Development and Evaluation of a Melon Shelling and Cleaning Machine

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Abstract
Melon seed is very rich in protein and forms an important ingredient in Nigerian soups (Egusi) and vegetable oil industry. The drudgery involved in the manual shelling of the seeds has discouraged the mass production and commercialization of the crop and this necessitates the development and evaluation of a motorized operated melon shelling machine using impact method. Relevant physical properties of the seeds determined were moisture content, size, angle of repose, weight and the terminal velocity. Tests on the sheller were carried out using the main cultivar of melon (Bara) cultivated in Nigeria. The sheller comprises of the hopper which contains the unshelled melon seeds and is opened directly to the shelling chamber. The shelling chamber comprises of the disc and the rotor. The inner part of the chamber is lined with tiny metal rods to give it a rough surface. Flat metal bars are welded around the concave (rotor) at an angle of 45°. The concave is attached directly to a 2-horsepower electric motor which drives it in an anticlockwise direction to shell the melon seeds. The shelled melon seeds and the cotyledon fall directly into the cleaning chamber where an installed fan blow away the chaff and the cotyledons are collected directly through an opening below the shelling chamber. The sheller was constructed from locally available materials and its operation does not require any special skills. Tests were carried out at speeds of 750, 950, 1200 rpm and moisture contents of 7% and 10% (WB). Analysis of Variance (ANOVA) at $P \leq 0.05$ and $P \leq 0.01$ was used to determine if the moisture content of melon seeds and the rotation of the shelling unit had any significant effect on the shelling capacity, cleaning capacity and the efficiency of the shelling unit. The results of the analysis showed that increase in the speed of the shelling unit increases the shelling and cleaning capacities of the sheller. However, breakages of the shelled melon seeds also increase with an increase in the speed of the shelling unit. When the moisture content of the melon seeds was increased from 7% – 10% there was drastic reduction in the amount of broken seeds from 95% to 3%. The shelling capacity was reduced from 148kg/h to 145kg/h at a concave speed of 1200 rpm, the cleaning capacity also reduced from 52kg/h to 39kg/h at a concave speed of 750 rpm. It could be concluded that melon seeds should not be shelled at a moisture content less than 10% and that the speed of shelling should be about 950 rpm. The efficiency of the sheller is about 90%. The sheller performed satisfactorily and is suitable for domestic and commercial shelling of melon seeds. This will encourage the industrialization of vegetable oil gotten from melon seed processing in Nigeria

Keywords: design, construction, testing; melon, seeds, sheller

INTRODUCTION
protein (Bankole and Joda, 2004). Analysis made on melon seeds by Ajilola et al. (1990) indicated that melon seeds consist about 50% oil by weight, 37.4% protein, 2.6% fibre, 3.6% ash and 6.4% moisture. Immature fruits of some types of melon are often cooked as vegetables. Matured seeds are sometimes roasted and eaten. Processing of melon include fermentation, coring, washing, drying, shelling and oil extraction. Traditional method of shelling melon is slow, time consuming, tedious, inefficient and involve drudgery, thus limiting the availability of the product in the market. This has given concern to scientist and researchers in the recent past, particularly since women are the major processors of the melon especially at shelling stage (Olayiwole, 1987). There has been no interest in the industrialization of oil extraction from melon. This is because melon seed shelling and cleaning is very tedious and time consuming. The drudgery associated with melon seed processing before its end use influences to a greater extent its cultivation and cost. Despite the large productivity and nutritional potentials of melon seeds, there have been a hindrance to the industrialization of oil gotten from this crop because of the drudgery associated with shelling of the melon seed. Though there have been some development in the mechanization of melon (egusi) shelling machines, the machines are unattractive to local farmers because of their sophistication and low output. The locally fabricated melon shelling machines are not available in the
market and tests conducted on the machines show that their efficiencies are not more than 30%. Some of the locally developed and fabricated machines are those of Odigboh (1978), Obienwe (2002), Rotimi (2006) and Olusegun and Adekunle (2008). The aim of this work is to develop a melon shelling and cleaning machine that can effectively shell and clean the main type of melon (Bara) found in Nigeria through electric powered operation, without damaging the cotyledon either through breakage or crushing, at an affordable price using local available materials.

