Development of a motorized cassava peeler to suite small and medium scale enterprises

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Abstract: In Ghana a lot of products are produced from cassava roots, but processing of most cassava product requires peeling. Cassava peeling in Ghana is a major manual activity, which is time consuming and labour-intensive and hence requires mechanization. A motorized cassava peeler with four different lining materials (concrete, metal, rubber and wood) was developed and tested with two local cassava varieties (Asi-Abayiwa and Dabon). The batch loading weight, peel removal efficiency, percent flesh loss and peeling capacity of the peeler were determined. The batch loading weight of the peeler was 6 kg, an average peel removal efficiency of 71.8%, average percent flesh loss of 28.83% and a peeling capacity range of 157-1439 kg h^{-1} for all lining materials. The test results showed that the peeler could perform its intended purpose efficiently. Rubber and wood lining material's ability to perform peeling was one of the greatest outcomes of this studies. Further studies should focus on the cassava varieties that will be favourable for mechanical peeling.

Keywords: peeling, cassava, testing, capacity and design

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1 Introduction

Cassava (*Manihot esculenta* Crantz), also known as manioc, mandioca, or yucca in South America, or tapioca in Asia, is a starchy root crop (Ferraro et al., 2016). Cassava ranks fourth among staple crops, after wheat, corn/maize and rice, with a global production of about 288 million tonnes in 2016, which is 8 million tonnes greater than the previous year, restoring cassava's status as one of the world's fastest expanding staple crop (FAO, 2016). Cassava is as rice for most African population and the Asian people, or as wheat and potatoes for the European people (FAO, 2013).

Sub-Saharan countries are the leading cultivators of cassava, altogether accounting for 62% of world production with Nigeria being the leading producer (Angelucci, 2013). Though cassava is an important carbohydrate source (32.68%) with very low protein content (2.09%), cassava can be processed into many food products such as *gari*, *fufu* and flour (Asare et al., 2011; Rajapaksha et al., 2017). Apart from human food, cassava is also used for animal feed and alcohol production (Oppong-Apane, 2013; Jansson et al., 2009).

African countries are still suffering from poorly developed post-harvest systems and processing

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technologies, which in the case of cassava needs to be particularly effective and timely given the high perishability of the fresh roots and the presence of cyanogenic compounds in the cassava roots (Angelucci, 2013). Fresh roots need to be processed within 48 hours from harvest (Adebayo et al., 2014). Available data shows that up to about 34 percent of the cassava produced in Ghana is lost along the food chain and hence processing of cassava into more storable forms offers an opportunity to overcome the perishability of the fresh produce (Office of Grant and Research, 2015). A wide variety of products are produced from cassava roots, especially in Africa and South America, and most of the products require peeling of the root. Peeling is simply the removal of the cassava peel (made up of the outer corky periderm and cortex) from the rest of the root (Heuzé et al., 2016). Several cassava processing operations have been mechanized successfully, however, cassava peeling remains a serious global challenge to engineers involved in cassava processing (Olukunle, 2012). In the food industry, the peel needs to be completely removed without removing the useful root flesh and is only the fufu method (peel is slit along the length of one side of the root and the knife blade and fingers are used to roll back the peels from the fleshy portion of the root) and dough method (the two layers of peel are carved with a knife in a motion resonant to sharpening of a pencil) of peeling can be used (Ugwu and Ozioko, 2015). The problem encountered in peeling cassava roots emanate from the fact that cassava roots exhibit appreciable differences in weight, size, shape, peel thickness, peel texture and strength of adhesion of peel to the root flesh. The way forward is the development of an appropriate mechanical device and system for peeling cassava before chipping or grating.

The objective of this study was to develop a motorized cassava peeler for small and medium-scale enterprises and test it with two popular local cassava varieties on the Ghanaian market (*Asi-Abayiwa* and *Dabon*).

2 Design Considerations

The design of a technical system to eliminate tedium and post-harvest loses associated with cassava peeling activities due to time spent during peeling is required. The purpose of the technical system is to separate cassava peels from flesh. The main flow of the system is material since it will peel cassava, hence the technical system is an equipment. The main function of the equipment is to peel and separate the flesh from the peels to be collected for further processing. The sub-functions of the system are to:

i) store cassava temporarily

ii) peel cassava

iii) clean cassava and

iv) eject cassava after peeling

The final design was selected after scrutinizing three potential design concepts shown in Table 1 with set criteria.

Table 1 Morphological chart of concepts

Solution					
Sub-functions		1	2	3	4
Working geometry	Shape	Square	cylinder	rectangle	Cone
	Position	Slanted	horizontal	Vertical	
Working motion	Type	Stationary	rotational	translation	
	Direction	about y-axis	about x-axis		

