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DEVELOPMENT OF AN ELECTRICALLY OPERATED CASSAVA SLICING MACHINE

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Abstract

Labor input in manual cassava chips processing is very high and product quality is low. This paper presents the design and construction of an electrically operated cassava slicing machine that requires only one person to operate. Efficiency, portability, ease of operation, corrosion prevention of slicing component of the machine, force required to slice a cassava tuber, capacity of 10 kg/min and uniformity in the size of the cassava chips were considered in the design and fabrication of the machine. The performance of the machine was evaluated with cassava of average length and diameter of 253 mm and 60 mm respectively at an average speed of 154 rpm. The machine produced 5.3 kg of chips of 10 mm length and 60 mm diameter in 1 minute. The efficiency of the machine was 95.6% with respect to the quantity of the input cassava. The chips were found to be well chipped to the designed thickness, shape and of generally similar size. Galvanized steel sheets were used in the cutting section to avoid corrosion of components. The machine is portable and easy to operate which can be adopted for cassava processing in a medium size industry.

Key words: Slicing, Cassava Chips, Machine, Fabrication, Efficiency

1. Introduction

Cassava (*Manihot esculenta crantz*) is a very interesting root crop grown in many parts of the world and is considered as one of the most valuable staple food source for a huge number of people in West African sub-region. It is very clear that a larger population of people in the developing countries of the world depend on cassava food products as their major source of carbohydrate. Cassava has been highlighted as an important source of energy food in Nigerian diets, which plays a major role in alleviating food crises because of its year round availability, suitability to present farming method and production of food energy in Africa.

It has been reported that Cassava was introduced into Nigeria by returnee slaves from America (Ikugbayigbe, 1992). It cultivates well in the country and the nation has become one of the largest producers of cassava (FAO, 2006). The government of Nigeria has continue to make it one of the major crops widely grown in Nigeria for cash, food, and raw materials for the production of starch, alcohol, pharmaceuticals and confectioneries (Francisco, 2004). It is consumed in various processed forms such as *gari*, chips, flour, fermented pastes and starch among others (Annebunwa et al., 1998). According to FAOSTAT (2009), estimated annual production in Nigeria was 36.8 million tons from an estimated area of 3.78 million hectares. The major problem of cassava is that it is extremely perishable and the root must be processed to reduce post harvest losses (Davies, 1991). The root can be processed into chips by slicing.

Slicing is cutting cassava tubers or agricultural materials to obtain the length greater than other section of cut. Slicing machine is workable and efficient, which can be adopted to reduce labor input in cassava chips processing and improve product quality. This work is targeted at the design, construction and evaluation of the performance of an electrically operated cassava-slicing machine.

2. Materials and Methods

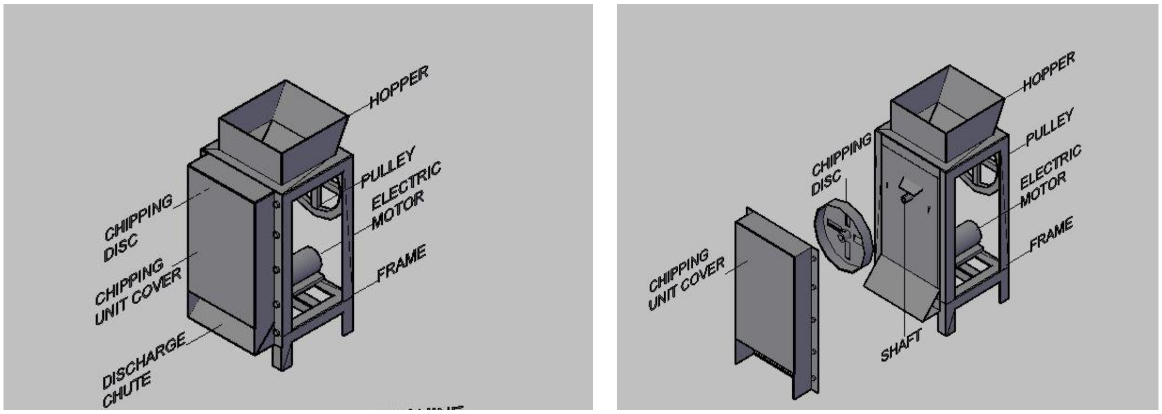
2.1 Design considerations and machine components

The materials for construction of the machine were chosen based on their availability, properties and economic considerations. The following were put into consideration while designing the machine:

i. Efficiency, portability and ease of operation.
ii. Corrosion prevention of slicing component of the machine because of the acidic and moisture content of cassava.
iii. The force required to slice a cassava tuber.
iv. Capacity of 10 kg/min.
v. Uniformity in the size of the cassava chips.

2.2 Description of the machine

The machine was designed for ease of operation as shown in Figure 1 a and b. A hopper is provided at an elevated position to aid the movement of cassava tubers to the chipping unit by gravity. A chipping disc was cut from galvanized steel sheet and provision for the cutting of the cassava immediately the tuber gets to it was provided across the sheet metal. To prevent the cassava chips from being flown away by the effect of centrifugal force on the cutting disc, a chipping cover was provided which helps to direct the chips through a discharge chute. The power transmission unit, which consist of a 0.5 watt (to compensate for losses and availability) electric motor, belt and pulleys were provided at a section of the machine to prevent any form of accident during operation.



