Design and Fabrication of a Cassava Peeling Machine

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ABSTRACT

The varying shapes and sizes of cassava tubers have made cassava peeling to be one of the major problems in the mechanization of cassava processing. A cassava peeling machine was designed and constructed. The design parameters include a power requirement of 0.36hp, belt tensions of 349.7 and 1807.5N and shaft diameter of 35mm. Its main component is a peeling chamber, which consists of two perforated drums rotating in the opposite direction. The machine had an average capacity of 44.50kg/hr, an average peeling efficiency of 83% and an average percent flesh loss of 5.38%.

Keywords: cassava, peeling, peeling efficiency

INTRODUCTION

Cassava (*Manihot esculenta Crantz*) is the 4th most important staple food in the world after rice, wheat and maize (IFAD/FAO, 2000). Its high yield in poor soils and ability to stay in the soil for long periods after maturity make cassava an important food security crop in low-income countries (de Bruijn and Fresco, 1989). The cultivation of cassava requires minimal input, but the processing of cassava roots is laborious and time consuming (Lancester *et al*, 1982). However processing of root crops is essential to reduce its perishability and therefore a very little portion is consumed as fresh products. This is because cassava roots deteriorate within few days after harvest with the onset and rate of deterioration varying between cassava varieties (Wenham, 1995). Some varieties deteriorate within 24 hr of harvest, while some can be left at room temperature for 7 to 11days.

Cassava can be processed into several storage products in Nigeria as listed by RAIDS/IFAD (1991) which include cassava flour, 'gari', 'lafun', 'fufu', 'pupuru', 'abacha', dried cassava chips/pellets and other industrial products like starch and alcohol. Processing cassava into storable and economic products involves different combinations and sequence of two or more of a number of processing steps which includes; washing, peeling, splitting (i.e chipping or slicing), pulping (i.e crushing, grating or grinding), steaming, water expressing/dewatering, fermentation, pulverizing, sieving or sifting of mash, roasting or frying and sun or smoke drying.

The operations involved in the preliminary processing of various forms or products of cassava include washing, peeling and size-reduction generally. Peeling which is defined as "to strip off the skin" is an important operation in the processing of any tuber or root crop. Traditionally, the operation of peeling is done manually using a knife to remove the thin outer layers of the tuber. This is often time wasting and energy consuming which invariably leads to low productivity. There is therefore the need for this operation to be done mechanically.

A number of peeling machines have been developed among which include the following: a continuous process cassava peeler developed by Odigboh (1976). It consists of a cylindrical knife assembly and a solid cylinder, mounted parallel and 20cm apart on an inclined frame. The machine was reported to have very high efficiencies, over 95%, when handling lots of even sized cassava tuber pieces, but had lower efficiencies, about 75%, when peeling mixed sizes of cassava tubers.

Another peeler, a batch process cassava peeling machine was developed by Odigboh (1979) and later modified (Odigboh, 1981). In this modification a cylindrical drum with abrasive inner surfaces was eccentrically mounted on a shaft and the eccentric movement of the cylinder causes the tuber to rotate and tumble thus peeling the tubers.

Ohwovoriole *et al (1988) developed a preliminary design for* a continuous process cassava tuber peeling machine. The design is based on the principle that if a cut is made on a tuber and the peel is held down or fixed; the whole peel would "unwind" as the tuber is rolled especially when it is fresh. Sheriff et al (1995) evaluated a cassava peeler developed at the Tamil Nadu Agricultural University (TNAU) where tubers were fed into the peeler through a feed tray. As the rotor shaft rotates, the cutting blades mounted along the circumference of the rotor scrapes off the tuber surface. The maximum capacity of peeler was 847kg/hr at 200 rpm and peeling efficiency and flesh loss were 50.64% and 15.87% receptively.

However, all these have not solved the problem of peeling cassava completely since the use of the machines led to other problems, which include complexity of design, inefficiency of peeling etc. Therefore the objective of this work is to design and fabricate a cassava peeling machine that is easy to operate and will effectively and efficiently peel cassava.

