frac{3.9}{4.57} \right) \times 100\% = 85.33\% \)

Table 3: Summary of Result of performance Test of Bambara nut Decorticator.

<table>
<thead>
<tr>
<th>S/N</th>
<th>Bambara nut</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Decorticating efficiency</td>
</tr>
<tr>
<td>2</td>
<td>Un-decorticated nut</td>
</tr>
<tr>
<td>3</td>
<td>Cracked and broken nut</td>
</tr>
<tr>
<td>4</td>
<td>Cleaning efficiency</td>
</tr>
<tr>
<td>5</td>
<td>Power requirement</td>
</tr>
<tr>
<td>6</td>
<td>Moisture content</td>
</tr>
<tr>
<td>7</td>
<td>Input capacity kg/30min</td>
</tr>
<tr>
<td>8</td>
<td>Decorticating speed</td>
</tr>
</tbody>
</table>

**Results and Discussion**

The machine was only subjected to preliminary test as it could not be fully evaluated. The moisture content of 8.3% was used which gave a decorticating efficiency of about 93%. This is similar to the result obtained by Yusuf and Suleiman (2004) who using a moisture content of 9.4% got a shelling efficiency of 95% in the performance evaluation of a Bambara groundnut Sheller. Similarly, the winnowing or cleaning efficiency of 85% is close to the 87% obtained by Yusuf and Suleiman 2004, the concave clearance though adjustable was set at about 27cm as Atiku et al recorded a maximum pod diameter of 20.16cm. Table 2 gives the summary of the test result of the machine.

**Conclusion**

Bambara nut decorticator was developed and its performance tested. The results obtained as presented in tables 2 and 3 gave a decorticating efficiency of 93%, and cleaning efficiency of 95% .This show good performance, The machine has very low figures of 2.7% undecorticated pods and 4.9% broken seeds indicating good performance though improvement of the machine can further reduce these figures and so the purpose for the design was achieved. Commercialization of this machine will increase bambara nut production in the country.

It is recommended that the machine be statically evaluated by varying parameters such as moisture content, cylinder speed, concave-cylinder - clearance, feed rate and size of sieve holes to obtain the best performance of the machine..

**Reference**


