



DEVELOPMENT OF A MOTORIZED PARBOILED CASSAVA TUBER SHREDDING MACHINE

M.C. Ndukwu^a, D. Onyenwigwe

DEPARTMENT OF AGRICULTURAL AND BIO-RESOURCES ENGINEERING, MICHAEL OKPARA UNIVERSITY OF AGRICULTURE, UMUDIKE, P.M.B. 7267, UMUHIA, ABIA STATE, NIGERIA. ^a *Emails:* ndukwumcb@yahoo.com; ndukwumcu@gmail.com

Abstract

A prototype motorized cassava tuber-shredding machine was developed and evaluated. The machine performed well in the shredding of parboiled cassava tubers of NR87184 variety at moisture content of 63.5%. The efficiency ranges from 67.80% to 72.2% while the throughput ranges from 13.09 to 27.02kg/hr when operating at 100 rpm while at 50rpm, the efficiency of the machine range from 60% to 75.2% and throughput ranged from 11.37 to 21.41kg/hr. Generally, the steaming time affected the efficiency, throughput and the length of shreds. The optimum performance was shredding at a speed of 50rpm and steaming time of 10minutes, which gave a longer shred length of 76mm with a width of 2.18mm and efficiency of 75% but with a throughput of 21kg/hr. For optimum performance at 100rpm, throughput of 27.02kg/hr and efficiency of 70.3% was obtained at a boiling time of 10mins, with average shred length of 54mm and width of 2.16mm.

Keywords: cassava shredding, steaming time, shred length, shred width

1. Introduction

Cassava [*manihot esculenta*] originated in South America [1]. It is a shrub with an average height of 1.0 - 3.5m and has a palmate leaf formation [2]. The stem is the planting material from which it grows the root and shoots. Cassava produces bulky storage root with a heavy concentration of carbohydrate. Cassava is one of the most staple food crop grown in Africa because of its efficient cheap energy, year round availability, tolerance to extreme ecological stress and sustainability to present farming and food system in Africa. Of late, the importance of cassava has been realized, not only as high energy giving food but also as industrial raw material and animal feed mix. Traditionally, cassava roots after maturing is left in the ground and harvested when needed. This underground practice has many disadvantages because it makes land unavailable for further cultivation and quality of root diminishes. Cassava tubers are extremely perishable when harvested and begin to deteriorate within 40-48 hours. This deterioration is caused by physical changes and subsequently by rot and decay. Mechanical damage during harvesting and handling stages also renders it unsuitable for long term storage. Therefore, processing of cassava into a more suitable form is required for storage. Cassava roots traditionally are processed

by various methods such as soaking, sieving and dewatering to produce Fufu; peeling, grating and frying to produce Garri [3]; cutting and drying to produce chips; steaming and shredding with perforated metals to produce tapioca [4]. This method involves a lot of drudgery with a low throughput which reduces the market availability of the products [5]. Several equipments has been designed and produced for the processing of cassava into various products. Some of these equipments include peeling machine [6, 7, 8], cassava graters [9, 10], dewatering machines [11], garri fryers [12], pulverizing and sifting gari mash [13] and manual operated cassava shredding machine [14]. Traditionally, cassava tubers are shred with the help of hand knives or perforated metals or plastics and then dried under the sun [12]. However, this method is tedious and time consuming. Besides it leads to delayed drying and gelatinization of starch may occur. Therefore developing a motor driven cassava shredding machine will enhance large scale production of shredded cassava which is used as tapioca and animal feed.

The objective of this work is to develop and fabricate a motor driven cassava-shredding machine, which can be adopted locally to reduce drudgery and ease the problem of shredding in the local production of tapioca, which is a local delicacy.

Cassava shredding machines have been very scarce

in literature. Most of the existing ones are manually operated shredding machines [15]. Presented a series of cassava shredding machine, which are manually operated. The cassava-shredding machine consists of a shredding disc, a trapezoidal shaped hopper, and a conical shaped slot for passing the cassava into the chamber. The operator holds the cassava with one hand while he uses the other hand to rotate the disc through a sleeve attached to it. This is very tedious with low throughput.

