Effect of Speed on Efficiency and Throughput Capacity of Cocoyam Peeling Machine

Nnaemeka C. Ezeanya

Abstract— The processing of cocoyam corms for both industrial and human use involves different operations of which peeling is the major task. This study aimed at the development and performance evaluation of a vertically-aligned cocoyam peeling machine. The cocoyam peeling machine was successfully developed at Federal University of Technology, Owerri, Nigeria. The peeling machine was operated at three rotational speeds of 98, 130, and 228 rpm. The speed variation was achieved by a 3-step pulley incorporated into the machine. The output parameters determined in the evaluation of the peeling machine are peeling efficiency and throughput capacity. Results obtained from the performance evaluation showed that both the peeling efficiency and throughput capacity increased with increasing rotational speeds of the peeling machine. Corresponding peeling efficiencies of 42.6, 61.54, and 80% were obtained for rotational speeds of 98, 130, and 228 rpm respectively; while corresponding throughput capacities of 73.53, 96.15, and 104.17 kg/hr were obtained for rotational speeds of 98, 130, and 228 rpm respectively. These results demonstrated that the developed cocoyam peeling machine could be used for effective peeling of cocoyam corms.

Index Terms— Cocoyam corms, Performance evaluation, Vertically-alligned, Rotational speed, Pully, Output parameters.

1 INTRODUCTION

Cocoyam is an important staple food crop commonly grown in Nigeria. Cocoyams are mostly cultivated because of their edible corms. Cocoyam corms are rich in carbohydrates and also have higher protein content than cassava and yam. Cocoyam corms are normally peeled and processed into flour. This cocoyam flour is normally used in soup preparation; and also in confectioneries for the production of biscuits, bread, and puddings.

Peeling is the act of removing or detaching the outer layer of a material. Peeling of cocoyam corms is the removal of the pericarp and leaving the endocarp in the desired condition.
Traditionally, peeling of cocoyam corms is done manually by the use of knife and manual peelers. This method has the disadvantage of time consumption and drudgery on the part of the operator. The extremely perishable nature of cocoyam corms poses a serious problem to storage [1].

Peeling machines have been developed in the past for peeling crops like cassava, yam, etc [2, 3]. A cocoyam peeling machine that peels by abrasion was developed by [1]. The optimal peeling efficiency recorded for this peeling machine was 68%. Information on research on peeling of cocoyam corms is scarce in literature. Also the available machines have relatively low peeling efficiencies, hence the need for this research work. The objectives of this research include: (i) To design and fabricate a cocoyam peeling machine (ii) To determine the effect of speed on the throughput capacity and peeling efficiency of the peeling machine.

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2 MATHERIALS AND METHODS

2.1 Materials Selection

The materials used for the research were selected based on the following factors:

1. Availability of material
2. Suitability of material for the working condition
3. The cost of materials

2.2 Design Consideration

These factors were considered in the design of the peeling machine:
1. Tuber crop factors such as particle size, weight, and porosity would be considered.
2. Machine factors such as stability, vibration, noise, and durability would be considered.
3. Ergonomic factors would be taken into consideration so as to improve operator comfort and safety.

2.3 Design Analysis

These parameters were analyzed in the design of the peeling machine: Batch size (capacity), peeling speed, force required for peeling, length of belt, torsional moment.

a. Capacity

The machine was designed to accommodate 130 pieces of cocoyam with highest diameter of 112.3 mm and weight of 0.108 kg.
Peeling capacity= 130 pieces of cocoyam x 0.108 kg = 14.04 kg.
Therefore 10 to 15 kg of cocoyam tubers will be peeled per batch.
Mass of rotary plate = 10.2 kg

Therefore total load on shaft = mass of rotary plate + mass of cocoyam
Therefore total load on shaft = 10.2 kg + 15 kg = 25.2 kg.

b. Peeling Speed

Diameter of prime mover pulley (D1) = 32.7 mm
Rotational speed of prime mover (N1) = 3600 rpm
Speed reducer ratio = 15:1
A 3 step pulley having diameters of 80.15, 60.2 and 34.3 mm was used to vary the peeling speed. The various speeds corresponding to the various pulley diameters were determined using Equation 1.

