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Development of a Motorized Rotary Cassava Peeling Machine

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Abstract
Cassava has become an important economic crop due to its growing use as a raw material in Food, Pharmaceutical and chemical industries causing rapid growth in the demand for cassava products. There is therefore an expansion in its production and processing. Peeling usually precedes most processing operations which makes it very essential. This machine is part of the efforts to mechanize cassava peeling to meet growing demands. The machine uses the abrasive mechanism to peel cassava roots in batches and is driven by an R.165 (6.5hp) diesel engine. Performance evaluation revealed that the machine could peel an average of 30kg cassava roots in 38s at an operating speed of 715 rpm; peel the same weight for 47s and 52s at 652 and 524 rpm respectively. The machine has an average throughput capacity of 0.790, 0.683 and 0.577 kg/s for operating speeds 715, 652 and 524 rpm respectively. Average peeling efficiency of 72.67, 63.83 and 57.67% was obtained for 715, 652 and 524 rpm respectively. It portends a significant breakthrough in the search for an effective mechanized cassava peeling machine

Key Words: *Development, Rotary, Motorized Peeling and Performance Evaluation.*

1. INTRODUCTION

Cassava (*Manihot Esculenta*) is a perennial crop with edible root prevalently grown in tropical and sub-tropical areas of the world. According to Ugwu *et al* (2015), it is a prominent cheap source of calorie intake for human diet and carbohydrate sources in animal feed. Cassava roots have become an important economic crop in most developing nations due to its ease of cultivation, high yield in marginal soil and its ability to stay in the soil long after maturity. Cassava starch is also fast becoming an important ingredient in the manufacture of pharmaceutical and chemical products soaring its export potentials. The resulting growth in local and international demand for cassava products has occasioned the expansion of cassava production and processing. Uthman (2011), declared that Nigeria is one of the highest producers of cassava in the world with a record level of 49 million tons per year

Peeling usually precedes several other operations of processing cassava into most of its useful products making it a vital cassava processing operation. In Nigeria cassava peeling is commonly done manually which is labor intensive and too slow for emerging processing rates. The effort at mechanizing the process of cassava peeling has being disconcerted with problems resulting from the wide variations in the sizes and shape of cassava roots. Olukunle *et al* (2006), stated that there is also the wide dissimilarity in the texture, chunkiness, and strength of adhesion of the peel to the flesh of the cassava root.

According to Egbeocha *et al*. (2016), several attempts have been made at mechanizing cassava peeling operation but machines have not been fully developed hence, cassava peeling still remains a global challenge to design engineers. A peeling machine that will efficiently remove the cortex of cassava roots with minimal loss of the useful flesh amongst other features is desired.

This work targets to design and produce a machine capable of peeling diverse sizes of cassava roots cut and sort to size, to the desired level of peeling efficiency and with minimal flesh loss. The research also seeks a simple and affordable design for a medium scale use.

2. MATERIALS AND METHODS

Abrasive motorized cassava peeling machine with an attached water sprinkling device to ease peeling and as well wash the cassava roots was designed, fabricated and tested. The peeling principle was chosen based on the performance of existing peeling machines and designed for optimum peel removal and minimal flesh loss. Materials used for fabrication were selected based on affordability, availability and viability without compromising functionality. The machine is intended for a medium-scale use.

2.1 Design Consideration

In order to achieve a desirable level of efficiency and reliability the following factors were considered in the design of this machine

i. effective peeling capacity and rate with minimal loss of useful flesh.
ii. The quality of food to be handled, hence material that will not contaminate it
iii. Affordability, availability, workability and strength of materials used for construction
iv. Physical and chemical properties of materials to be peeled
v. Overall cost and capacity of machine putting it within reach of a medium scale farmer or processor.