2. Materials and Method

2.1. Design consideration

Engineering design has to do with the various activities that lead to proper and effective development of machines and engineering processes. In the design of the cassava shredder the following factors were considered

1. Higher capacity compared to traditional method of shredding cassava.
2. Reduction in drudgery associated with the traditional method of shredding cassava.
3. Reduction in drudgery associated with the hand driven cassava shredder
4. Strength of material should withstand the forces acting in the various component of the machine
5. Simplicity and flexibility of the machine should suit the targeted users
6. The inclination variable for the hopper was $0 - 35.5^\circ$ to the horizontal, which was the angle of repose on mild steel, determined in the laboratory for the peeled and parboiled cassava of the variety NR87184 harvested at one year old.

2.2. Machine features

i. Hopper

The hopper is made up of 1mm gauge mild steel iron sheet. It is trapezoidal in shape but with an extension that links it to the shredding chamber, hence allowing the flow of cassava tuber from the hopper into the shredding chamber. It is designed based on the angle of repose 35.5° of cassava on mild steel, determined for the peeled and parboiled cassava of the variety NR87184 harvested at one year old

ii. Frame

The frame is made up of a $30 \times 30 \times 5$ mm angle iron. The frame provides support for the entire assembly. It has a maximum length of 600mm, width of 600mm and height of 800mm

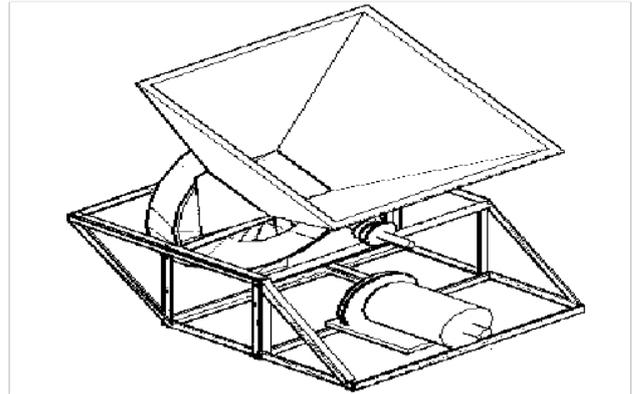


Figure 1: Isometric view of the developed cassava shredding machine.

iii. Shredding disc

It is a revolving circular blade held by an X-shaped flywheel for shredding cassava tubers. It contains openings or screen perforated from one side with 24mm diameter opening at the centre from where the shaft is passed to the flywheel. It has a thickness of 2mm and a diameter of 500mm.

iv. Shredding chamber

The shredding chamber is made up of a 1mm gauge mild steel iron sheet. It is circular in shape and houses the shredding disc. It has a diameter of 550mm.

v. orifice (collar)

The collar through which the cassava passes into the shredding chamber was casted. This is done to maintain the rigidity between the shredding disc and the cassava tuber as the shredding continues.

2.3. Description of the machine

The developed cassava shredding machine (figure 1-3) was fabricated and assembled at the engineering workshop of nearby NRCRI Umudike. The machine consists of the frame made up of an angle iron made up of $30 \text{mm} \times 30 \text{mm} \times 5 \text{mm}$ angle iron. This is to provide support for the machine assembly. The cassava tuber is fed through a hopper in the shape of a frustum of a pyramid made up of 1.5mm mild steel that is welded at an angle of curve (repose) to 2.5mm gauge casted orifice. The casted orifice opens up into the shredding chamber where the shredding disc is rotating. The shredding disc is made up of 1mm gauge galvanised steel with a circular shape, 500mm in diameter. The disc consists of opening perforated from one side to create the shredding action on the other side. The disc is held by a flywheel of 5mm thickness to prevent excessive gyration. The shaft made up of 24mm gauge mild steel was attached to the shredding disc and powered by a 0.18kW electric gear motor revolving at 27rpm with belt and pulley connections.

