INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH & DEVELOPMENT

ISSN 2278 – 0211 (Online)

Design of Versatile Cassava Shredding Machine for Food Processing Industries

Jinyemiema, Tamuno K
Lecturer, Department of Mechanical Engineering,
Ken Saro Wiwa Polytechnic, Bori. Rivers State, Nigeria
Tekena G. Amie-Ogan
Lecturer, Department of Chemical Engineering,
Ken Saro Wiwa Polytechnic, Bori. Rivers State, Nigeria
Gloria Dan-Orawari
Lecturer, Department of Mechanical Engineering,
Ken Saro Wiwa Polytechnic, Bori. Rivers State, Nigeria
Amadi Hachimenum
Lecturer, Department of Electrical Engineering,
Rivers State University, Port Harcourt, Rivers State, Nigeria

Abstract:
Manual processing of cassava tubers into its derivatives like tapioca, starch is tedious and time-consuming; this drudgery has led to this study. The purpose of this study is to enhance agricultural performance via the design and fabrication of an improved cassava shredding machine that is capable of producing different sizes of cassava slices for further processing. The essence is to reduce processing time through increased surface area. This design produces different sizes for tapioca, ijapu, abacha, lafu and for other uses. The sizes range from 8-20mm in diameter. The machine consists essentially of a hopper where peeled cassava roots are put, beneath the hopper is the shredding plate with varied cutting blades coupled to a horizontal shaft which when in operation undergoes reciprocating motion. The horizontal shaft derives its motion through a slider crank mechanism coupled to an electric motor via a belt drive with a pulley for primary speed reduction and regulation. A rugged framework is provided for mounting of the machine and electric motor. The capacity of the machine is 320kg/hr. Maximum shredding efficiency of 82% was obtained with a shred aperture ranging from 5-12mm at a shredding speed of 1200rpm.
.

Keywords: *Agriculture, drudgery, potentials, economy, sizes, sustainable*

1. Introduction

Agriculture is central to economic growth and development in Nigeria. Although, Nigeria is an oil-rich nation, agriculture remains an important economic sector that serves as a major source of raw material, food and foreign exchange and it employs over 70% of the labour force. (Liverpool- Tasie et al., 2011). Cassava is an important crop that has great potential to support agricultural growth in Nigeria due to its wide range of uses, from human consumption to industrial applications (CMP 2006). Africa produces 40-50% of the global cassava output (FAO, 2004; Nang'ayo et al., 2007) and Nigeria is the leading producer of cassava globally (Othman, 2011). Demand for cassava derivatives such as starch, garri (a type of processed cassava), tapioca etc, have doubled over the last two decades (Nweke, 2004). Therefore, there is a need for the design and fabrication of a shredding machine that will enhance the processing of cassava to its derivatives.

Shredding is a size reduction process (Brennan 1981). Therefore, shredding has potentials to improve cassava products quality, even though the process is not widely used in cassava processing. Reducing the size of the tubers to be processed into a food product which require fermentation and drying has been recognized as an effective method of reducing process time and improving the product quality (Jeon 1992). Cassava shreds known within the eastern parts of Nigeria as Ighu, Nsisa, Ijapu or Abacha are local delicacies. It is made from peeled and shredded cassava tubers, after steaming and fermentation for about 24hours. The product is then washed and eaten as a snack or made into a main meal or dried for storage. Cassava shredding is still done manually. The mechanization of cassava shredding introduces changes in the quality characteristics of the slices produced. This can enhance the agricultural performance of farmers in Niger Delta, since the machine eliminates the drudgery involved in processing cassava tubers into its derivatives that can be packaged and even exported as semi-finished products for further processing. The development of agriculture is the process of constantly evolving improved condition for agricultural practice and/ or the harnessing of the agricultural potential of a place. This can be done through an improvement of the knowledge of the business of agriculture and/or development of appropriate technologies and formulation of sustainable strategies. The very essence of this machine is to reduce drudgery, process time, and injury to operators that is common during processing and enhance mass production of cassava slices.

This paper focuses on the design of a shredding with ability to produce different sizes of slices of cassava for various usage as practiced mostly in the Eastern and Niger Delta regions of Nigeria.

2. Materials and Methods

2.1. Design Consideration and Design Analysis

The following factors were considered for successful design, fabrication and operation of the machine.

2.1.1. Mechanical Factors

- Strength, rigidity and availability of materials for the construction of the machine.
- The shredder should accommodate different speeds of operation.
- The hopper is to be designed in such a way as to accommodate different sizes of cassava tubers available.
- The collector should be designed in such a way as to collect all the shredded cassava and minimize loses.
- The machine must be adaptable to the environment.