2.2 Design Analysis

2.2.1 Volumetric capacity of peeling chamber

The peeling chamber was made of a cylindrical drum, hence the volume is determined using the expression:

$$v = \pi r^2 h \qquad (1)$$

Where, r is the radius of the cylinder (m); h is the height of the cylinder (m)

2.2.2 Speed of drive plate

The equation below gives the operating speed of the drive plate:

$$\frac{N_1}{N_2} = \frac{D_2}{D_1} \qquad (2)$$

Where, N_2 is the speed of prime mover; N_1 is the speed of the driver plate; D_2 is the diameter of the prime mover pulley (m); D_1 is the diameter of driver plate pulley (m).

2.2.3 Power required to peel cassava

The force required for peeling is equivalent to the force due to centrifugal action of the rotating drum which is given as:

$$F = \frac{\rho \times v \times 4\pi^2 N^2 \times r}{3600} \qquad \text{(Ike, 2004)} \qquad (3)$$

Where; ρ (kg/m^2) is the density of mild steel used, v (m^3) is the volume of the peeling drum, r (m) is the radius of the peeling drum, N (rpm) is the rotational speed of the peeling drum.

Power required to peel the cassava roots is therefore equal to the power required to drive the drive plate which is given by:

$$P = Tv \qquad (4)$$

But, $T = m \times a \times r$ (5)

While, $v = \dfrac{2\pi N}{60}$ (6)

Where; P is power, T is Torque, v is Speed, m is Mass; a is Acceleration due to gravity, r is Radial distance, N is Speed of the peeling drum.

2.2.4 Shaft Design

The shaft design considered the maximum shear and bending stresses acting on the shaft due to the twist and bending moment it is subjected to. The shaft diameter d, was given by the expression:

$$d = \sqrt[3]{\frac{16T_e}{\pi \times \tau_{max}}} \quad (7)$$

$$T_e = \sqrt{(K_m \times M)^2 + (K_t \times T)^2} \quad (8)$$

Where; K_m is a combined shock and fatigue factor for bending, K_t is combined shock and fatigue factor for torsion, M is the maximum bending moment and T_e is equivalent twisting.

The Torque T, on the shaft can be expressed as:

$$T = F \times r \qquad \text{Khurmi and Gupta (2005)} \quad (9)$$

Where; F is the force required for peeling, r is the radius of the peeling drum.

2.2.5 Length of Belt

The length of the belt used was determined by the equation:

$$L = \frac{\pi}{2}(d_1 + d_2) + 2x + \frac{(d_1 - d_2)^2}{4x} \qquad \text{Srivastava } et\ al. \text{ (2006)} \quad (10)$$

Where, L is the length of the belt; d_1 is the diameter of prime mover pulley; d_2 is the diameter of the driven pulley; x is the center distance between the two pulleys.

2.3 Machine Description

The machine consists of a cylindrical mild steel drum open at both ends, which doubles as the frame and the peeling chamber. The peeling chamber region of the cylinder is lined with a perforated galvanized steel plate which serves as the abrasive peeler, it has an outlet for discharge of peeled cassava root after every batch operation. At the base of the abrasive wall of the peeling chamber is a bottom mild steel drive plate also lined with perforated galvanized steel plate to assist peeling. This plate is driven by a 6hp diesel engine connected to the driver shaft by a belt, pulley arrangement via a reduction gear fixed below the peeling chamber as shown. Another plate was welded to cover the cylinder wall just below the drive plate and slightly inclined to collect peels and direct it to a delivery chute cut out of the wall of the machine.

While at the top a sprinkler that collects water via a flexible water hose from a tap is placed as shown in figure 1 to continuously water and clean the cassava roots during peeling operations.