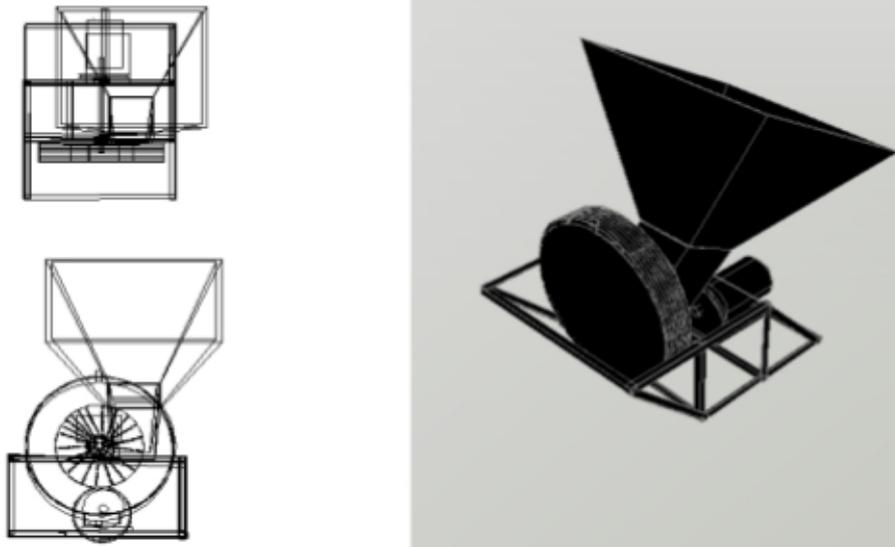


Figure 2: Orthographic view of the developed cassava shredding machine.



Figure 3: A student demonstrating the developed cassava shredding machine.

2.4. Machine component selection and design calculations

2.4.1. Shredding Speed of the disc

$$N_1 D_1 = N_2 D_p \tag{1}$$

Where, D_p = Diameter of pulley on the shredding shaft (mm) = 80, 160; D_1 = Diameter of motor pulley (mm) = 296; N_1 = Speed of motor (rpm) = 27rpm; N_2 = required shredding speed (rpm) = 100, 50

2.4.2. Shaft design

According to [12], shaft is used to transmit power from one place to another with members such as pulley mounted on it. The member along with the forces exerted on them causes the shaft to bend which

causes torsion and bending moment. In actual practice, shafts are subjected to fluctuating torque and bending moments. In order to design such shafts, the combined shock and fatigue factor must be taken into consideration for the computed twisting moment (T) and equivalent bending moment (M_e). Torque transmitted by the Shaft was given by [16]

$$T = \frac{P \times 60}{2\pi N} \tag{2}$$

T is the torque in Nm, N is the speed in rpm and P is the power transmitted in W: $P = 0.18\text{kW}$; $N = 100\text{rpm}$; $T = 169.64\text{Nm}$. Equivalent twisting moment is given by [16]

$$T_e = \sqrt{M^2 + T^2} \tag{3}$$

Where, T_e = twisting moment (Nm); M = maximum bending moment (Nm) was calculated as 10.15Nm; T = is the torque transmitted by shaft which was calculated as 169.64Nm.

Inserting the value of M into equation 3, gives T_e as 169.94Nm. The equivalent bending moment was calculated as (15);

$$T_e = \frac{\pi}{16} \times \delta \times d^3 \tag{4}$$

δ is the maximum allowable shear stress given as 42MPa for shafts with allowance for keyways [16] d is the diameter of the shaft, $d = 27.42\text{mm}$.

