Design and Performance Evaluation of a Cassava Chipping Machine

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Abstract

Cassava, Manihot esculenta Crantz, is a major staple food in tropical countries. Nigeria is the world’s largest producer of cassava, with the potential for higher production. Cassava tubers cannot be stored for long in the fresh form because they are highly perishable. Thus, it is necessary to develop other means of utilizing the surpluses and hence the design and evaluation of a chipping machine. The developed cassava chipping machine was evaluated by varying the weights of sample fed into it and observations made. The average feed time was 0.87mins (52 seconds) while the average chipping time was 0.91mins (55 seconds). The average feed rate was also observed to be 7.74kg/min (464.4kg/hr) with average chipping rate of 7.36 kg/min (441.71 kg/hr). A mean loss of 4.88% of total sample was also observed. Chipping efficiency was an average of 96.81%. This is far more than can be achieved by manual processing and is expected to aid processing of cassava in rural communities given that it is not dependent on electricity. Chipped cassava is also easier to dry and store for further processing.

Keywords: chipping, cassava, efficiency, feed rate, chipping rate

INTRODUCTION
Cassava, Manihot esculanta crantz, a dicotyledonous perennial plant belonging to the botanonical family Euphorbiaceae is of importance in many developing tropical economies such as parts of Africa, West India, Brazil, Malagasy, Indonesia, Philippines, Malay, Thailand and China (Ajibola, 2000). In tropical Africa, cassava and other tubers like yam form the most staple food crops which are the main source of carbohydrate in the diets of this region. Its high yield in poor soil and the ability to stay in the soil for long periods after maturity make cassava an important food security crop in low-income countries. Cassava is an important food crop in the tropics and a major carbohydrate staple consumed in various forms by humans.

It contributes significantly to the nutrition and livelihood of 800 million people and thousands of processors and traders around the world. It forms a base for a wide variety of fermented foods in Africa, Asia and Latin America and serves as raw material in the manufacture of processed foods, animal feed and industrial products [Balogopalan (2002), Aloy and Mings (2006), Taiwo (2006)]. Cassava tubers once harvested begin to deteriorate and cannot be stored for more than a few days. Thus, there is a need for rapid processing of the tubers into a more shelf stable form. Nigeria currently is the largest producer of cassava in the world. Processing the tubers into dried chips reduced the moisture content to a very low level and reduced postharvest losses [IITA (1990), Ugwu (1996)].

Cassava can be dried naturally in the sun or artificially in the oven [FIIRO, (2005), Irinkoyenikan et al (2008)] to produce dried cassava chips. Chips are commonly used in animal feed production; however several studies have shown that cassava chips can be reconstituted and converted to desired products such as starch, flour [Famokunwa (1994), Olomo and Ajibola (2006)], fufu and garri. Cassava being extremely perishable, harvested tubers must be processed to curb post harvest losses (Davies, 1991). Cassava processing is constrained by a lack of steady supply of tubers throughout the year, high transport cost to processing centres, inadequate processing equipment and low returns from small-scale processing [RTEP, (2003), Asiedu, (1989)]. World production of cassava is around 250 million tonnes (Mt) a year with Africa contributing to more than half of the global supply. Nigeria at around a figure of 45 Mt produces more than a third of African production and is also the largest world producer by far (UNCTAD, 2013).

With this statistics, Nigeria produces a third more than Brazil and almost double the production capacity of Thailand and Indonesia but despite this, Nigeria is not an active participant in the International markets when compared with these countries. Although, the cassava crop has relatively few problems in production, its problem seems to multiply at the post-harvest stage. Storage of fresh tuber, mechanization of harvesting and mechanized processing are areas which pose the greatest challenges. The processing of cassava tubers for...
industrial or human use involves different operations of which chipping is an important one when exports are considered. The study was carried out with the aim of producing chips with average size below 20mm. The samples used were limited to freshly harvested tubers with moisture content within the range of 68.5 – 81.2% wet basis.