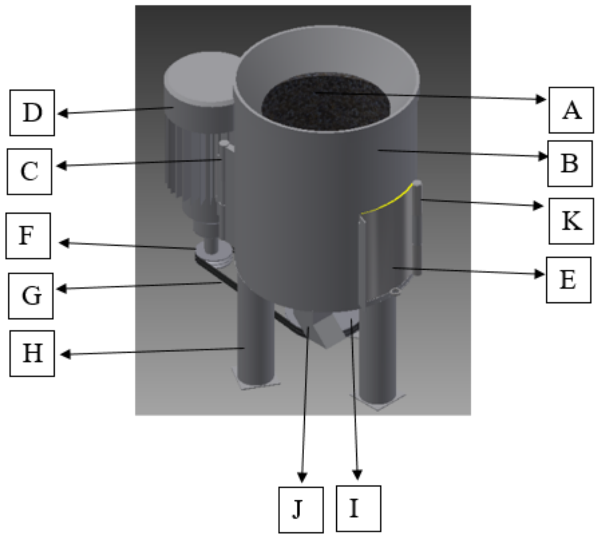
S3 S2 S1

Concept screening matrix was used and concept S3 outweighs all the other two concepts (Figure 1). The concept of abrasion was used in developing the cassava peeler and the principle of a stationary, internally abrasive drum with a rotating abrasive base plate was employed. Cassava root will be fed into the drum, and with the appropriate speed of the rotating base disc, which will be transmitted from a motor, the cassava roots will be peeled as the rotating disc moves it and it scratches the walls of the drum for some period. The questions that arise in the attempt to adopt this peeling concept for which this peeler was designed to address are:

What must be the average time for an efficient peeling of roots?

At what speed, must the rotating base plate move such that effective peeling will be achieved?

What quantity of roots, should be fed into the peeler for effective peeling?



A- Lining assembly, B- Cylindrical drum, C- Motor seat assembly, D- Electrical motor, E-Gate, F- Driver pulley, G- V-belt, H- Stand, I- Driven pulley, J- Peel spout, and K- Gate hinge

Figure 1 Motorized cassava peeler

2.1 Design analysis and material selection

The following design parameters were identified in sizing and analysing the essential component of the peeler:

2.2 Capacity design

Volume of the peeler (V) = Area (A) × Height(h) {i.e. equation of volume of cylinder}

Where, design diameter of drum (D) = 0.42 m and design height of drum = 0.49 m.

$$V=\frac{\pi(0.42)^2}{4}\times 0.49 = 0.06789\ m^3 \approx 0.068\ m^3$$

$$\approx 68000\ cm^3\ at\ full\ load \quad (1)$$

Bulk density of raw cassava (ρ) = 630 kg m B^{-3} source: (Charrondiere et al., 2012)

The available capacity of the machine in kg is given by; M = ρv = 42.84 kg (2)

2.3 Power required

For the force needed to drive the rotating plate and the mass of cassava at full capacity (42.84 kg) in order to peel it, the mass, M_t, has to move with a tangential acceleration, *a*, (Physics Tutor, 2016)

M_t = Mass of cassava at full capacity

M_t = 42.84 kg

$$Ns \times Ds = Nm \times Dm \quad (3)$$

$$Ns=\frac{Nm.Dm}{Ds} \quad \rightarrow Ns=\frac{1450\times 10}{29}= 500\ rpm$$

Where, Ns is the speed of the driven pulley

Nm is the speed of the driver pulley, which is the motor speed (standard speed of motor on Ghanaian market = 1450 rpm)

Ds and Dm are the diameters of the driven and driver pulleys, respectively

Therefore,

$$Power\ (P) = T\omega \quad (4)$$

Where, 'T' is, the torque required to move the shaft and 'ω′ is the angular velocity or the rotational speed

$$T = M_t \times \mu \times g \times r \quad (5)$$

Where 'g' is acceleration due to gravity (9.81 m s^{-2}), M_t is mass of cassava at full capacity, 'μ' is the highest coefficient of static friction between the disc lining and the cassava roots and 'r' is the radial distance from the center of the rotating disc to the edge (0.21 m).

T=42.84 ×0.625×9.81×0.21= 55.16 Nm

Therefore, $P = T\omega = 55.16\times\frac{2\pi(500)}{60} = 2888.13\ W$

$P = \frac{2888.13}{764} = 3.78\ hp \approx 3.8\ hp$

A 5 hp was selected to run the peeler.

2.4 Belt design and selection

Considerations:

More wedging action is required in order to avoid frequent adjustment of initial belt tension, since constant torque transmission is needed at the rotating disc for efficient peeling.

Easy installation and changing.

Shock adsorption.

More grip on pulley during operation since the drive is going to be about the vertical axis

Synchronization of motor and shaft is not important due to limited space, since the clearance between the base of the peeler and the ground cannot accommodate the size of the motor.

In view of these critical requirements a V- belt is the best flexible drive that qualifies.

The optimum velocity (peak capacity) of V-belt is 4500 ft min^{-1} i.e. about 90% to 98% efficiency due to the good wedging action it possesses (Mott, 2004).