2.1.2. Operational Factors

- The cassava root shredder should ensure the uniformity of shreds for the different sizes produced.
- A capacity machine ability to achieve fast processing of the cassava roots.
- Ensure safety of operators

2.1.3. Economic Factors

The economic factors considered in the development of the motorized cassava shredder were:

- Availability and the cost of its construction materials.
- Manufacturing methods employed in its fabrication.

2.2. Design Analysis

Some basic considerations in the analysis of the different components
The hopper has a trapezium shape
Perpendicular Height of hopper = 35cm
Length of top = 40cm
Width of top = 43cm
Length of base = 25cm
Width of base = 29cm
Area of base, A = 25x 29 = 725cm^2
Volume, V = $\frac{1}{3}$x area of base x H
V= $\frac{1}{3}$ x 725 x 35 = 8458.33cm^3

2.2.1. V–Belt Selection

$$L = n(r_1 + r_2) + 2c \frac{(r_1+r_2)^2}{c}$$

Where; L is total length of the belt in mm, rpm
Or

$$L = \frac{\pi}{2}(D_S + D_m) + 2C + \frac{(D_S - D_m)^2}{4c}$$

Where:
C = Centre distance between pulleys = 80cm
D_S= Diameter shaft pulley = 20cm
D_m= Diameter of motor pulley = 5cm

Substituting values, we obtain the V-belt length as;

$L = {}^{\pi}/_{2}\ 20 + 5 + 2 \times 80 + \frac{(20+5)^2}{80}$
= 39.25 + 160 + 0.7
= 199.5cm (2m)

2.2.2. Shaft Design

d = $[\frac{16}{\pi s}(\sqrt{(K_b M_b)^2} + K_t M_t)^2)]^{1/3}$
Where, M_b =maximum bending moment on shaft (1000Nmm)
M_t = maximum torsional moment on shaft (16540Nmm)

S = allowable shear stress for steel (310N/mm^2)
K_t, K_b = fatigue and shock factor for torsion and bending moments (1.5 and 1.0).
Five shafts are involved in the development of the machine. The shafts are.

- The shaft connecting the driven pulley to the driver sprocket
- The shaft connecting the driven sprocket to the slider and crank mechanism
- The main shaft of the slider and crank mechanism
- The perpendicular shaft of the slider and crank mechanism
- The shredding plate shaft

The diameters of the shafts obtained where 20mm, 20mm, 20mm, 20mm and 15mm respectively.

2.2.3. Design of the Frames

$S_t = \frac{Se}{Fs} - \frac{Se}{S_{yp}} \times Sm$

S_r=Superimposed alternating stress

$S_r = \frac{\text{Maximum stress-Minimum stress}}{2}$

Minimum stress is due to the weight of the machine components on the frame like the hopper, the shafts, electric motor, pulleys and sprockets only. While the maximum stress is due to all the weights above plus the weight due to cassava tubers used in filling the hopper and the force exerted by the electric motor on the machine members.

Se = Maximum endurance stress of mild steel= 107.696x10^{3}KN/m^2

Syp= Yield strength of mild steel= 801.414x10^{3}KN/m^2

Sm= Mean stress $= \frac{\text{Maximum stress + Minimum stress}}{2}$

A 3mm thick steel plate with 40mm width was selected to avoid any underestimation.

2.2.4. Electric Motor Selection

The power from a single-phase electric motor required to shred the cassava root was derived as follows;
Shredding force=Weight obtained from spring balance due to cassava resistance to shredding x Acceleration due to gravity.
(f=m x g)
Work done=Shredding force x Distance moved by the cassava root on the shredding plate (length of shredder) *(W=F × d)*

Power= Work done/time

$P = \frac{W}{t}$

Where;
F = shredding force
M = weightobtainedfromspringbalanceduetocassavarootresistancetoshredding
g = acceleration due to gravity
W= work done to shred cassava root
P = Power required to shred cassava root
t= Time required to shred root from my experiments,
m = 25.7Kg
$F = 25.7 \times 9.81 = 252N$
Since, Torque = Force x shaft radius
And distance moved by root (length of shredder) = 0.001m

Torque, T = 252 × 0.01 = 2.52Nm
Power = Torque x angular velocity
= 2.52 x 157.08 = 395.84W
The above did not take into cognizance internal resistance from moving member.
Hence, with an expected 80% efficiency,
Power, P = 1.80 x 395.84 = 712.515Watts
The above value of 712,515 approximately equal to 1.0Hp, but design purposes 1.5Hp electric is chosen, this is to avoid unnecessary breakdown during operation as a result depreciation and overloads from users.