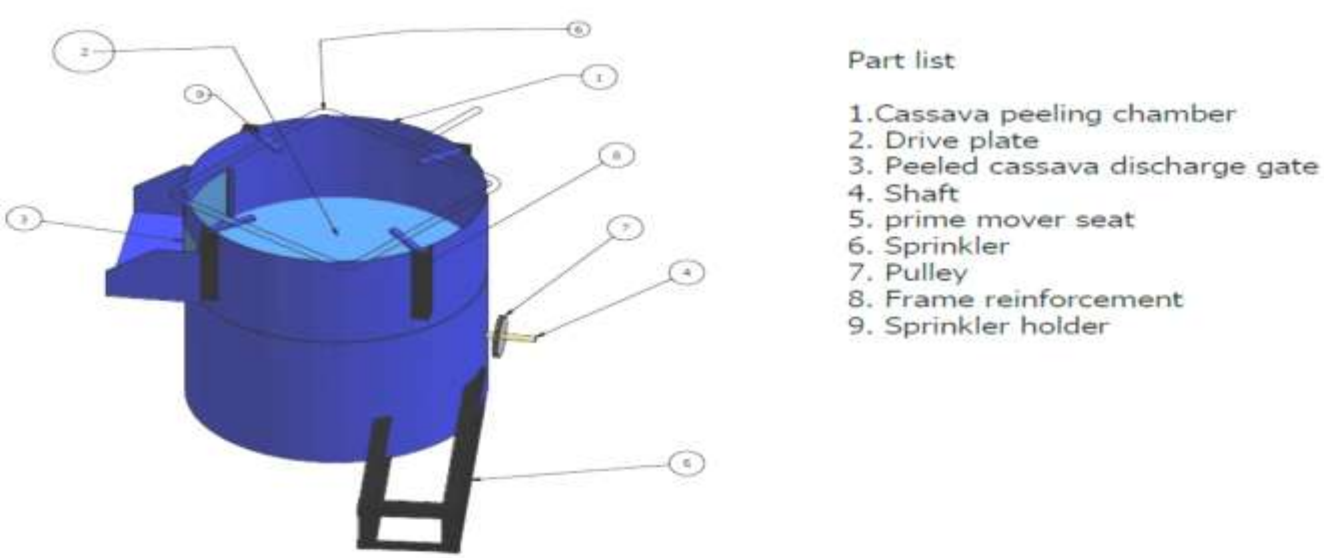

Figure 1. Isometric veiw of the Cassava Peeling Machine.

2.4 Principle of operation

The motorized cassava peeling machine is designed to peel cassava roots in batches. The drive plate is set in motion via the prime mover after which cassava roots are poured directly into the peeling chamber. These cassava roots are agitated by the rotation of the rotary bottom plate thereby robbing them against the abrasive walls of the peeling chamber. The cassava roots are moisturized to enhance peeling by continuously sprinkling water on it via the sprinkler at the top of the peeling chamber. Water runs from a tap through a PVC hose into the sprinkler pipe.

At the end of each batch when peeling is completed, the discharge gate is opened for the peeled cassava roots to be released into a collection bowl. Cassava peels on the other hand fall on the collection plate beneath the peeling chamber, and then conveyed to the chute from where it is collected.

2.5 Fabrication of the Peeler

The cassava peeling machine consists of the following components:

2.5.1 Frame: the frame is made from a 3mm thick mild steel sheet rolled into an 890mm diameter, 1220mm high open end cylinder. It holds the whole system, while its upper part serves as the peeling chamber wall. Eight 610mm long 50x50x2mm mild steel angle iron were evenly lined along the perimeter of the outer frame wall to reinforce its and as well carry the sprinkler holders.

2.5.2 Peeling chamber: this is the main component of the machine which constitutes the upper region of the frame, 490mm dip from the top. A perforated 1.5mm thick galvanized steel sheet raspier was riveted on the entire inner wall. Fixed at the base of the peeling chamber is a 300mmx520mm door for the discharge of peeled cassava roots. A drive plate of 860mm diameter made cut out of a 3mm thick mild steel sheet was also welded at the bottom of this chamber. It was also lined with a perforated 3mm thick galvanized steel sheet raspier. The drive plate was connected to a 30mm drive shaft which was also connected to reduction gear and then via a belt pulley arrangement to a 6.5hp diesel engine.

2.5.3 Peel collection chamber: it is a 3mm thick mild steel sheet welded around the frame wall at a 30^0 inclination below the rotary plate. It has a 230x320mm opening chute for the delivery of peels.

2.5.4 Sprinkler: the sprinkler was made from a 25.4mm PVC pipe with 2mm holes drilled on it to jet out water flowing through it from the water source.