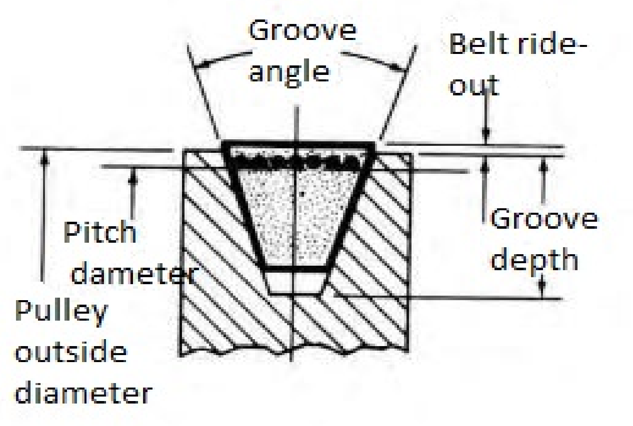


Figure 2 Belt section and groove geometry (source: Mott, 2004)

Design power rating, with respect to the available motor

$(h_{pr})_{input} = h_p(f_1+f_2)$ (Budynas and Nisbett, 2006) (6)

Where,

h_{pr} = design horse power

f_1=overload service factor for various types of driven unit = 1.4

f_2 = extra overload factor = 0.4

h_p= motor power = 5 hp single phase motor is used for the purpose of belt selection.

Allowable driven speed of the disc (Ns) = 500 rpm

Motor speed (Nm) = 1450 rpm

Centre distance between the two shaft (C_d) = 15 inch = 381 mm

Pitch diameter of the peeler pulley = 290 mm

$(h_{pr})_{input}$= 5 (1.4+0.4) = 9 hp

$$\text{Speed ratio (gr)}=\frac{Nd}{Ns}=\frac{1450}{500} \quad (7)$$

$gr = 2.9:1$

The driven pulley at the limit is D_s = 290 mm

$$\text{Hence driver pulley, } D_m = \frac{D_2}{gr} = \frac{290}{2.9} = 100 \text{ mm} \quad (8)$$

B belt section was selected using the design horse power 9 hp. The closest standard B belt section pulley = 101.6 mm and with motor speed of 1450 rpm the base hp rating of 3.92 hp was selected and also using the motor speed of 1450 rpm and the standard pulley 101.6 mm speed ratio adder of 0.725, was selected. Since the speed ratio is 2.9:1, i.e. 100 mm and 290 mm are the design driver and driven pulleys respectively. Choosing standard pulleys that are close and give the same speed ratio, driver pulley is 101.6 mm and driven pulley being 304.8 mm.

Belt length (L)

$$= \sqrt{(2Cd)^2-(D_s-D_m)^2}+\frac{\pi}{2}(D_s+D_m)+\pi\frac{(D_s-D_m)}{180}\alpha \quad (9)$$

Losing arc contact

$$(\alpha) = \sin^{-1}\frac{(D_2-D_1)}{2C_d}, \quad \alpha=\sin^{-1}\frac{(12-4)}{2(17)}=13.6° \quad (10)$$

$$L = \sqrt{(2\times17)^2-(12-4)^2}+\frac{\pi}{2}(12+4)+\pi\frac{(12-4)}{180}\times13.6°$$

L= 60.07 inch = 152.6 cm = 1526 mm

Standard transmission = transmission horsepower + speed ratio adder (Bando.com, 2016).

Standard transmission = 3.92 + 0.725 = 4.645 hp

$$\text{No. of belts} = \frac{\text{Design Hp}}{\text{standard transmission Hp} \times \text{coefficient of arc of contact} \times \text{coefficient of belt length}}$$

The coefficient of arc of contact and coefficient of belt length is 0.93 and 0.90 respectively (Bando.com, 2016).

$$\text{No. of belts} = \frac{9}{4.645 \times 0.93 \times 0.90} = 2.3 = 3 \quad (11)$$

Therefore 3- B60 belts are to be used in this drive, with a minimum centre distance allowance for installation (inches); 1.25 (31.75 mm).

2.5 Shaft Design

The shaft should be able to withstand;

i) Torsional shear stress,

ii) Horizontal or vertical shear stress,

iii) Bending stress, and

iv) Deflection or buckling due to the weight of cassava.

Mild steel was selected for the design, since it has good ductility which is good in absorption of shocks. For a shaft that will have keyway; according to ASME the ultimate tensile strength, S_u = 30% of the material ultimate tensile strength. Hence; S_u = 0.3(841) = 252.3 MPa.

Endurance strength of specimen:

S_n=0.5 ×S_u=0.5(252.3)= 126.15 MPa,

for steel where S_u<1400 Mpa,

Actual endurance strength, $S_n^{'} = S_n \times (C_m)(C_{st})(C_R)(C_s)$ (12)

Where,

C_m is the material factor (i.e. C_m= 1 for wrought steel).

C_{st} is the type of stress factor (i.e. C_{st} = 1 for bending stress).

C_R is the reliability factor (i.e. C_R= 0.75 for maximum reliability).

C_s is size factor (i.e. C_s = 0.75 for a 40 mm critical section).

$S_n^{'}$=(126.15)(0.75)(0.75)(1)(1)=70.96 MPa

Source: All the above factors were adopted from Beer et al. (2012) and Mott (2004).

From Figure 3 and 4, the Net driving force,

$$F_N = F_1 - F_2 \quad (13)$$

F_1 and F_2 are the forces on the tight and slack side of the belt, respectively.