MATERIALS AND METHODS

Machine Description

The peeling machine (Fig. 1), which was fabricated at Federal College of Agriculture, Ibadan consists of the following components;

(i) Peeling drums which were constructed using guage 18" galvanised metal sheet. Two metal sheets, one of dimensions 104cm x 145cm for the outer cylinder (Fig. 2) and another of dimensions 99cm x 82cm for the inner cylinder (Fig. 3) were rolled into cylindrical shapes to form drum of diameters 46cm and 26cm respectively. The outer drum was punched with a chisel on the inner side while the inner drum was punched on the outer side to give the abrasive surfaces for peeling. The outer drum has two openings, one on the upper part of the drum, which serves as an inlet for tubers to be peeled and another opening on the opposite lower part of the drum to serve as an outlet for peeled tubers. The position of the peeling drums ensures effective contact between the tubers and the abrasive surfaces.

(ii) A shaft for rotating the drums, which was produced using mild steel rod.

(iii) A frame, which is at an angle to the horizontal (to achieve easier discharge of peeled tubers). It is the main supporting stand upon which other components are mounted and is constructed using mild steel angle iron.

(iv) The power unit, which consists of three V-belts, used to transmit power from the electric motor to the various components of the machine.

Operation Of Machine

The tubers were washed and placed in water to soften it before being loaded into the space between the inner and outer cylinder through the inlet. The machine was not fully loaded so that effective peeling can be achieved. The inlet opening was closed and the power was switched on. The speed of the electric motor was transmitted, and reduced subsequently, to a shaft situated 35cm from the top of two of the frame legs. The power was further reduced as other belts transmit the power to the two cylinders. The spiral arrangement of the belt of the pulley of the inner drum results in the inner drum rotating in the opposite direction to the outer drum. The opposite rotation of the two peeling cylinders/drums increases the efficiency of peeling. The power was switched off, the outlet was opened and the peeled tubers were collected at the lower end.

DESIGN CONSIDERATIONS

The following equations were used to design the components of the cassava peeling machine.

(i) Capacity Design

Mass of cassava contained in chamber = Volume of chamber x Density of cassava . (1)

(ii) Power Requirement

Total power required = Pr + Ps + Pp .... (2) (Hall *et al*, 1983)

Where Pr = power to rotate cylinder + tubers

Ps = power to rotate shaft

Pp = power to peel tubers

(a) $Pr = Tr \times Wr$ .... (3)

where Wr = speed of rotation of tuber + cylinder

Tr = Torque needed to rotate cylinder

(b) $Ps = Ts \times Ws$ .... (4)

where Ws = speed of rotation of shaft

Ts = Torque needed to rotate shaft

(c) $Pp = Tp \times W$ .... (5)

where W = speed of rotation

Tp = Torque needed to peel cassava

∴ Power required = Pr + Ps + Pp

= 83.9 + 4.77 + 183.4 watts

= 272.07 watts = 0.2702 kw

$= \frac{\text{Total power}}{0.746}$ hp = 0.36 hp

Using a factor of safety of 2, power required is 0.72 hp. Therefore a motor of 1 hp is chosen to provide power to rotate cylinder, tuber and shaft and also to peel cassava.

(iii) **Belt Design**

$$\frac{T_1 - MV^2}{T_2 - MV^2} = e^{\mu a / \sin \frac{1}{2} q} \quad \text{........ (6)}$$

(Hall *et al*, 1983)

For open belt drive

Angle of wrap,

$$a = 180 \pm 2\sin^{-1}\frac{(R - r)}{C} \quad \text{............ (7)}$$

(Hall *et al*, 1983)

While for crossed belt,

Angle of wrap,

$$a = 180 + 2\sin^{-1}\frac{(R + r)}{C} \quad \text{.................. (8)}$$

(Hall *et al*, 1983)

Angle of wrap,

$$a = 180 \pm 2\sin^{-1}\frac{(R - r)}{C} \quad \text{.................. (9)}$$

For design, the pulley with smaller value governs design. Therefore the angle of wrap for the open belt drive was chosen because it was lower.