$$N_1D_1 = N_2D_2 \quad (1)$$

Where N2 = rotational speed of driven pulley (rpm)
D_2 = diameter of driven pulley (mm)
For D_2 = 80.15 mm,

$$N_2 = \frac{3600 \times 32.7}{80.15} = 1469 \text{ rpm}$$

$$\text{Actual rotational speed} = \frac{N_2}{\text{speed reduction ratio}}$$

$$= \frac{1469}{15} = 98 \text{ rpm}$$

For D2 = 60.2 mm

$$\text{Actual } N_2 = \frac{3600 \times 32.7}{60.2 \times 15} = 130 \text{ rpm}$$

For D2 = 34.3 mm

$$\text{Actual } N_2 = \frac{3600 \times 32.7}{34.3 \times 15} = 228 \text{ rpm}$$

c. Determination of Torsional Moment

Torsional moment is expressed as Equation 2.

$$T = (P \times 60)/2\pi N \quad (2)$$

Where T = torsional moment (Nm)
P = power of prime mover (Watts)
N = rotational speed of pulley (rpm)
Actual N = 3600/15 = 240 rpm. Therefore

$$T = \frac{6500 \times 60}{2 \times \pi \times 240} = 258.63 \text{ Nm}$$

d. Force Required to Peel the Cocoyam

The force required to peel the cocoyam is expressed according to [4] in Equation 3.

$$F = T/r \quad (3)$$

Where F = force (N)
T = torque (Nm)
r = radius of peeling drum (m)

$$F = 258.63/0.155 = 1668.58 \text{ N}$$

f. Determination of Length of Belt

The length of belt was determined as per [5] and expressed in Equation 4.

$$L = 2C + \frac{\pi(D + d)}{2} + \frac{(D - d)^2}{4C} \quad (4)$$

Where L= length of belt (m)
C= centre distance between the two pulleys (m)
D= diameter of peeling drum pulley (m)
d= diameter of prime mover pulley (m)

2,4 Description of the Machine

The cocoyam peeling machine consists of rotary plate, cylindrical drum, prime mover, speed reducer, pulleys, V-belt. The pictorial view of the cocoyam peeler is shown in Figure 1.

Figure 1: Pictorial view of the cocoyam peeling machine

S/n	Description
A	Cylindrical drum
B	Prime mover
C	Speed reducer
D	Discharge chute

i, Rotary Plate

This absorbs and transmits the rotary motion from the speed reducer. It is made of mild steel plate of 309mm and coated with abrasive material of 10mm thickness. It has contours on the surface that assist in tumbling motion.

ii, Cylindrical Drum

This is the chamber where the peeling takes place. It consists of folded mild steel plate of 2mm thickness and casted with the abrasive material of 10mm thickness. The cocoyams to be peeled are fed directly into this chamber.

iii, Prime Mover

This is a petrol-powered internal combustion engine that provides the power to operate the peeling machine. It has a rated power of 3.7 kW and rotational speed of 3600rpm.

iv, Speed Reducer

This is a gear train positioned between the prime mover and the transmitting section of the cocoyam peeler. The speed reducer reduces the speed generated by the prime mover in the ratio of 15:1.

The orthographic and isometric views of the cocoyam peeling machine were shown in Figures 1 and 2.