$F_N = \frac{2T}{D}$, where T is rotational torque and D is the design diameter of the driven pulley = 29 cm

$$F_N = \frac{2}{0.29} \times \frac{764 \times 5}{52.96} = 503.17 \text{ N} \quad (14)$$

Bending force, $F_B = F_1 + F_2$ (15)

$F_B = 1.5F_N$. F_B = 1.5(503.17) = 754.76 N (16)

$F_2 = F_B - F_1$ $F_1 = \frac{754.76+503.17}{2}$ = 628.97 N (17)

Summation of all forces, i.e. $\sum f_x = 0$, $\sum f_y = 0$, $\sum M_x = 0$ and $\sum M_y = 0$

$\sum f_x = 0$, →R_1 - R_2 = F_N (18)

$\sum M_x = 0$, → R_2

×0.09+(F_N×0.08)=0 → $R_2 = \frac{503.17 \times 0.08}{0.09}$ = 447.26 N (19)

Substituting Equation 19 into Equation 18

R_1=503.17+447.26=950.43

Resolving all forces acting perpendicular to the rotation axis, i.e. from Figure 3.

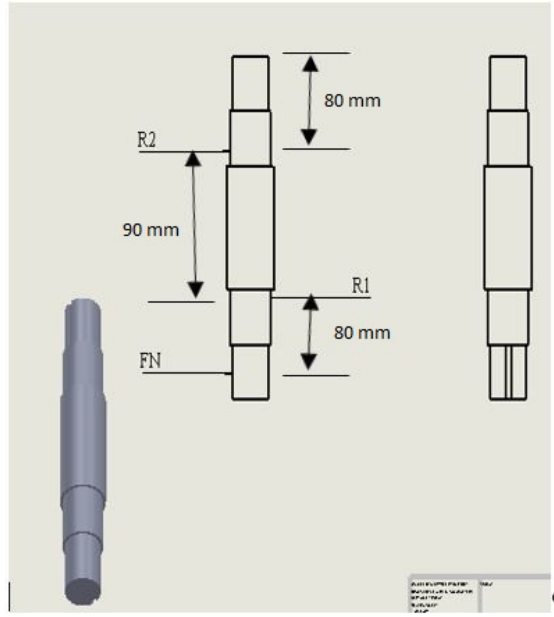


Figure 3 Shaft with its reaction forces

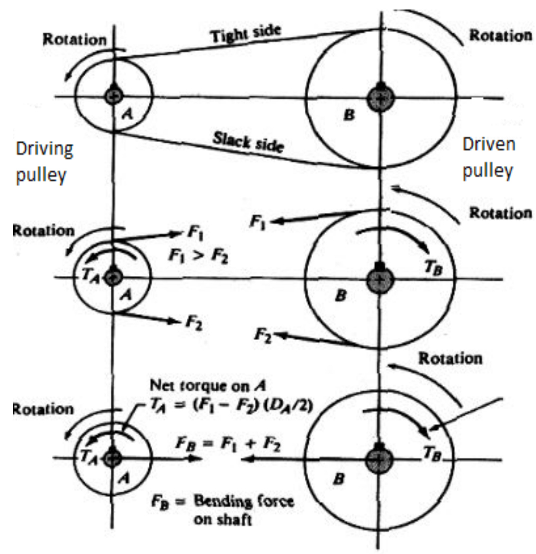


Figure 4 Schematic diagram of forces acting on a rotational shaft [source: Mott (2004).]

From the various considerations (Figure 5), torsional shear stress, horizontal or vertical shear stress, bending stress, and deflection or buckling, their shaft diameters were

D ≥ 17.3 mm, D ≥ 6.5 mm,

D ≥ 26.2 mm and D ≥ 1.73×10^{-6} mm, respectively. This means that bending stress is more critical and hence should be prioritized when selecting the size of the shaft. For the purpose of this work, a minimum shaft diameter of 40 mm was selected.