$T_1 = 1807.5N$ and $T_2 = 349.7N$

Resultant of belt tensions is $T_1 + T_2$

$\therefore T_1 + T_2 = 1807.5 + 349.7$

$= 2157.2N$

(iv) **Shaft Design**

(a) Design of Shaft Based on Strength

Shaft diameter is calculated as follows.

$$d^3 = 16/\delta S_S \sqrt{(K_t M_t)^2 + (K_b M_b)^2} \quad \text{....... (10)}$$

(Hall *et al*, 1983)

Where K_b = combined shock and fatigue factor applied to B.M

= 1.5 for rotating steel shafts

K_t = combined shock factor applied to torsional moments (TM)

= 1.0 for rotating steel shafts

S_S = Allowable for steel shafts = $55MN/M^2$

M_t = 30.36Nm

M_b = 299.5NM

∴ d = 30.5mm and a diameter of 35mm is chosen

(b) Checking shaft based on torsional deflection

$$\theta = \frac{584 M_t L}{G d^4} \quad \text{..... (11) (Hall } et\ al\text{, 1983)}$$

Where è = deflection degree

M_t = torque in Nm

L = 147cm = 1.47m

G = Modulus of rigidity = 80 GN/M^2

∴ θ = 0.488

∴ Angle of twist/meter $= \frac{0.488}{1.47m}$

$= 0.33\ ^{o}/_{m}$

For steel shafts, permissible angle of twist = $3\ ^{o}/_{m}$

The angle of twist per meter is less than the permissible angle of twist, therefore torsional deflection criteria is satisfied.

Performance Tests

The cassava tubers were weighed and then loaded into the peeling chamber (the space between the two peeling drums) (Fig. 4). The drums were rotated in opposite directions for 8, 10 and 12 min before it was stopped. The discharge opening was opened and the samples were removed. The peeled tubers were weighed. The remaining peels were carefully peeled manually and reweighed to obtain weight of peels remaining on the tubers after using the peeling machine.

The operation of the machine was compared to the manual method of peeling. For the manual method of peeling, different tubers each of known weights were selected and peeled manually. Tests were carried out to compare the use of the machine to peel with the manual method of peeling.

(i) Percentage weight of peel (%).

$$\% \text{ wt of peels} = \frac{\text{weight of peels}}{\text{weight of unpeeled tubers}} \times \frac{100}{1}$$

(ii) Peeling efficiency (PE)

$$PE = \frac{\text{weight of peels moved by machine}}{\text{Total weight of peels}} \times \frac{100}{1}$$

$$= \frac{\text{percentage weight of peel-weight removed manually}}{\text{percentage weight of peel}}$$

Where Total weight of peels = % wt of peels x weight of unpeeled tubers

(iii) Percentage flesh loss (% F.L.)

$$F.L. = \frac{\text{weight of flesh removed by machine}}{\text{total flesh weight of tubers}}$$

(iv) Machine through put capacity (M.T.C)

$$M.T.C = \frac{\text{Mass of cassava peeled (kg)}}{\text{Time taken to peel (hr)}}$$

RESULTS AND DISCUSSIONS

The results obtained from the performance tests are as shown in Table 1 for the manual peeling and Table 2 for the mechanical peeling.

Table 1: Manual Peeling of Cassava.

Wt of tuber (kg)	Wt of peeled tuber (kg)	Wt of peels (kg)	% weight of peels
8.15	6.48	1.67	20.49
8.00	6.38	1.62	20.25
7.10	5.64	1.46	20.56
7.00	5.57	1.43	20.43
6.50	5.15	1.35	20.77
6.45	5.13	1.32	20.47
		Mean	20.5