2.4.3. Other design data

Length of belt was given as [16]

$$L = 2C + \frac{\pi(D_1 + D_p)}{2} + \frac{(D_p - D_1)}{4C} \tag{5}$$

C is the centre distance of the two pulleys and C is calculated as 403.63mm; $L = 1.398\text{m}$, V-belt (A-type) having width of 13mm, thickness of 8mm and angle of groove of 34° . For belt transmission between two pulleys

$$\frac{T_1}{T_2} = e^{\mu\theta} \quad (6)$$

T_1 and T_2 is the tension on tight and loose sides. θ is the angle of lap and μ is a coefficient given as 0.3 [16]. The theoretical power requirement was given as

$$P = (T_1 - T_2)v \quad (7)$$

P was calculated as 0.124kW.

2.5. Performance test procedures

2.5.1. Sourcing and preparation of the test sample

A bulk sample of cassava tuber (NR87184 variety) was procured from the research farm of the National Root Crop Research institute Umudike Nigeria. The cassava tubers were examined to ascertain the quality. The cassava tuber was cleaned and washed of dirt and other physical contaminants. Some samples were collected to determine the initial moisture content. The cassava was grouped based on its length and intermediate diameter. The cassava tuber within the length range of 25-30cm with which forms the mode of the distribution was selected.

The machine was evaluated based on shredding speed, time, weight of completely shredded tuber, weight of uncompleted shredded tuber, at different steaming time at a constant rate of heat application. The cassava was peeled, washed and steamed with a gas cooker set at a constant position to maintain a constant rate of heat application before the shredding. This was done to simulate the local method of preparation of tapioca (Abacha), which is where this machine is targeted. The cassava tuber was removed every two minutes and immediately shredded to avoid gelatinization of the starch at a speed of 100 and 50rpm. Before the shredding, the machine was switched on and run on no load for 15minutes to enable the machine to stabilize.

The cassava tuber was fed through the hopper and a wooden stick was used to adjust the cassava tuber as the shredding continues. The stopwatch was used to time the shredding. This was completed in triplicate. The weight of the shredded and unshredded and the time of shredding were recorded and used in performance evaluation.

2.5.2. Performance criteria

The functional efficiency was defined as the percentage of the product output in terms of mass completely shredded cassava tuber to the material input.

$$E_s = \frac{m_s}{m_i} \times 100 \quad (8)$$

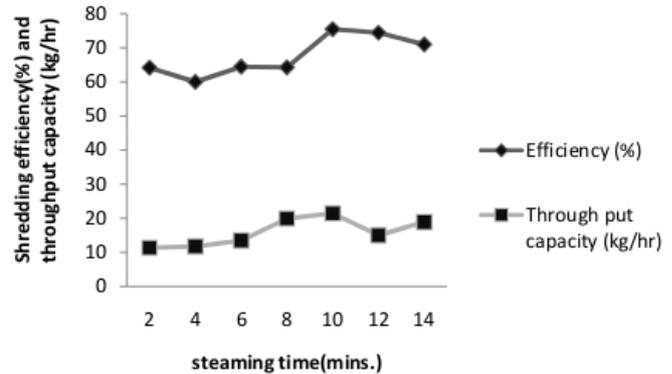


Figure 4: Evaluated Parameters for the Prototyped Motorized Cassava Tuber Shredding Machine at 50rpm.

E_s is functional efficiency, m_s is the weight of shredded cassava, m_i is the initial weight of cassava fed into the shredder. The throughput capacity was defined as the mass of tuber fed into the system and the time taken to completely leave the system.

$$T_c = \frac{W_s}{T} \quad (9)$$

W_s is the weight of tuber (kg), T is the time taken for shredding (hr), T_c is the throughput capacity (Kg/hr).