Description and Operation of the Sheller

The major components of the sheller are the hopper, the shelling chamber and the cleaning chamber. The hopper is made up of four welded metal sheets slanting towards an opening to form a trapezium. It has two openings. The larger upper opening is for introducing the melon seeds into the sheller while the smaller lower opening connects the hopper to the shelling chamber. The shelling chamber consists of the concave and the cylinder (convex), which is powered by an electric motor. The concave is made from mild steel and the inner part of the drum is lined with tinny metal rods, while the cylinder is lined with flat metal blades. The cleaning chamber is made of galvanized mild steel plate folded to form a pipe. A regulated fan is installed at one end of the pipe to supply air to separate the chaff from the cotyledon after shelling. The frame is the support on which the whole unit rest. The pictorial view and the complete assembly drawing of the machine are presented as in Fig. 1a and 1b.

The sheller employs the principle of energy absorption by the melon seeds, as a result of collision between the seeds and the stationary wall of the drum and this causes the cracking and removal of the husk from the seed. Unshelled melon seeds are fed into the hopper of the sheller. When the sheller attains a suitable speed of about 950rpm, the seed control device is opened to allow the seeds to fall directly into the shelling chamber. The melon seeds which are dropped into the shelling chamber from the hopper move anticlockwise in the space between the vaned rotating disc and the rough stationary drum. Since the average thickness of melon seeds is 2.5mm, the seeds will tend to move in a single row. The rotation of the impeller causes the removal of the coat from the cotyledon of the seeds as they rub against the rough surface of the fixed wall of the drum. The chaff and the cotyledon fall by gravity into the cleaning chamber of the sheller. A regulated fan installed in the chamber blow off the chaff and the cotyledons fall by gravity and are collected at the seed discharge unit of the sheller. The air velocity in the cleaning chamber must be less than the terminal velocity of the melon seed.
MATERIALS AND METHODS
The performance of the sheller was evaluated. Using melon seeds (Bara) whose properties were determined to know its characteristic behaviour and physical properties. The length, width, weight, angle of repose and the terminal velocity of melon seeds were determined. The machine was constructed with the locally available materials such as mild steel and plastic materials. The shelling and cleaning efficiencies of the machine at three different impeller speeds and two different moisture contents (WB) were determined. The effect of speed and moisture content on melon seed shelling was evaluated. ANOVA $P \leq 0.05$ and $P \leq 0.01$ was used to determine if impeller speeds of 750, 950, 1200rpm and moisture content of 7% and 10% had significant effect on the shelling, cleaning capacity and breakage of the melon seeds during shelling.

Terminal Velocity
Pneumatic separation of grains involves the separation of foreign materials from the grain with the aid of air stream. The air is made to pass through the disposed material to effect their separation. The design of fan for effective grain cleaning takes advantage of the variation in the aerodynamic properties of the grain (Ogunlowo and Ademosun, 1990). The terminal velocity of the shelled seeds and chaff was determined as follows:

$$Mg = \frac{1}{2} \rho V_t^2 C_d A$$ \hspace{1cm} (1)

Where:
- $M$ = mass of the object (kg)
- $g$ = gravitational acceleration (m/s$^2$)
- $C_d$ = drag coefficient
- $\rho$ = air density (kg/m$^3$)
- $A$ = projected area (m$^2$)
- $V_t$ = terminal velocity (m/s)

Power Requirement
An electric motor was used to operate the sheller. The sheller was tested at a maximum speed of 1200rpm, but for effective shelling operation the speed of 950rpm is recommended (Olusegun and Adekunle 2003).

$$P = T \times \omega$$ \hspace{1cm} (2)

Where $T$ = Torque
- $\omega$ = Speed in radians
  $$\omega = \frac{2 \pi \times N}{60}$$ \hspace{1cm} (3)
  $N$ = number of rotor revolution per minute
  $r$ = radius of shelling disc