**Design Principles**

The design principles employed for the development of the machine are as follows:

- The dropping (by gravity) of the peeled cassava tubers from the loading platform through the inclined partitioned hopper to the rotating chipping plate.
- The continuous chipping force (shear force) imparted on the tubers by the sharp expanded edges on the chipping plate. This continuous shear force is made possible by the rotation of shaft, bearings, pulleys and belt.

**Description of Machine**

The design drawing and photograph of machine are shown in Fig 1 and 2. The machine consists of the following components:

- Loading platform
- Partitioned inclined hopper
- Chipping plate
- Expanded cutting edges (knives)
- Transmission shaft
- Bearings
- Pulleys
- Internal combustion (petrol) engine
- V-belt
- Structural frame
- Cover plates
- Chip outlet channel (chut)
- Bolts and nuts
- Adapter
- Screw and rivets
- Keys and key sets
- Re-enforcement webs

The loading platform is made spacious enough so as to contain large quantity of peeled cassava. The inclined inlet hopper has three partitions for different sizes of peeled cassava tubers. The inclined hopper is positioned at one end of the loading platform. The incline hopper is channeled to the expandable cutting edges on the re-enforced circular cutting disc. The cutting edges are two in number and are positioned at an angle of 180° opposite each other. The re-enforced circular disc is connected at the center with the transmission shaft. The transmission shat is mounted on two bearings. The other end of the transmission shaft is connected to a large pulley (flywheel). The fly wheel is connected to the pulley on the shaft of the I.C engine via a v-belt. The cover plates are used to shield the dynamic components from interference and for good aesthetics. All the components systematically arranged are carried on a rigid structural framework.

**Principle of Operation**

The cassava tubers to be chipped are carried on the loading platform. The I.C engine provides the primary motion required to power the machine. The rotation and torque from the I.C engine is transmitted to cutting discs via the pulley, belt, shaft and bearings. During machine operation, the cassava tubers are channeled to enter the partitions on the inclined hopper. They now slide down to the rotating chipping plate by gravity. At the rotating plate, the expanded cutting edges act on them, cutting them to the required thickness (size). The thickness of the chip is equal to the gap between the expanded cutting edges on the chipping plate. The chips drop by gravity from the chipping plate to the chip exit channel into a receiver.

**Advantages**

1. The machine is simple to operate and can be made mobile by incorporating rollers
2. It requires only one operator
3. Materials of construction are all locally sourced
4. A production cost of one hundred and fifty thousand Naira (₦150,000) an equivalent of ($765.31) at the rate of ₦196/$ is within the reach of rural farmers.
5. The machine can be powered by either an I.C. engine or an electric motor.

The dimensions of the machine are as follows; Overall length = 800 mm, Overall width = 650 mm, overall height = 1020 mm, the diameter of the reinforced cutting plate = 400 mm.
MATERIALS AND METHODS
Sample Preparation
Freshly harvested cassava tubers were obtained from Akwata Market in Enugu State, Nigeria. They were then peeled using table knives and placed in a basin. 35 kg of samples divided into weights of 3, 5, 7, 9 and 11 kg were collected and stored in plastic containers. These were fed into the fabricated machine and preselected parameters were observed and recorded. The experiment was repeated twice in each case and average values were recorded and analyzed.

RESULTS
Table 1 gives the data collected from the experimental runs and it is presented in appendix 1. The design drawings are shown in appendix 2.