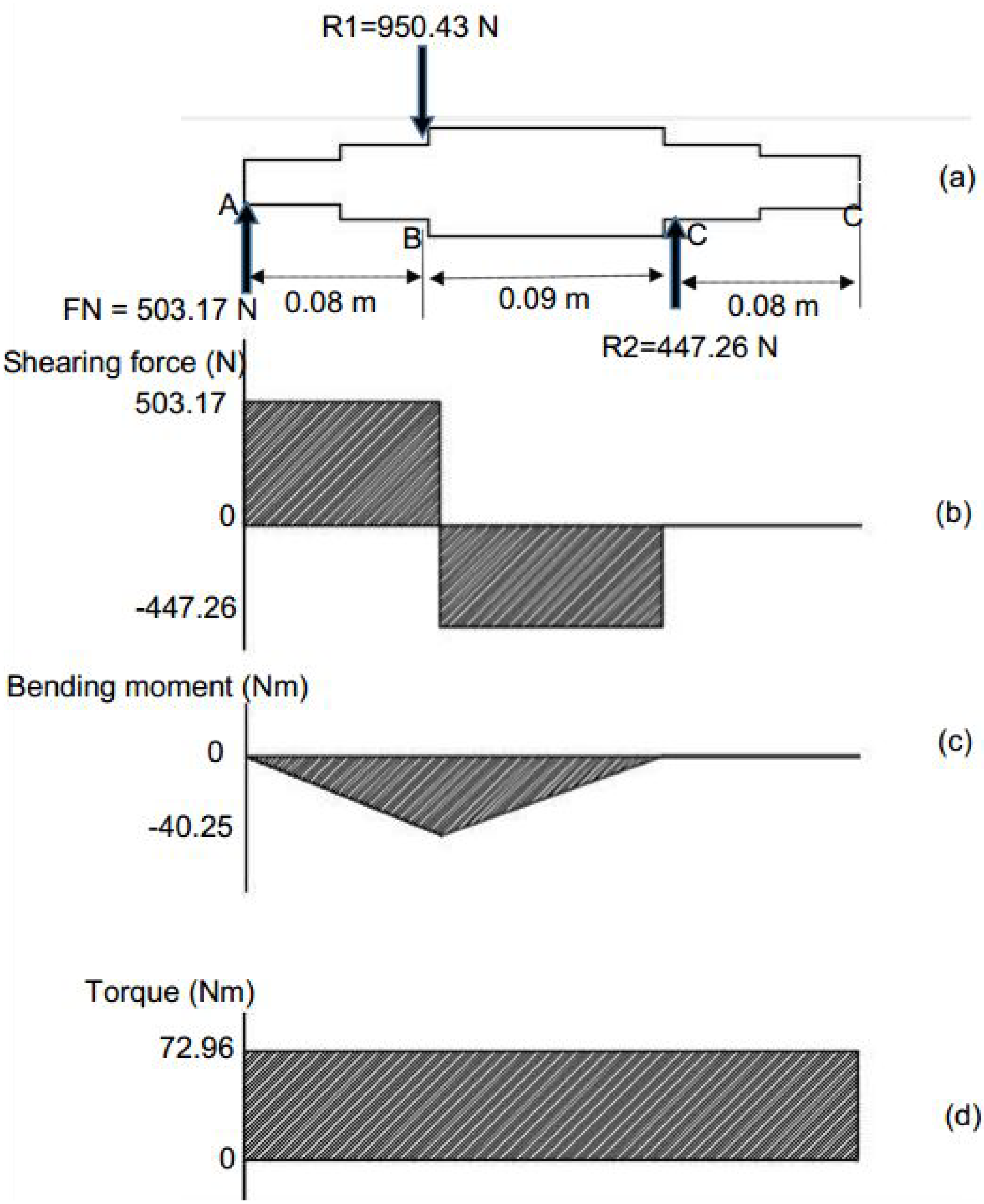


Figure 5 Force diagrams of shaft (a: Axial force diagram, b: shearing force diagram, c: bending moment diagram and d: torsion diagram)

3 Materials and Methods

Two prototype peelers (Figure 6) were constructed from the same design at the Department of Agricultural and Biosystems engineering, KNUST workshop (Latitude 6^{o}8’40.50” N, Longitude 0^{o}49’22.05” E) using mild steel at a cost of Gh¢ 2800. The construction and experiment were carried out on January 2016-June 2017.

Properties of mild steal used are as follows:

Ultimate tensile strength (Su) = 841 MPa

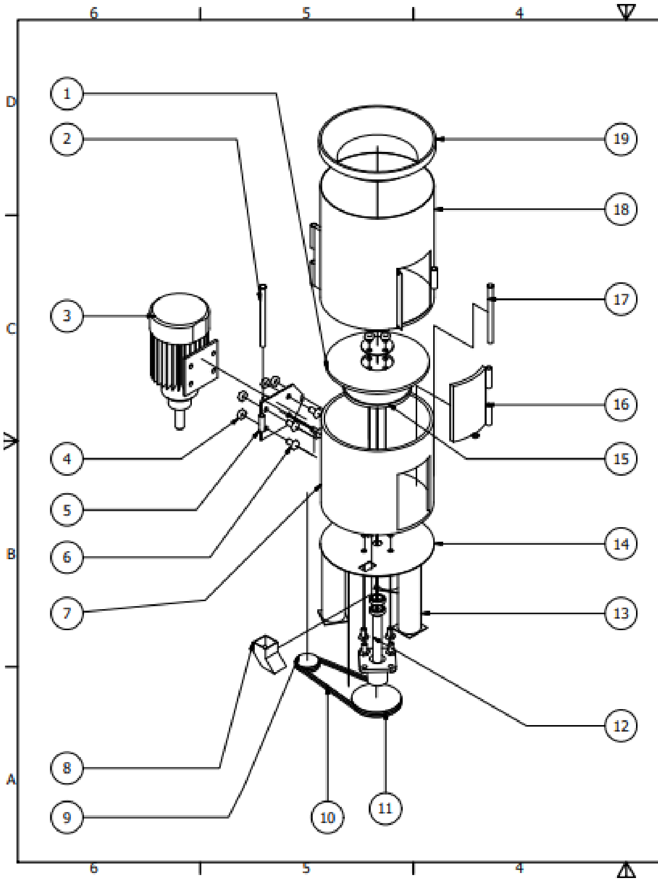
Yield strength (sy) a. tensional = 250 MPa, b. shear = 145 MPa