Therefore,

$$P = \frac{\pi T}{r}$$ \hspace{1cm} (4)

Construction of the Sheller
Flat metal bars of 105mm length were welded at an angle of 45$^\circ$ along the diameter of the rotor, which form the vanes on the rotating cylinder. Metal rods of gauge 12 thickness were welded along the walls of the fixed drum to form the spikes. A 600mm galvanized mild steel plate was folded to form a pipe to house the fan. An opening of 225mm was made below the pipe to allow the seed to be collected in a container. The chaff of the melon seeds are blown by air current from a regulated fan to fall outside the pipe. Mild steel plate was used to cover the top of the supporting frame. A hopper was attached to a 190mm diameter opening cut on the fixed drum. Fixed beneath the opening of the hopper is the feed metering metal flap which controls the feed rate. An electric motor of 2hp is mounted on an angle iron at the left side of the frame to provide the required power. Electric cable is connected from the motor to the power source which is either a generator or electricity power socket.

Performance Evaluation of the Sheller
The performance evaluation of the melon sheller was carried out with a 2-horsepower electric motor, using melon seeds of various quantities. The unshelled melon seeds at moisture content of 7% was first used to shell at three different speeds of 750, 950 and 1200 rpm of the cylinder. The second sample of melon seeds was sprinkled with water and partially dried with natural air for 10 minutes. This made the skin coat to become slightly softened and the cotyledon was easier to detach from the shell, thus making shelling more efficient (Olusegun et al., 2008). The moisture content of the melon seeds that were sprinkled with water and dried for 10 minutes was found to be 10%. This was used for the second test. The number of seed shelled and unbroken, shelled but broken, partially shelled and unbroken, partially shelled but broken and the number of seeds unshelled were counted separately after shelling operation. The quantity of chaff blown by the fan was also collected and weighed at the different speeds of 750, 950 and 1200 of the sheller.

The number of seeds in sample is represented as $N_s$, number of seeds shelled and unbroken as $N_1$, number of seeds shelled but broken as $N_2$, number of seeds partially shelled and unbroken as $N_3$, number of seeds partially shelled but broken as $N_4$ and number of seeds unshelled as $N_5$ (Odigboh, 1978). The shelling capacity of the machine was calculated as the weight of the sample shelled per unit time.

Shelling capacity = $\frac{W}{t_1}$ kg/h \hspace{1cm} (5)

The cleaning capacity is the quantity of seeds cleaned per unit time = $\frac{W}{t_2}$ kg/h \hspace{1cm} (6)

Shelling efficiency
$$E_s(\%) = \frac{(100X_s)}{(X_s + X_c)}$$ \hspace{1cm} (7)

Cleaning efficiency
$$E_c(\%) = \frac{(100X_c)}{(X_d + X_c)}$$ \hspace{1cm} (8)
Where;
\[ X_d = \text{weight of seeds received at the seed outlet} \]
\[ X_b = \text{weight of chaff received at the seed outlet} \]
\[ X_c = \text{weight of grain received at chaff outlet} \]
\[ X_d = \text{weight of seeds received at chaff outlet} \]

Source: Nigerian Industrial Standard (1997)

The fraction of melon seeds completely shelled
\[ \frac{N_d}{N_o} \times 100 \]  
(9)

Fraction of seeds partially shelled
\[ \frac{N_p}{N_o} \times 100 \]  
(10)

Fraction of seeds unshelled
\[ \frac{N_u}{N_o} \times 100 \]  
(11)

(Odigboh, 1978)

**Experimental Design and Statistical Analysis**

The experimental design for the statistical analysis (Obi, 1995) follows a 2-treatment effect (moisture content and shaft speed) in a split-plot factorial design with RCBD (Randomized Complete Block Design) involving a 2-way classification. The experimental unit comprises 2 factors (two varieties) in each of the three levels of the shaft speed giving 6-treatment combinations for the three different experiments as follows:

i) shaft speed (750 rpm) versus moisture content
ii) shaft speed (950 rpm) versus moisture content
iii) shaft speed (12000 rpm) versus moisture content