![Fig 1 (a&b): Photograph of designed machine](image)

![Fig 2 (a & b): Samples before and after chipping](image)

![Fig 3: Sample weights versus average feed time](image)
Fig 3 showed that as weight increased, feed time increased with a slight drop at 9kg. The mathematical model which best describes this relationship is a third order polynomial with its equation and $R^2$ value given in equation 1. The plot (Fig.4) for sample weight versus chipping time showed similar trend to that of Fig 3. Its best fit equation is given in equation 2 which is also a polynomial function.

\[ Y = 0.003x^3 - 0.079x^2 + 0.618x - 0.747 \quad (R^2 = 0.965) \]  
\[ (1) \]

Fig 4: Sample weights versus average chipping time 
\[ Y = 0.003x^3 - 0.078x^2 + 0.601x - 0.660 \quad (R^2 = 0.973) \]  
\[ (2) \]

Combining both plots (Fig 5) shows the similarities of both feeding and chipping operations on the designed machine and how the sample weights affected them. It can be seen that chipping time was slightly higher than feed time. This is expected as one happens before the other but their close values shows that the designed machine achieves chipping as soon as it is fed with material and gives an insight to its efficiency.

Fig 5: Sample weights versus average feed and chipping time

For feed rate and chipping rate, the paths of the plots are different from those of feed and chipping time. Fig 6, showed slight increase for the first three sample weights and then showed sharp increase after this. This trend was repeated in the plot of sample weights versus average chipping rate. Their best fit mathematical models are also third order polynomial equation with their $R^2$ values stated in equations 3 and 4.

\[ Y = -0.030x^3 + 0.633x^2 - 3.509x + 11.76 \quad (R^2 = 0.933) \]  
\[ (3) \]

Fig 6: Sample weights versus average feed rate

\[ Y = -0.027x^3 + 0.550x^2 - 2.872x + 10.02 \quad (R^2 = 0.949) \]  
\[ (4) \]

Fig 7: Sample weights versus average chipping rate

Combining both plots (Fig 8) shows the similarities of both feeding and chipping operations on the designed machine and how the sample weights affected them. It can be seen that chipping time was slightly higher than feed time. This is expected as one happens before the other but their close values shows that the designed machine achieves chipping as soon as it is fed with material and gives an insight to its efficiency.

Fig 8: Sample weights versus average feed and chipping rate
From Fig 8 it can be observed that the chipping rate was lower than the feed rate for all sample weights and this can be attributed to the fact that chipping only begins after feeding. The close values also give an indication on the effectiveness of chipping. Chipping efficiency was found to increase with increase in sample weight and also had third order polynomial as its best fit mathematical model. However, it was found to increase with increase in sample weight until 9kg after which it decreased. The average chipping rate of samples tested was 7.36kg/min.

\[ y = -0.009x^3 + 0.174x^2 - 0.835x + 97.45 \]

\[ R^2 = 0.994 \]

**CONCLUSION**

From the results obtained it can be seen that the average feed time for the 35kg of sample tested in sample sets of 3, 5, 7, 9 and 11kg is 0.87mins (52 seconds) while the average chipping time is 0.91mins (55 seconds). The average feed rate was also observed to be 7.74kg/min (464.4kg/hr) with average chipping rate of 7.36 kg/min (441.71 kg/hr). This means a loss of about 4.88% of total sample material was observed. This loss were sample material that were shredded into tiny bits or broken bits of tubers resulting from the chipping action of the cutting edge. The average chipping efficiency was found to be 96.81%. This is far better than what can be achieved by manual labour and greatly enhances the processing of cassava so that it can be dried and stored.

**REFERENCES**


Table 1: Average data Obtained from test runs

<table>
<thead>
<tr>
<th>Wt (kg)</th>
<th>Feed time (mins)</th>
<th>Chipping time (mins)</th>
<th>Feed rate (kg/min)</th>
<th>Chipping rate (kg/min)</th>
<th>Average Mass collected (kg)</th>
<th>Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>0.499</td>
<td>0.542</td>
<td>6.01</td>
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<td>2.888</td>
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<td>5</td>
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<td>6.64</td>
<td>6.35</td>
<td>4.826</td>
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<td>7</td>
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</tr>
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<td>97.03</td>
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</table>

(Source: Agulanna et al., 2014)