Modulus of elasticity (E) = 200 GPa

Modulus of rigidity = 77.2 GPa

Density (ρ) = 7860 kg m^{-3}

Coefficient of thermal expansion = 11.7 GPa



PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	Abrasive Plate	Concrete
2	1	Motor sit pin	MS 12mm rod
3	1	Electrical motor	5 hp
4	4	Nut	M16
5	1	Motor sit	MS 5mm plate
6	4	Bolt	M16 x 60
7	1	Cylinder lining	15mm Concrete
8	1	Peels outlet	MS 3mm plate
9	1	Grooved Pulley1	100mm diameter
10	2	V-Belt	Type B
11	1	Grooved Pulley2	214mm diameter
12	1	Shaft	40mm x 250mm
13	3	Motor Sit Pin	Stand
14	1	Base	MS 3mm plate
15	1	Rotating Plate	MS 5mm Plate
16	1	Gate	MS 3mm plate
17	1	Gate pin	MS 12mm rod
18	1	Cylinder	MS 3mm plate
19	1	Hoper	MS 3mm plate

Designed by	Checked by	Approved by		Date	
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KWAME NKRUMAH UNI. OF SCI. TECHNOLOGY COLLEGE OF ENGINEERING DEPARTMENT OF AGRIC. AND BIOSYSTEMS ENG.			Cassava Peeler Exploded view Part list	Edition 1	Drawing no. 002

Figure 6 Exploded view and part list of peeler

3.1 Construction of peeler

A 3 mm mild steel rolled into a cylindrical drum of 500 mm diameter and 600 mm height. The cylindrical drum was covered with a 5 mm circular plate, having a 55 mm hole created at the center to accommodate the shaft and the bearing seat. The gate 200 mm × 300 mm, which is shaped in such a way that its forms a curved surface with a radius equal to that of the drum. A circular strip of metal was cut and rolled into a truncated cone like shape with a 352.68 mm smaller diameter and a 512 mm bigger diameter to form a hopper. The rotating disc was cut into a circular shape of 420 mm diameter.

For the linings, concrete of 150 mm was cast into the drum of one peeler and the other linings (wood, rubber and metal) were fitted on a galvanized metal drum and made removable to be used in the second peeler.

3.2 Cassava varieties

Two of the popular local cassava varieties on the market; *Asi-Abayiwa* and *Dabon* were used for the experimental testing of the peeler. The cassava roots that were used to evaluate the peeler were obtained from cassava plants aged between 12 and 20 months after planting (MAP). The physical and mechanical properties of the varieties that affects mechanical peeling such as moisture content, bulk density, root peel thickness, root diameter flesh percent, shear stress, shear force and coefficient of friction were determined.

3.3 Performance testing

The machine was tested after design and construction, for observation of experimental short falls and also with the basic aim of verifying if the equipment could carry-out the basic function of peeling. Finally, known samples of two different cassava varieties (*Asi-Abayiwa* and *Dabon*) were used to test-run the peeler to verify if its efficiency of peeling is satisfactory. The peeler was tested with varying batch loading weight of cassava (5 kg, 6 kg and 7 kg) at 500 rpm or 52.36 rad s^{-1} (rotational speed) and the periods for satisfactory peeling were recorded. The results were collated and analysed and compared to manual methods of peeling (*dough* and *fufu* method of peeling cassava).

3.4 Determination of performance and operational parameters

The performance of the peeler was measured by the following parameters: peel removal efficiency (%), percent flesh loss (%) and peeling capacity (kg h^{-1}) of the peeler. The following equations and parameters were very essential in determining the performance of the peeler:

Mass of unpeeled cassava (m_{bp})

Mass of manually peeled cassava (m_{mc})

Mass of cassava after machine peeling (m_{mp})

Mass of cassava after manual hand trimming (m_{ht})

(i) Peel retained after mechanised peeling, kg (A) = $(m_{mp} - m_{ht})$ (20)

(ii) Gross loss, kg (G) = $(M_{bp} – M_{mp})$ (21)

(iii) Peel to flesh ratio (p) = $\frac{M_{bp}-M_{mc}}{M_{bp}} \times 100$ (22)

(iv) Actual mass of cassava flesh (B) = $\frac{(100-p)}{100} \times M_{bp}$ (23)

(v) Actual mass of peels, C (kg)= $M_{bp} - B$ (24)

(vi) Mass of peel that is removed by the peeler, C_R (kg) = C – A (25)

(vii) Mass cassava flesh that is recovered after peeling, R (kg) $= B - (G - C_R)$ (26)

(viii) Peel removal efficiency (μ_p) = $\frac{C_R}{C} \times 100$ (27)

(ix) Machine capacity (T.C) = $\frac{\text{mass of unpeeled cassava (kg)}}{\text{time (h)}}$ (28)

(x) Percent flesh loss (Pf) = $\frac{(G-C_R)}{B} \times 100$ (29)

(xi) An overall peeling quality index, (Q) = R× C_R (30)

3.5 Data analysis

The data collected during testing of the peeler was tested for normality using the Anderson-Darling normality test tool in the basic statistics tool park of Minitab version 17. The normalized data was analysed at 95% confidence level.

4 Results and discussion

4.1 Manual peeling

In Table 2 below, the peel removal efficiency, peeling capacity, percent flesh loss and peeling quality index of the two manual methods of peeling used (i.e. *fufu* method and *dough* method) are showed.