The moisture content has two levels while the shaft speed has three levels. The moisture content separately forms the levels for factor A while the shaft speed in any of the three combinations forms the levels of factor B. On the whole the analysis studied three different operations of shelling capacity, cleaning capacity and percentage of shelling at P ≤ 0.05 and P ≤ 0.01

**RESULTS**

Table 1 is a summary of measured physical properties of melon seeds (Bara). The average performance data of the sheller at moisture content of 7% and 10% and cylinder speeds of 750, 950 and 1200rpm are shown in table 2. The performance indices of the sheller are given in table 3. Tables 4, 5 and 6 are the analysis of variance (ANOVA) for shelling capacity, cleaning capacity and efficiency of the sheller respectively.

The calculated power requirement and terminal were 2hp and 6.4m/s respectively

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Unshelled Seeds</th>
<th>Shelled + Cotyledon</th>
<th>Shelled Seed</th>
<th>Chaff</th>
</tr>
</thead>
<tbody>
<tr>
<td>7% m.c. Angle of repose (θ) (deg)</td>
<td>35.7</td>
<td>40.5</td>
<td>43.3</td>
<td>-</td>
</tr>
<tr>
<td>Coefficient of friction (θ) (deg)</td>
<td>0.72</td>
<td>0.85</td>
<td>0.95</td>
<td>-</td>
</tr>
<tr>
<td>10% m.c. Angle of repose (θ) (deg)</td>
<td>36</td>
<td>45.8</td>
<td>44</td>
<td>-</td>
</tr>
<tr>
<td>Coefficient of friction (θ) (deg)</td>
<td>0.73</td>
<td>1.03</td>
<td>0.97</td>
<td>-</td>
</tr>
<tr>
<td>Weight of one seed (g)</td>
<td>0.124</td>
<td>0.124</td>
<td>0.022</td>
<td>0.0221</td>
</tr>
<tr>
<td>Length of seed (mm)</td>
<td>12.4</td>
<td>-</td>
<td>11.0</td>
<td>-</td>
</tr>
<tr>
<td>Width of seed (mm)</td>
<td>7.6</td>
<td>-</td>
<td>6.5</td>
<td>-</td>
</tr>
<tr>
<td>Thickness of seed (mm)</td>
<td>2.5</td>
<td>-</td>
<td>1.8</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 2: The Average Performance Data of the Melon Shelling Machine at Two Different Moisture Contents of 7% and 10% at 3 Different Speeds of 750, 950 and 1200 rpm.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>7% m.c.</th>
<th>10% m.c.</th>
</tr>
</thead>
<tbody>
<tr>
<td>750</td>
<td>950</td>
<td>1200</td>
</tr>
<tr>
<td>weight of unshelled seeds (g)</td>
<td>7.7</td>
<td>7.1</td>
</tr>
<tr>
<td>Time to complete shelling t₁ (s)</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Time to complete shifting t₂ (s)</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>No. of seeds in sample (N₀)</td>
<td>578.5</td>
<td>575</td>
</tr>
<tr>
<td>No. of seeds shelled and unbroken (N₁)</td>
<td>36.5</td>
<td>17</td>
</tr>
<tr>
<td>No. of seeds shelled but broken (N₂)</td>
<td>277</td>
<td>244</td>
</tr>
<tr>
<td>No. of seeds partly shelled and unbroken (N₃)</td>
<td>29</td>
<td>6</td>
</tr>
<tr>
<td>No. of seeds partly shelled but broken (N₄)</td>
<td>217</td>
<td>305</td>
</tr>
<tr>
<td>No. of seeds unshelled (N₅)</td>
<td>23</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 3: Performance Indices of the Shelling Machine

