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DESIGN AND DEVELOPMENT OF AN IMPROVED CONTINUOUS CASSAVA PEELING MACHINE

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ABSTRACT

Cassava peeling remains the only unsuccessfully mechanized process which has constituted a global challenge to the cassava food industries. A major constraint in existing cassava peeling machine is the poor quality of finished products obtained, coupled with poor efficiency of the technologies. This research work is focused on the design and development of an improved continuous cassava peeling machine. The machine frame work is rectangular in shape measuring 2700mm in length by 1200mm in width. The principal parts of this design work includes a hopper, electric motor, shafts, bearings, wire brushes, pressure plate and a V-belt attached to the pulley that rotates the shafts embedded with wire brushes. Two conceptual designs were generated of which the best concept was selected via decision matrix for detail design. The machine was fabricated and tested and the following results were obtained from the analysis. An average value of 0.0617 and 0.095 were obtained for the throughput capacity and mechanical damage. An average value of 4.99% of useful flesh was lost and average peeling efficiency of 72.67 was obtained and this shows that the continuous cassava peeling machine was efficient.

***Keywords:* Cassava, peeling machine, efficiency, design, mechanical damage.**

INTRODUCTION

Cassava manihotesculenta, with common names cassava, Brazillian arrowroot, manioc and tapioca is a woody shrub of the euphorbiaceae (spurge) family and native of South America is extensively cultivated as an annual crop in tropical and subtropical regions for its edible starchy tuberous root, a major source of carbohydrate (Abdulkadir, 2012). Nigeria is currently the largest producer of cassava in the world with an annual output of over 34 million tonnes of tuberous roots (Uthman, 2011). It is majorly classified as sweet or bitter (manihot utilissima or manihot palmate) cassava respectively (Orhorhoro et al., 2016). According to Olukunle (2012), cassava production is needed in several areas; for enhanced food security, means of foreign exchange and tool for rapid industrialization. However, the drudgery in post-harvest processing can be minimized or eliminated through adequate mechanical processing (Adetunji and Quadri., 2011). The processing of cassava tuber industrially requires different operations such as harvesting, peeling, grating, etc. of which peelings has huge effect on the quality of the resultant product especially as regards to unwanted contents.

Before cassava tuber is processed into any of its food and some of its non-food products, it must be peeled. In food industries, the peel must be completely removed without removing the useful tuber flesh. Major cassava peeling problem arises from the fact that cassava roots exhibit appreciable differences in weight, size and shape (Adetunji and Quadri., 2011). There are also differences in the properties of the cassava peel which varies in thickness, texture, and strength of adhesion to the root flesh. The unit operation in cassava processing includes peeling, grating, boiling, drying, milling, sieving, extrusion and frying. Several cassava processing methods have been mechanized successfully. However, cassava peeling remains a global challenge to design engineers. A major constraint in existing cassava peeling machine is the poor quality of finished products obtained from these machines, coupled with poor efficiency (Olukunle and Akinnuli, 2013). In other to solve the problem of peeling cassava tubers, there is a need to design and develop an improved cassava peeling machine, capable of peeling cassava conveniently with improve efficiency.

MATERIALS AND METHOD

This phase involves how the materials and components used in the design of the cassava peeling machine are selected, practically fabricated and eventually put together. The machine frame work is rectangular in shape measuring 2700 mm in length by 1200 mm in width. It consists mainly of hopper, electric motor, shaft, bearing, wire brush and V-belt attach to the pulley that rotate the shaft embedded with wire brush. The cassava peeling machine was evaluated to determine the power, speed and force that are required to remove the cortex without significant loss of the starchy flesh. The power required to peel the cassava tuber is the power required to drive the shaft carrying the wire brush.

Design requirement

The following design requirements were applied;

i. Estimation of force and power required by the machine (watts)
ii. Determination of approximate length of the belt (m)
iii. Determination of load on shaft pulley and belt tensions (N)

iv. Selection of bearing for shaft
v. Determination of minimum shaft diameter (m)

Design consideration

These facets were considered in the design process:

i. Materials for fabrication,
ii. Ease of use,
iii. Maintenance,
iv. Safety,
v. Cost.