2.6 Test Procedure

A preliminary performance test was carried out on the peeling machine at three different operating speeds of 715, 652 and 524 rpm respectively using freshly harvested cassava roots. The machine was driven by an R.165 (6.5 hp) diesel engine as a power source. Three replicates Sample of 30kg each of the freshly harvested cassava roots were weighed and used for the test at a different speed. The weight of the entirely and partially peeled roots, the weight of the peels, time is taken to peel each batch were recorded and analyzed to determine the performance parameters.

2.6.1 Performance Parameters

The data collected from the preliminary test were used to determine the performance parameters of the machine as follows:

a) **Throughput capacity, T_c (kg/h):** this is the total quantity the machine can handle per batch and it is expressed as:

$$T_c = \frac{W_t}{T} \quad \text{(Ariavie and Ohwovoriole, 2002)} \qquad (11)$$

Where, W_t is the average weight of cassava roots fed into machine; T is the average time for the roots and peel to leave machine (h).

b) **Peeling efficiency, n (%):** the ratio of the average weight of peeled cassava roots to the average weight of fed cassava tubers. It is expressed as:

$$n = \frac{W_p}{W_t} \times 100 \qquad (12)$$

Where, W_p is the average weight of peeled root at the outlet, W_t is the average weight of cassava root fed into the machine

c) **Mechanical damage, λ:**

$$\lambda = \frac{W_f}{W_p + W_f} \quad \text{(Ariavie and Ohwovoriole 2002)} \qquad (13)$$

Where, W_f is the average weight of cassava flesh loss with peel by machine, W_p is the average weight of completely peeled cassava root.

3.0 RESULTS AND DISCUSSIONS

Results obtained from the preliminary performance test carried out on the peeling machine at an operating speed of 715, 652 and 524 rpm using freshly harvested cassava roots are presented in Table 1. The results revealed that the machine could peel an average of 30kg cassava roots in 38s at an operating speed of 715 rpm; peel the same weight for 47s and 52s at 652 and 524 rpm respectively. The machine has an average throughput capacity of 0.790, 0.683 and 0.577 kg/s for operating speeds 715, 652 and 524 rpm respectively. Average peeling efficiency of 72.67, 63.83 and 57.67% was obtained for 715, 652 and 524 rpm respectively.

Table 1: Performance Parameters obtained from the preliminary test of the Peeling Machine.

Sample	W_t (kg)	W_p (kg)	W_{PCH} (kg)	W_{PC} (kg)	W_{TP} (kg)	n (%)	T_L (%)	T_c kg/s	P_t (s)	Speed (rpm)
A	30.00	21.80	3.00	5.20	8.20	72.67	30.67	0.790	38.00	715.00
B	30.00	19.25	2.85	7.90	10.75	63.83	39.17	0.683	47.00	652.00
C	30.00	17.90	2.70	9.40	12.10	57.67	44.33	0.577	52.00	524.00
Average	30.00	19.65	3.38	8.03	11.42	64.72	38.06	0.683	45.66	630.33

4.0 CONCLUSION AND RECOMMENDATION

A rotary, batch cassava root peeling machine was designed, fabricated and tested at the National Centre for Agricultural Mechanization (NCAM), Ilorin. This machine was developed as an improvement to the existing versions of peeling machines. It was designed to handle different sizes of cassava roots cut, sorted and delivered in batches. Results of preliminary tests carried out on the peeling machine revealed an average 2458.80 kg/h throughput capacity and a 72.67 % peeling efficiency at the maximum 715rpm operating speed.

Since the peeler removed a satisfactory level of peel from the root while the peeling efficiency increased with an increase in speed, a comprehensive performance test is recommended to optimize the operating speed and other variable parameters of the machine. This would enhance its performance parameters. The possibility of peeling other root crops is also recommended to be explored.