<table>
<thead>
<tr>
<th>Parameters</th>
<th>7%</th>
<th>10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shellings Capacity (kg/h)</td>
<td>65</td>
<td>128</td>
</tr>
<tr>
<td>Fully shelled (%)</td>
<td>54</td>
<td>45</td>
</tr>
<tr>
<td>Partly shelled (%)</td>
<td>42</td>
<td>54</td>
</tr>
<tr>
<td>Unshelled (%)</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Broken (%)</td>
<td>85</td>
<td>95</td>
</tr>
<tr>
<td>Cleaning Capacity (kg/h)</td>
<td>52</td>
<td>85</td>
</tr>
<tr>
<td>Efficiency of the Sheller (%)</td>
<td>96</td>
<td>98</td>
</tr>
</tbody>
</table>
The parameters studied were the percentage number of shelled and unshelled melon seeds, shells broken but unshelled seeds and the partially shelled melon seeds at 7% and 10% wb and concave speeds of 750, 950 and 1200 rpm. At concave speeds of 750, 950 and 1200 rpm, and moisture content of 7% wb, the calculated shelling capacity of the sheller were 65, 128 and 148kg/h respectively. The cleaning capacity was 52kg/h, 85kg/h and 85kg/h respectively. When the moisture content of the melon seeds was increased to 10% wb by sprinkling the seeds with water and allowing it to dry by natural air, the shelling capacity became 53kg/h, 88kg/h and 145kg/h for the concave speeds of 750, 950 and 1200 rpm respectively (Table 3). At 10% moisture content the cleaning capacity reduced from 53kg/h to 39kg/h at the speed of 750rpm and from 85kg/h to 66kg/h at the speed of 950rpm. However, at 1200rpm the cleaning capacity increased from 85kg/h to 109kg/h (Table 3).

The fraction of melon seeds fully shelled by the sheller when the moisture content of the melon seeds remained at 7% wb using the concave speeds of 750, 950 and 1200rpm were 54%, 45% and 45%. The percentage of seeds broken were 85, 95 and 97%, the number of partially shelled seeds were 42%, 54% and 54%. The percentage number of melon seeds that were unshelled were 3.9%, 1% and 0.3%. The 97% breakage of the melon seeds seems too high for the sheller to operate at these speeds when the melon seeds moisture content was 7% wb. Although all the melon seeds fed into the sheller at the moisture content of 7% were shelled, there was high mechanical damage of the seeds which leads to deterioration of the seeds as was observed by Shittu et al. (2002).

When the moisture content of the melon seeds was raised to 10% wb using the same concave speeds of 750, 950 and 1200rpm the percentage number of broken seeds reduced to 0.8%, 2.3% and 8.9%. The results of the studies were further subjected to statistical analysis to know how each of the parameters affects the shelling, cleaning capacity and the efficiency of the sheller at P ≤ 0.01 and P ≤ 0.05 levels of significance.

From Table 4, blocking the experiment values are not significant at any levels of probability while the mean values of moisture content showed very significant effect on the shelling capacity of the sheller at P < 0.01. This observation was true with the mean values of the shaft speed showing very significant effect at both levels of probability. The interaction of the two factors was also found to be very significant (P < 0.01).

Table 5 shows that the mean values of moisture content and shaft speed are both statistically significant in the analysis of variance (ANOVA). While the moisture content showed very significant (P< 0.01) effect, the same trend was also shown by the mean values of shaft speed indicating very significant effect at 1 % percent level of probability. The interaction effect was also found to be of highly significant effect (P < 0.01).
Similarly, Table 6 indicated that both factors and their interaction were significant in the same magnitude.

**Cost of Production of the Melon Sheller**

Material cost = ₦ 12,050  
Labour cost = ₦ 12,000  
Production cost = Material cost + Labour cost  
= ₦ 12,050 +  ₦ 12,000  
=  ₦ 24,050  
Contingency allowance = 10% production cost = ₦ 2,450  
Total production cost =  ₦ 24,050 +  ₦ 2,450  
=  ₦ 26,500

**CONCLUSION**

It can be concluded that:

i. the sheller can be used for the commercial shelling of melon seeds to reduce the drudgery associated with its shelling,

ii. the efficiency of the machine increases with the concave speed;

iii. increase of concave speed at all moisture contents of melon seeds increase the quantity of damaged melon seeds.

iv. moisture content of melon seeds had significant effects on the breakage of melon seeds during shelling operation.

**REFERENCES**