2.5. Performance Evaluation of the Cocoyam Peeling Machine

The cocoyam tubers used for the experiment were bought from the markets at Owerri, Imo state. The tubers were sorted according to average diameter of 112.3 mm. 10 to 15 kg of cocoyam tubers were poured inside the cylindrical drum and peeled. The peeling time and the quantity of peeled and unpeeled tubers were determined.

a, Determination of Throughput Capacity

Throughput capacity is the quantity of cocoyam that was peeled by machine per unit time. It mathematically expressed as

$$Q = \frac{M_c}{t} \quad (5)$$

Where Q= Throughput capacity (Kg/hr)

Mc= Mass of cocoyam fed into the machine (Kg)

t= Time taken for the cocoyam and its peels to leave the machine

b, Determination of Peeling Efficiency

The peeling efficiency (η) of the cocoyam peeling machine was given as per [6] and expressed in Equation 6.

$$\eta = \frac{M_p}{M_{pr} + M_p} \quad (6)$$

Where Mp= Mass of peels collected (Kg)

Mpr= Mass of peels of partially peeled tubers (Kg)

3 RESULTS AND DISCUSSION

The results of performance evaluation of the cassava peeling machine are summarized in Table 1.

Table 1: Results of Performance Evaluation of the Cocoyam Peeling Machine

Speed (rpm)	Mc (Kg)	Time (mins)	Efficiency (%)	Q(Kg/hr)
98	10	8.10	41.67	73.53
130	10	6.15	61.54	96.15
228	10	5.44	80	104.12

Mc=mass of cocoyam fed into the machine; Q=throughput capacity

3.1 Effect of Speed on Throughput Capacity of the cocoyam Peeling Machine

It was evident from Table 1 and Figure 2 that the throughput capacity of the cocoyam peeling machine increased with increasing peeling speeds. The throughput capacities ranged from the lowest value of 73.53Kg/hr obtained at the speed of 98rpm, corresponding to the highest peeling time of 8.10 minutes; to the highest value of 104.12Kg/hr obtained at the speed of 228rpm, corresponding to the smallest peeling time of 5.44 minutes. This trend in the variation of throughput capacity with speed is attributed to the fact that the increasing peeling speeds of the machine facilitate the peeling of more cocoyam tubers and thus an increase in the throughput capacity. This trend in the variation of throughput capacity with speed is in agreement with previous research findings for cocoyam and cassava tubers [1, 2].

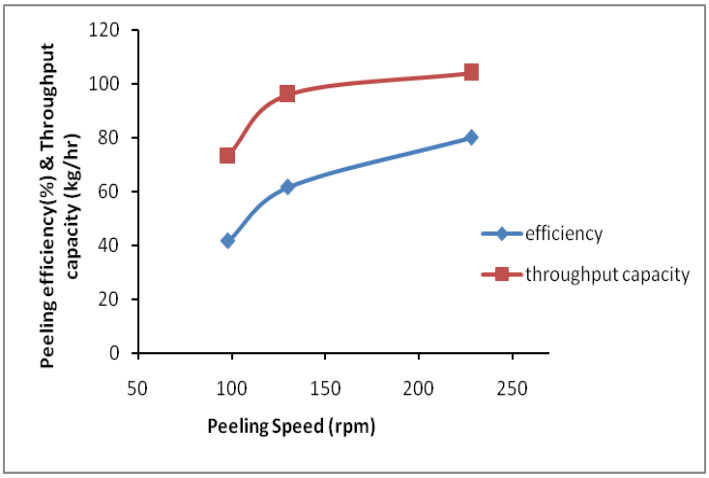

Figure 2: Effect of Speed on Drying Efficiency and Throughput Capacity of Cocoyam Peeling Machine

3.2 Effect of Speed on Peeling Efficiency of the Cocoyam Peeling Machine

The data in Table 1 and the illustrations in Figure 2 showed that the peeling efficiency of the cocoyam peeling machine increased with increasing peeling speeds for all the speeds that were considered. The peeling efficiency ranged from the

lowest value of 41.67% obtained at the speed of 98rpm to the highest value of 80% obtained at the speed of 228rpm. This trend in the variation of peeling efficiency with speed is in agreement with previous research findings for cocoyam and cassava tubers [1, 2].

4 CONCLUSION

This study was aimed at the development and performance evaluation of a cocoyam peeling machine. In the course of this study, the cocoyam peeling machine was successfully developed to operate at different speeds of 98, 130, and 288 rpm. The study revealed that that the peeling efficiency and throughput capacities increased with increasing speeds of the cocoyam peeling machine.

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