To ensure that the electric motor is able to drive all the machine moving parts, shred the tubers efficiently, and to avoid any underestimation, I selected one Horsepower (1Hp) electric motor.

2.2.5. Pulleys Selection

$D_s = \frac{Dm \times \omega_m}{\omega_s}$

Where;
D_S = Diameter of shaft pulley (mm)
D_m = Diameter of electric motor pulley (mm)

ω_m = Speed of electric motor (rpm)

ω_s = Speed of shaft (rpm)

The shaft pulley selected was 20cm (0.2m) in diameter, while the electric motor pulley was 5cm (0.05m) in diameter. The speed of the electric motor selected was 1500rpm (due to availability in market).

Therefore, speed of driven shaft $\omega_s = \underline{D_m W}$

$$\omega_s = \frac{5\times1500}{20} = 375rpm$$

2.3. Materials for Fabrication

Material selection is of utmost importance to ensure that the components to be fabricated have the desired performance requirements. Since different components of the cassava shredding machine would be subjected to varying forms and the degree of stresses strains, torque and frictional effect, the material with the appropriate engineering properties was chosen.

2.3.1. Materials

The materials to be used for fabrication were selected after a careful study of the desired physical, mechanical and chemical and even aesthetic characteristics of a number of proposed materials. For this project, due economic considerations and availability of raw materials, high and medium carbon steel was mostly used for body parts and chuck materials while cast iron was chosen for the pulley. Springs chosen were compressive type springs with adequate stiffness to hold the tuber in position firmly without crushing it. Manufactured vulcanized belt with adequate tension were used.

2.3.2. Fabrication Techniques

A lot of activities were involved in a bid to fabricate the cassava shredding machine. The activities range from accuracy and technical marking out the components, cutting, drilling, and welding.

3. Description of Cassava Shredding Machine

The machine consists essentially of a hopper where peeled cassava roots are put. Directly beneath the hopper is the shredding plate coupled to a horizontal shaft which when in operation undergoes reciprocating motion. The shredding plate is enclosed within the collector assembly. The horizontal shafts devices its motion through a slider and a crank mechanism coupled to an electric motor via a belt drive with a pulley for primary speed reduction and regulation. A rugged framework is provided for mounting the machine and electric motor.

4. Results and Discussion

The cassava shredding machine is a food processing machine; hence it works on the principle of slider crank mechanism. As a food processing machine, it has four major components namely, electric motor, the feed, the cutter mechanism and the flywheel.

In order to test the cassava shredding machine, the following procedures must be followed,

- Plug the cassava shredding machine to A.C electric source.
- Switch on the machine for sometimes to allow it attain its working capacity.
- Feed in cassava into the hopper and allow the press mechanism to exert pressure on it.

A reciprocating motion cassava shredding machine was developed using locally available construction materials and technology. The machine performed satisfactorily well during test. Results showed that the size of the shredding aperture of the machine significantly affected the shredding efficiency of the machine. The shredding efficiency of the machine decreased with increasing shredding aperture, but increased with shredding speed. Maximum shredding efficiency of 65% was obtained when the shred aperture was 2mm and the shredding speed was 975rpm. The throughput capacity of the machine increased with speed of shredding with a maximum value of 319.89kg/hr at 975rpm and a minimum value of 301.54kg/hr at 325rpm.

5. Conclusion

Based on the results obtained above, this cassava shredding machine is capable of producing different sizes of chips. Slices produced based on the design are for tapioca, ijapu, abacha and lafu. It is most efficient at 319.89Kg/hr at a speed of 975rpm. However, the quality of chips produces which are between 5-12mm have better integrity. The machine so designed is more efficient and yields cassava chips of better quality as compared to the traditional method of shredding the crop. The machine is capable of shredding different varieties of cassava tubers as well as different sizes of chips.

6. References

i. Akinnagbe, O. (2010). Constraints and strategies towards improving cassava production and processing in Enugu north agricultural zone of Enugu State, Nigeria. *Bangladesh Journal of Agricultural Research,* 35, 387–394.

ii. Awoyinka, Y. A. (2009). Cassava Marketing: Option for Sustainable Agricultural Development in Nigeria. *Ozean Journal of Applied Science*, 2 (2), 175–183.

iii. Dipin, A. (2014) Solar powered vision based robotic lawn mower. *International Journal of Engineering Research and Reviews.* 1(2), 53-56.

iv. FAO. (2004). Plant Production Marketing and Protection. Food and Agricultural Organization Series No 3a Rome 2004 www.fao.org.