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References

i. ***Abdulkadri, B.H., (2012):*** *Design and Fabrication of a Cassava Peeling Machine, IOSR Journal of Engineering (IOSRJEN). 2 (6): 01-08*

ii. ***Alhassan, E.A., Ijabo, O.J. and Afolabi, E.O., (2018):*** *Development of Cassava Peeling Machine Using an Abrasive Mechanism, Journal of Production Engineering. (21)1:61-66*

iii. ***Ariavie, G.O. and Ohwovoriole, E.N., (2002):*** *Improved Rotary Cassava Tuber Peeling Machine, Nigerian Journal of Engineering Research and Development. 1(2): 61-63*

iv. ***Egbeocha, C.C., Aboegwu, S.N. and Okereke, N.A.A., (2016):*** *A Review of Performance of Peeling Machines in Nigeria, Federal University of Technology, Owerri Journal Series. 2(1): 140-168*

v. ***Ike, E.A., (2004):*** *Introduction to University Physics, Grace Production Arts and Prints, Jos. 349-443*

vi. ***Khunmi, R.S. and Gupta, J.K., (2008):*** *A Text Book on Machine Design, Eurasia Publishing House Ltd. Ram Nagar, New Delhi. 456-568.*

vii. ***Olukunle, O.J. and Ademosun, O.C., (2006):*** *Development of a double action Self-fed Cassava Peeling Machine, Journal of Food, Agricultural and Environment, Federal University of Technology, Akure (4): 3-4*

viii. ***Srivastava, A.K., Carroll, E.G., Roger, P.R., Dennis, R.B., (2006):*** *Mechanical Power Transmission. St joseph, Michigan. 65-90*

ix. ***Ugwu, K. C. and Ozioko, R. E., (2015):*** *Development and Performance test of Cassava Peeling and Washing Machine, International Journal of Scientific and Engineering Research, 6(6):1572-1579*

x. ***Uthman, F., (2011):*** *Design and Fabrication of Cassava Lump Breaking and Sieving Machine, Oasis Journal of Research and Development (12): 40-42*

APPENDIX 1

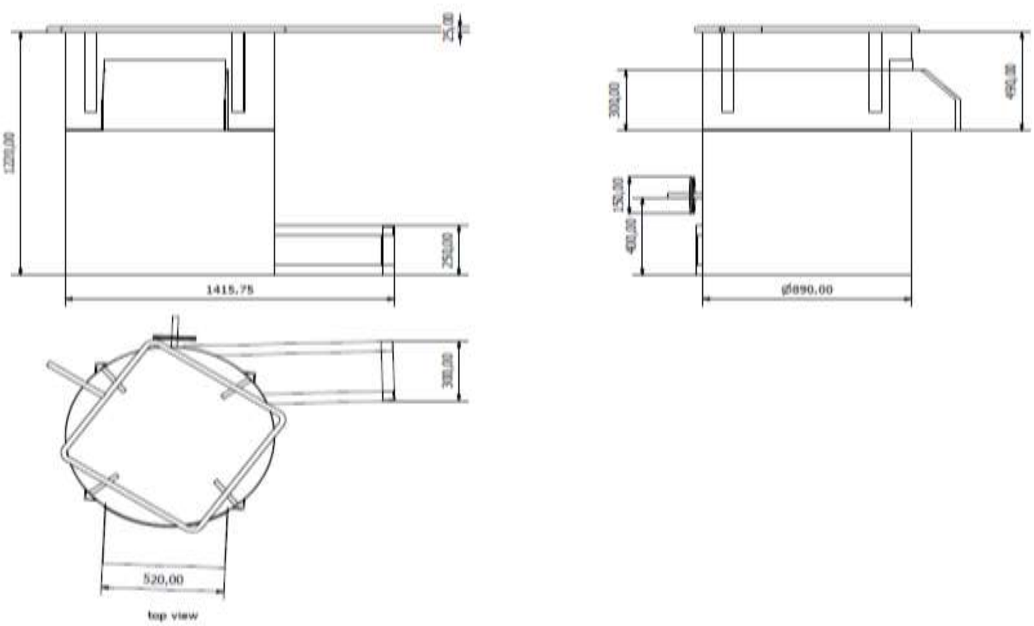

Figure 2. Orthographic View of Cassava Peeling Machine

Plate 1. Pictorial View of the Rotary Cassava Peeling Machine.