Table 2: Mechanical peeling of cassava

Speed of rotation rpm	Duration of peeling (mins)	W_1 (kg)	W_2 (kg)	W_3 (kg)	W_4 (kg)	W_5 (kg)	W_6 (kg)	W_7 (kg)	PE (%)	F.L. (%)	Capacity kg /hr
57	8	6.50	5.18	1.32	4.97	0.21	1.33	5.17	84.2	3.87	48.75
57	10	6.00	4.77	1.23	4.58	0.19	1.23	4.77	84.6	3.98	36.00
57	12	7.00	5.54	1.46	5.33	0.21	1.44	5.56	85.4	4.14	35.00
66	8	8.00	6.31	1.69	6.02	0.29	1.64	6.36	82.3	5.35	60.00
66	10	7.50	5.92	1.58	5.66	0.26	1.54	5.96	83.1	5.03	45.00
66	12	7.00	5.50	1.50	5.26	0.24	1.44	5.56	83.3	5.40	35.00
90	8	7.50	5.84	1.66	5.55	0.29	1.54	5.96	81.2	6.88	56.25
90	10	7.00	5.46	1.54	5.19	0.27	1.44	5.56	81.3	6.65	42.00
90	12	8.50	6.60	1.90	6.28	0.32	1.74	6.76	81.6	7.10	42.50
								Mean	83.0	5.38	44.50

Where W_1 = weight of unpeeled tubers
W_2 = weight of tubers after peeling with machine
W_3 = weight of peels + flesh removed by machine
W_4 = weight of tubers after removing remaining peels manually
W_5 = weight of peels not peeled by machine
W_6 = Assumed weight of peels = 0.205 x W_1 (from Table 1)
W_7 = Assumed weight of tuber flesh

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The capacity of the machine ranged from 35 kg/hr to 60kg/hr as shown in Table 2. It is generally observed that an increase in speed of rotation decreased the peeling efficiency. This is probably due to the fact that as speed of rotation increases, the tubers to be peeled have less contact time with the peeling surfaces, therefore the amount of peels removed within the same duration will be less than when the speed of rotation is decreased. Thus the machine should be run at low speeds of rotation.

The percent flesh loss, which is an indication of the amount of useful flesh removed with the peels, increased with an increase in speed of rotation. This is probably due to the fact that an increase in speed of rotation of drums also increases the speed of rotation of the tubers and therefore within seconds, the tubers would have rotated such that the same surface will be peeled again.

Generally, the peeling efficiency and the flesh loss increased with time of peeling. This is because as the peeling continues, due to the rotation of the drums more surfaces of the tubers come in contact with the peeling surfaces and as a result, the peels are removed and in areas where the peels have already been removed, more of the useful flesh will be removed.

CONCLUSION

The fabricated machine had an average peeling efficiency of 83.0% and an average percent flesh loss of 5.38%. Low speeds of rotation of the machine will increase the peeling efficiency and decrease percent flesh loss.