Table 2 Manual peeling of *Asi-Abayiwa* and *Dabon* variety results

Parameters	*Fufu* Method		*Dough* Method	
	Asi-Abayiwa	*Dabon*	*Asi-Abayiwa*	*Dabon*
Percent flesh loss (%)	0	0	11.65	9.55
Capacity (kg h^{-1})	32.07	43.64	40.59	50.96
Peel removal efficiency (%)	100	100	100	100
Peeling quality index	5.08	4.97	4.49	4.49

From the data for manual peeling (Table 2) for all two varieties the capacity of the *dough* method is higher than the *fufu* method. This has influenced the losses that occur during peeling with the *dough* method and the overall peeling quality index is also affected.

4.2 Effective loading weight

The peeling capacity in kg h^{-1} of the various linings tested at the different batch loading weight in kg is represented in Figure 7 and 8.

From Figures 7 and 8, the performance of the various lining materials at the different batch loading weights does not have any uniform pattern. The more weight added for rubber and concrete lining materials, the more the decrease in capacity. This is because an increase in load causes the roots at the base to grate rather than peeling, hence requiring more time to get majority of the roots peeled. For metal and wood, more loading weight causes higher capacities. This is because, the peeler grates the roots at the base and with metal lining being the most abrasive of all the lining materials, the higher the weight faster its ability to abrade and grate almost everything, hence the reduction in time of peeling which leads to higher capacities. Wood lining material does not grate but it breaks the roots when the loading weight is high, hence destroying the root and taking less time to peel.

In order to select the effective peeler loading weight, the mean performance for all linings at the three different weights were determined. A graph of means that show the trend in performance in terms of peel removal efficiency and percent flesh loss was plotted in Figure 9.

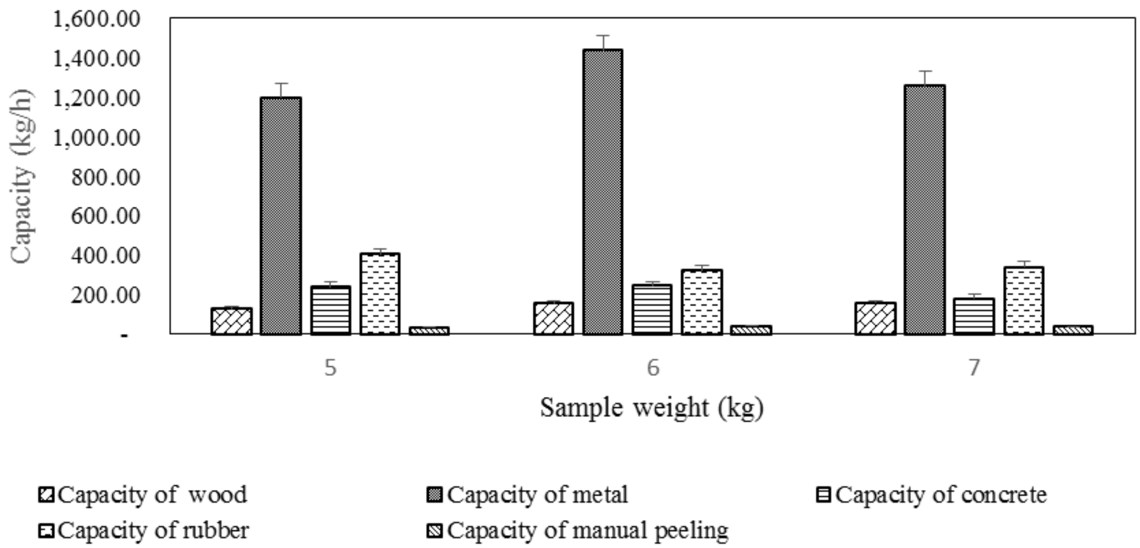

Figure 7 Capacity for motorized peeler for all the linings (*Asi-Abayiwa*)

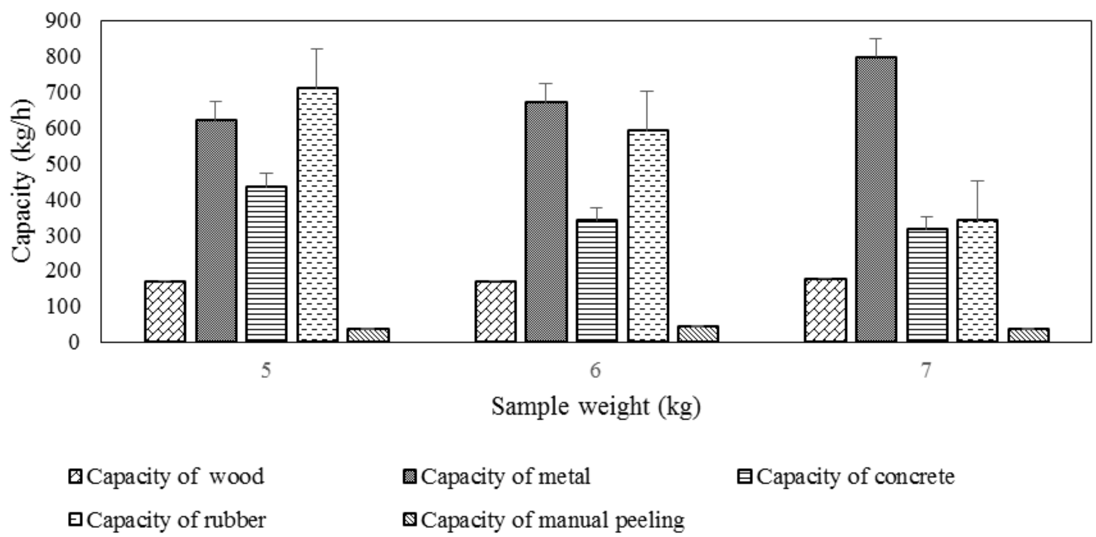

Figure 8 Capacity for motorized peeler for all the linings (*Dabon*)