A B

Figure 1: Cassava chipping machine, A: part list and B: exploded view

2.3 Principle of Operation

The machine is simple to operate requiring only one operator at a time. Before it is operated, all the parts must be properly set and fixed together. As the shaft rotates, it turns the chipping disc in anti-clockwise direction and the peeled roots will be fed through the hopper, which directs it to the chipping disc. The rotation of the chipping disc will perform an impact action on the tubers and the sharp groove on the disc will cut the tubers by impact shear force to the designed thickness of 10 mm of an equal shape. The chips then proceeds to the discharge chute by gravity where they are collected on a tray.

2.4 Design Analysis

2.3.1 Power requirement

Volume of cutting disc, V_C, is given by Khurmi and Gupta (2008) as

$$V_C = \pi r^2 h \tag{1}$$

where: r = radius of the cutting disc and h = thickness of the cutting disc

Mass of the cutting disc, M_c, is given by Khurmi and Gupta (2008) as

$$M_c = \rho V_C \tag{2}$$

where ρ = density of galvanized iron (7850kg/m^3) (Khurmi and Gupta, 2008) and *Vc* = volume of cutting disc (m^3).

Force due to centrifugal action of wheel, F, is given by

$$F = \frac{M_c V^2}{r} \tag{3}$$

where V = velocity of the cutting disc = ωr, and ω = angular velocity in rads/sec. For an N rpm,

$$\omega = \frac{2\pi N}{60} \tag{4}$$

Total torque required, T, is

$T = F \times r$ (5)

where F = Total force required in N and r = Radius of the cutting disc in m.

Power required to drive the machine (W), is

$P = \frac{2\pi NT}{60}$ (6)

where N = speed of the cutting disc in rpm and T = total torque required in Nm.

2.3.2 Pulley Design

The diameter of the pulley required was obtained from velocity ratio relationship.

Velocity ratio, $D_1N_1 = D_2N_2$ (7)

where D_1 = diameter of the driver pulley, m, N_1 = speed of the driver, rpm, D_2 = diameter of the driven pulley, m and N_2 = speed of the driven pulley, rpm.

2.3.3 Belt Design

Power transmitted; $P = (T_1 – T_2)\, v$ (8)

where T_1 = tension in the tight side, N, T_2 = tension in the slack side, N and

v = velocity of the belt in m/s

The maximum tension on the belt, $T_{max,}$ is given by

$T_{max} = \delta_b \times b \times t$ (9)

where b = width of the belt, m, t = thickness of the belt, m and δ_b = stress on the belt, N/m^2

Mass of the belt per unit length, M_b is given by the expression

$M_b = \rho \times A$ (10)

where ρ = density of a leather belt ($1000 kg/m^3$) (Khurmi and Gupta, 2008), and

A = cross-sectional area of the belt, m^2

Centrifugal tension of the belt is given as T_c

$T_c = M_bV^2$ (11)

where M_b = mass of the belt per unit length in kg/m and V = velocity of the belt, m/s.

Width of the pulley is given as B

$B = 1.25b$ (12)

2.3.4 Shaft Design

Since the shaft will be subjected to a twisting moment, the diameter of the shaft was obtained using the torsional equation

$\frac{T}{J} = \frac{\tau}{r} = \frac{G\Theta}{L}$ (13)

where T = twisting moment (or torque) acting upon the shaft, J = Polar moment of inertia of the shaft about the axis of the rotation, $J = \frac{\pi d^4}{32}$, τ = torsional shear stress and r = distance from neutral axis to the outermost fiber $= \frac{d}{2}$; where d is the diameter of the shaft, G = modulus of rigidity (G = 82.5 GPa) of the shaft, Θ = angle of twist of the shaft, and L = length of the shaft.

2.3.5 Machine performance tests and analysis

The designed and fabricated machine was tested to evaluate its performance on the basis of chipping capacity and machine efficiency. The chipping capacity of the machine was determined by feeding the tubers into the machine to slice it within a period of one minute and then the chips produced weighed in order to determine the chipping capacity vis-a-vis to determine the efficiency of the machine. The efficiency of the machine was determined by slicing 10 kg of tubers, after which the chips produced were weighed. The weight of the tubers and that of the chips produced was compared in order to determine the efficiency of the machine.

3. Results and Discussion

Table1 shows that the machine has a minimum and maximum chipping capacity of 4.5 kg/min and 6.0 kg/min respectively. The average capacity of the machine was calculated to be 5.3 kg of cassava chips per minute.

Table 1: Chipping capacity

Serial number	Time taken to chip (minutes)	Weight of the chip (kg)
1.	1	4.5
2.	1	5.0
3.	1	5.5
4.	1	6.0
5.	1	5.5

Average capacity of the machine = 5.3 kg of cassava chips per minute

Table 2: Efficiency of the machine

Serial number	Time taken to chip (minute)	Weight of cassava before Chipping (kg)	Weight of chipped cassava (kg)
1.	1.50	10	9.5
2.	1.49	10	9.6
3.	1.52	10	9.5
4.	1.50	10	9.7
5.	1.51	10	9.5

Average machine efficiency = 95.6%

From Table 2 it can be seen that the average efficiency of the machine was 95.6%. Inspection of the cassava chips produced showed generally similar size was obtained. The design of the chipping section helped in achieving this quality attribute. This provides a very easy way of obtaining cassava chips at a very high rate.

4. Conclusions

A cassava slicing machine was designed, fabricated and tested. It has an efficiency of 95.6% with an average capacity of 5.3 kg/min and highest capacity of 6.0 kg/min. The machine produced chips of similar size and shape. It has been designed for ease of operation and maintenance without special training. The machine is recommended for medium scale cassava processing.

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