3. Result And Discussion

3.1. Shredding efficiency, through put capacity and operational speed of the shredder

The result of the test of the performance evaluation of the prototype motorized cassava shredding machine is shown in figures 4, 5 and 6 at different steaming time. The efficiency for the motorized cassava tuber shredding machine is also presented in figure 4 and 5 at different steaming time. The efficiency ranges from 67.80% to 72.2% at steaming time of 2-14 minutes, while the throughput capacity ranges from 13.09 to 27.02kg/hr for 100 rpm while for 50rpm, the efficiency of the machine range from 60% to 75.2% and throughput capacity ranges from 11.37 to 21.41kg/hr. However, when the speed of 100rpm and 50rpm is compared, the highest efficiency of 75.42% was obtained at a boiling time of 10mins for 50rpm also highest throughput capacity of 27.02kg/hr was obtained at a speed of 100rpm and boiling time of 10mins.

However when the quality of the shredded products is examined at different speeds, the speed of 50rpm gave a longer unbroken products on the average than 100rpm. For the two operational speeds, the length of shred increased as the steaming time increased as shown in figure 6. The cassava shredding machine can produce a cassava shred at an average length of 41 - 54mm at average width of 2 .16 to 3.48mm at a speed

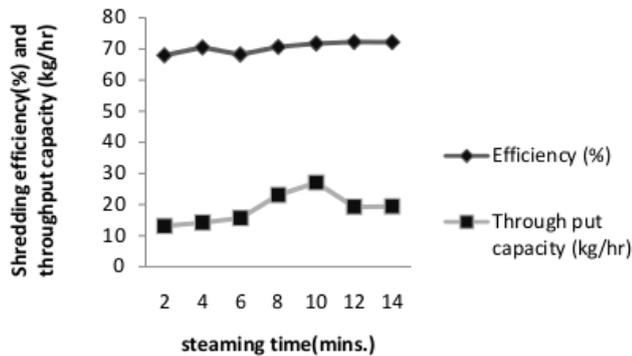


Figure 5: Evaluated Parameters for the Prototyped Motorized Cassava Tuber Shredding Machine at 100rpm.

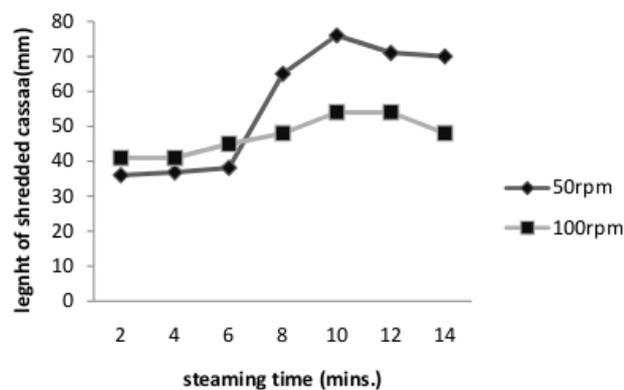


Figure 6: Tuber shredding length of the Machine at 50 and 100rpm.

of 100 rpm. However it can also produce a cassava shred, of length 36-76mm at average width of 2.0 to 3.50mm at a speed of 50 rpm.

Enquiries made from the local producers and consumers of the shredded cassava known as tapioca (abacha) which were the targeted user showed that the product is better and more costly when the strands are longer with a smaller width and dries faster. Therefore, for optimum performance at 50rpm, there should be a balance between the efficiency, throughput and the quality of the product. From the performance evaluation result, shredding at a speed of 50rpm and at a steaming time of 10minutes gave a longer shredding length of 76mm with a width of 2.18mm at efficiency of 75% but with a relatively lower throughput of 21kg/hr. Therefore shredding at 50rpm and steaming time of 10minutes gives the best performance. However for optimum performance at 100rpm, highest throughput of 27.02kg/hr and efficiency of 70.3% was obtained at a speed of 100rpm and boiling time of 10mins, with average shred length of 54mm and width of 2.16mm. The values above show a good performance for the motorized cassava-shredding machine.