From the peel removal efficiency trend line in Figure 9, the performance of the machine seems to increase from 5 kg loading weight and peaks around the 6 kg loading weight, with a value of 71.8%. The performance in terms of peel removal efficiency tends to decrease at loading weights above 6 kg, which the trend suggests lower performance at higher loading weights. When the load is heavy the disc lining causes roots at the base to grate more or record more loses, hence leaving the top roots with less percentage of peel removed.

The effect of restriction to effective movement by cassava roots to be peeled due to higher loading weight is evidenced by observing the trend line for percent flesh loss after peeling in Figure 9. From the trend line, the mean percent flesh loss increases with the increasing loading weight of about 3% per every 1 kg load addition and this is so because, the roots that are at the base grate almost entirely before the top roots make contact with the abrasive surfaces.

Considering the trend of performance showed in Figure 9, the 6 kg loading capacity stands out in terms of peel removal efficiency. Its flesh loss percent is 28.83%, which is also acceptable being compared it to the manual method of peeling for *dough* by the small-scale industries (Tables 2) and also less than 42% that was reported by Olukunle and Jimoh (2012). The peeling capacity of 6 kg loading weight for the four lining materials ranges from about 157to 1439 kg h^{-1}, which is higher than that of the manual methods as 10.4 kg h^{-1} reported by Agbetoye et al. (2006), hence 6 kg loading weight was selected.

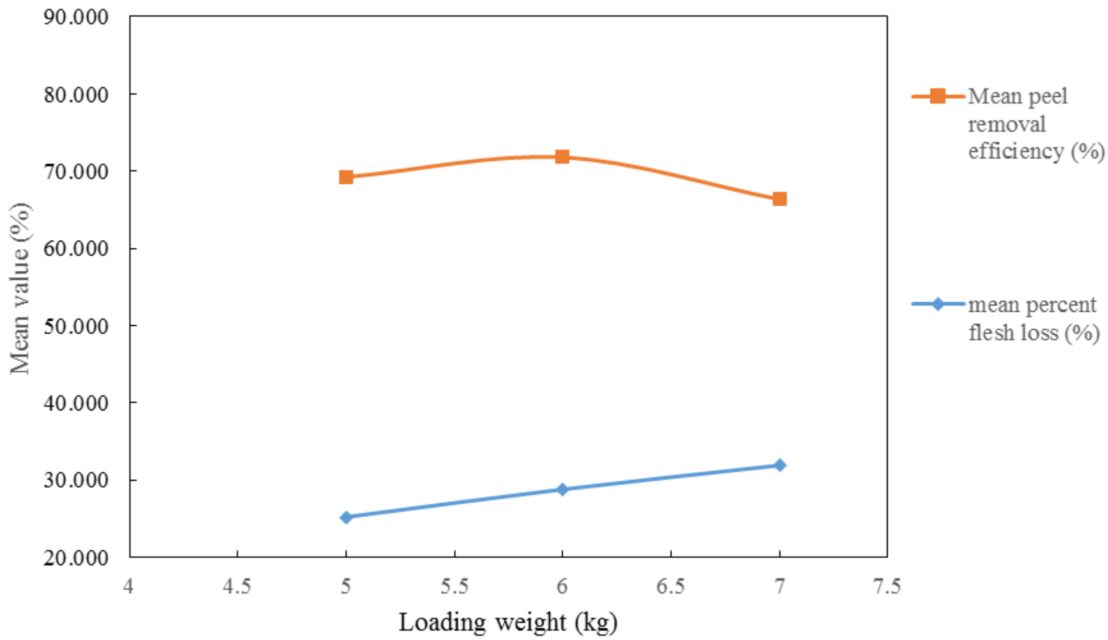

Figure 9 Average performance of the peeler at the different batch loading weights

4.3 Peeling duration and peeling quality index

Based on the selected batch loading weight of 6 kg, several tests were run with the different lining materials and the average peeling quality index at an optimized peeling time recorded in Table 3.

Table 3 Time for effective peeling for the lining materials at the design speed

Lining materials	Peeling quality index	Time in sec
Concrete	3.17	30
Metal	3.70	15
Rubber	3.82	40
Wood	3.79	150

The peeling duration (time) of the various lining materials shows the abrasiveness of their surface. The lower the peeling duration, the more abrasive a lining material and hence metal lining is more abrasive followed by concrete lining, rubber lining, and wood lining material.

4 Conclusions

After an intensive research, design, drafting and fabrication works, two prototype motorized cassava peelers with one having a fixed concrete lining and the other fitted with removable rubber, wood and metal linings were constructed and tested. Rubber and wood lining material's ability to perform peeling was one of the greatest outcomes of this studies.

A rated batch loading weight of 6 kg was derived for the prototypes. The average peel removal efficiency and percent flesh loss for all lining materials were 71.8% and 28.83%, respectively.

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