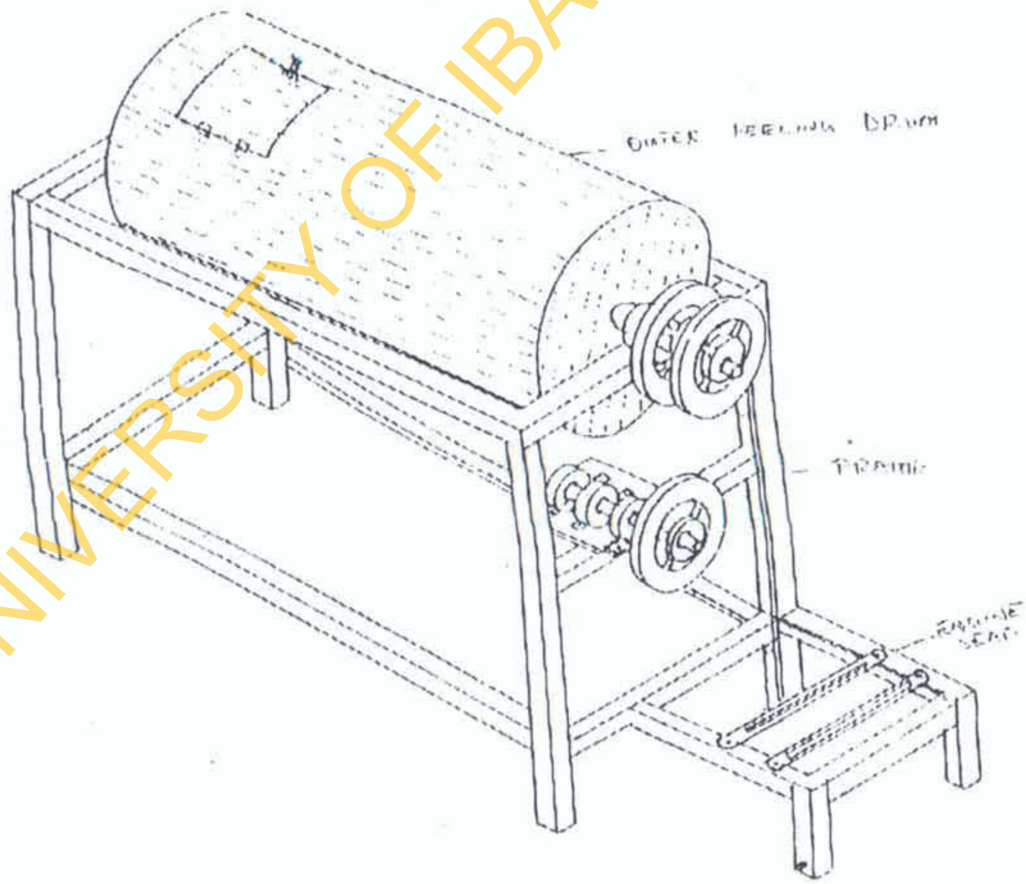

Fig. 1: Peeling Machine

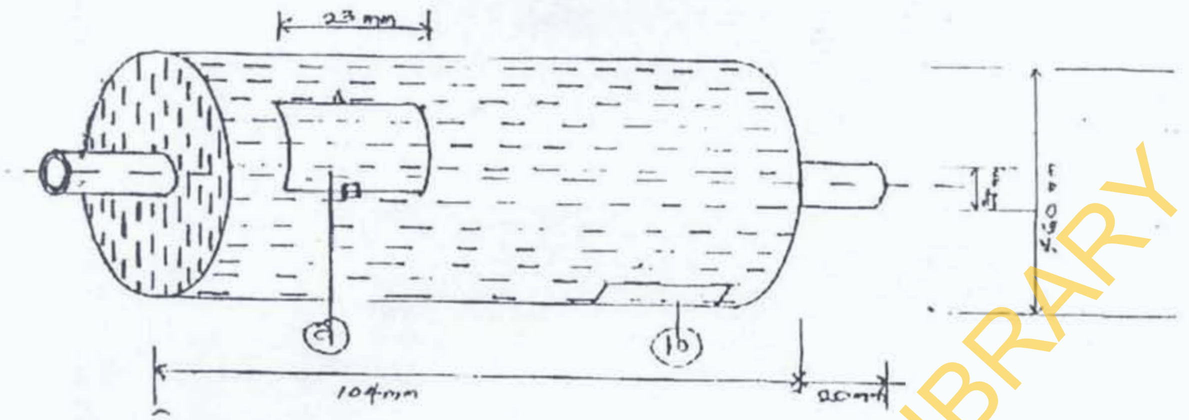

Fig. 2: Outer Peeling Cylinder Drum

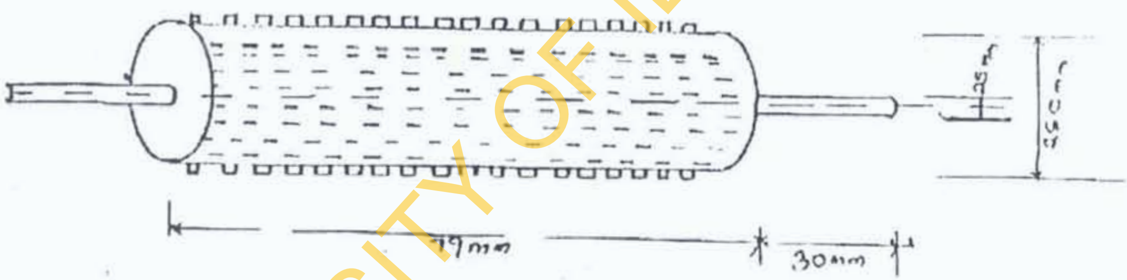