v. Igbeka, J. C. (2002): Agricultural Engineering and the Society. NIAE Quarterly, 3(2), 3-11.
vi. Igoni, A. H. & Harry, I. S. K. (2017). Agricultural Mechanization as a Tool for Economic Prosperity of the Niger Delta Region of Nigeria.
vii. Igoni, A. H. (2013a). The Role of Engineering in Agricultural Productivity in Rivers State.
viii. Igoni, A. H. (2013b). Mechanization of Agriculture for the Enhancement of Niger Delta Economy.
ix. Jeon, Y.W., Halos, L.S. (1992). An Unpublished Training Manual: Design, Operation and Maintenance of IITA-developed Postharvest Technologies.
Nweke, F.I (2004), New Challenges in the Cassava Transformation in Nigeria and Ghana, Environment and Production Technology Division, IFPRI, Washington, D.C. 2006
x. Othman, F. (2011), Design and fabrication of cassava lump breaking and sieving machine. *Oasis Journal of Research and Development*, 1(2): 42-50.

Appendix

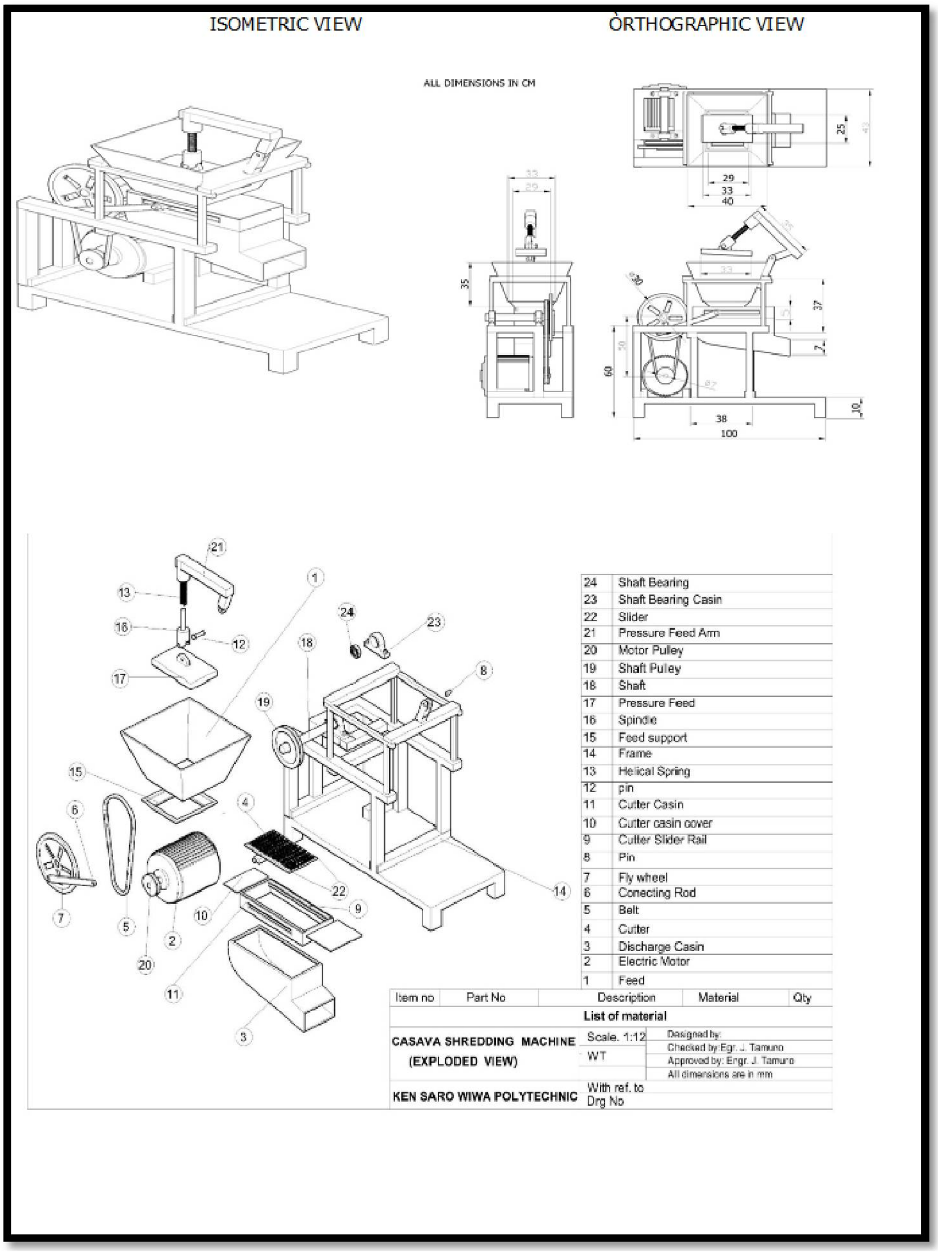

Figure 1