4. Conclusion

The motorized cassava-shredding machine was evaluated. The cassava-shredding machine performed well in the shredding of parboiled cassava tubers of NR87184 variety at moisture content of 63.5%. The efficiency ranges from 67.80% to 72.2% while the throughput capacity ranges from 13.09 to 27.02kg/hr for 100 rpm while for 50rpm, the efficiency of the machine range from 60% to 75.2% and throughput capacity ranges from 11.37 to 21.41kg/hr. From the performance evaluation result, shredding at a speed of 50rpm and at a steaming time of 10minutes gave a longer shredding length of 76mm with a width of 2.18mm at efficiency of 75% but with a relatively lower throughput of 21kg/hr. However for optimum performance at 100rpm, highest throughput of 27.02kg/hr and efficiency of 70.3% was obtained at a speed of 100rpm and boiling time of 10mins, with average shred length of 54mm and width of 2.16mm. Generally, the steaming time affected the efficiency, throughput and the length of shreds.

References

- Oyedepi, O.A., Agbetoye, L.A.S. and Adedeji, O.T. *Development and performance evaluation of a cassava stem planter*. 11th International Conference and 32nd Annual General Meeting, of the Nigerian Institution of Agricultural Engineers Ilorin Nigeria, October 2011.
- Karmal, A.R. and Oyelade, O.A. Present status of Cassava peeling in Nigeria. *Journal of agricultural Engineering and technology*, Vol.18, No. 2, 2010, pp.7-13.
- Alissa, A., Froustet, A., Glasgow, C. and Lawson, J. *Garri processing*. Proceedings of the KGCOE Multi-Disciplinary Engineering Design Conference. Rochester Institute of Technology, Rochester, New York 146, 2007.
- FAO. *Plant Production Marketing and Protection*. Food and agricultural organization Series No 3a Rome 2004 www.fao.org.
- Balagopalan, C., Padmaja, G., Nanda, S.K. and Moorthy, S.N. *Cassava In food, feed and industry*. CRC, Press Boca Ranton Florida 1988.
- Olunkule, O.J. and Ademosun, O.C. Development of double action self-fed cassava peeling machine. *Journal of food, agriculture and environment*, vol. 4, 2006, pp. 3-4.
- Olunkule, O.J. and Atere, O.A. *Development in Cassava peeling mechanization*. International Conference of the Nigerian Institution of Agricultural Engineers/ West Africa society of Agricultural Engineers, Ile-Ife Nigeria, 2009.
- Olunkule, O.J. and Oguntunde, O. Analysis of peeling pattern in an automated cassava peeling system. *Nigeria journal of technological development*, Vol 6, no. 1 and 2, 2008, pp 41-52.

9. Akinyemi, J.O, and Akinlua, O. Design, construction and testing of cassava grater. *International journal of tropical agriculture*, vol. 17, 1999, pp103-108.
10. Odigbo. E.U. A manually operated cassava grating machine. *Nigerian Journal of Technology*, Vol. 8, No. 1, 1984, pp 15–18.
11. Odigbo. E.U. *Cassava production, processing and utilization*. In [12], 11th International Conference and 32nd Annual General Meeting of the Nigerian Institution of Agricultural Engineers Ilorin Nigerian, October, 2011,
12. Ajayi O.O , Olukunle, O.J. Design of garri fryer. *Journal of agricultural Engineering and Technology*, Vol. 18, no. 1, 2010, pp 50–62.
13. Odigbo. E.U. A machine for pulverizing and sifting gari mash. *Nigerian Journal of Technology*, Vol. 8, No.1, 1984, pp 19–23.
14. IITA. *Cassava tropical Africa. A reference manual*. International institute for tropical agriculture. Ibadan, Nigeria, 1990.
15. IITA. *Cassava processing/ Cassava shredding machine*. IITA Media library Ibadan, Nigeria. old.iita.org/medialib/displayimage. Accessed March, 2011
16. Khurmi R.S , Gupta J.K *A textbook of Machine Design*. Euroasia publishing house (PVC) Ltd. Ram Nagar, New Delhi 2007.