Fig. 3: Inner Peeling Cylinder Drum

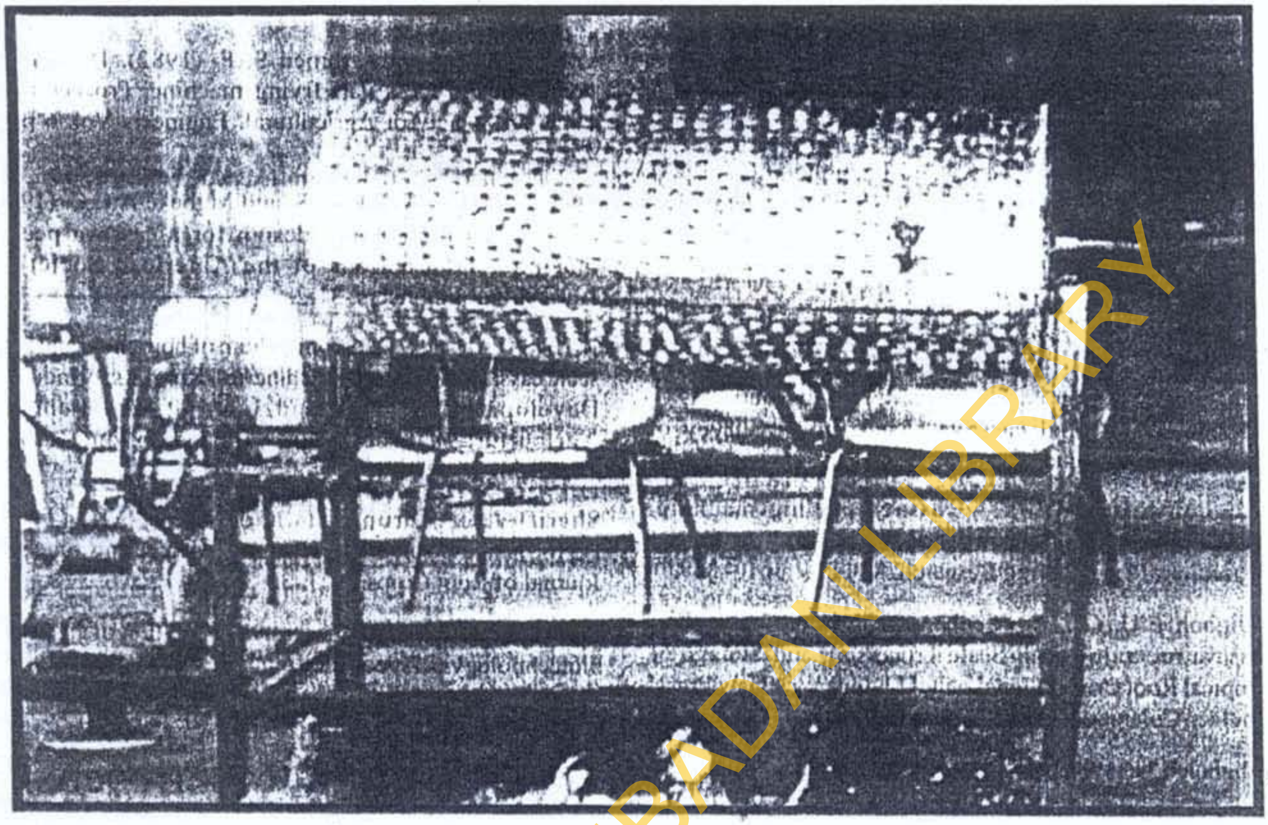

Fig. 4: Peeling Machine in operation

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