Conceptual designs

To achieve the end goal, two different conceptual designs were carried out. A concept is a more specific implementation idea of the strategy chosen.

Design concept one

The first concept involves loading the cassava tuber into a hopper, attached to a peeling chamber consisting of three blades fixed on a solid shaft. The components of the machine are; bearing, belt, mild steel, variable electric motors and shaft. The loaded cassava tubers go into the peeling chamber. The peeling operation is based on the orientation of the peeling blade. The forward linear speed of the tuber is governed by the relative opposing motions of the peeling blade on the shaft. The opposing movement of the peeling blade causes the shear force needed to peel and turn the tubers. The turning effect exposes other unpeeled part of the tubers to be peeled. Hence, peeling is achieved. The machine is powered by an electric motor. Figure 1 shows the model view and Figure 2 shows the skeletal view of design concept one.

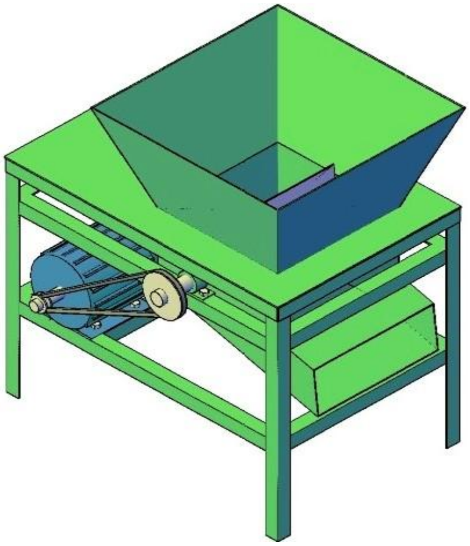
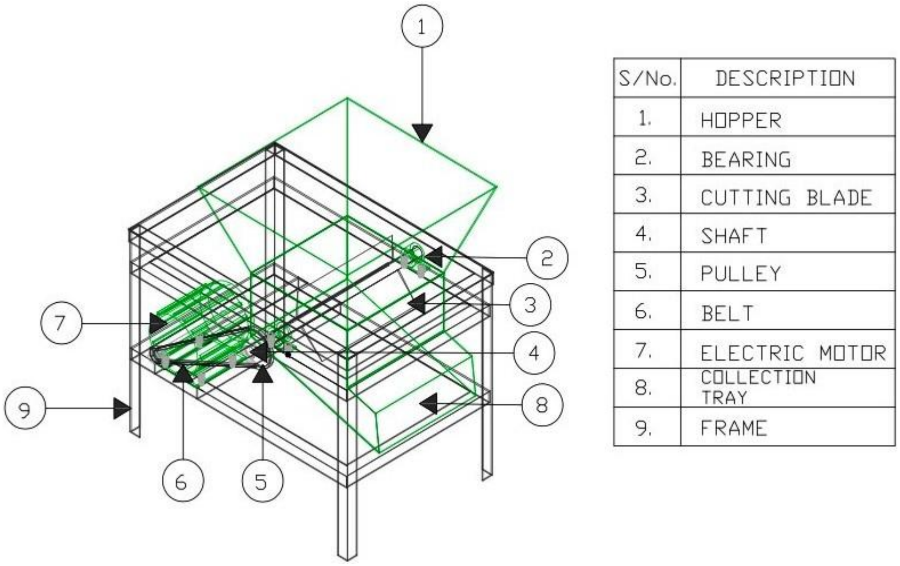


Fig. 1 Modeled View of Concept One



S/No.	DESCRIPTION
1.	HOPPER
2.	BEARING
3.	CUTTING BLADE
4.	SHAFT
5.	PULLEY
6.	BELT
7.	ELECTRIC MOTOR
8.	COLLECTION TRAY
9.	FRAME

Fig. 2 Skeletal View of Concept One

Disadvantages

i. It causes loss of fleshy tuber.
ii. It is a batch process.
iii. It is difficult to fix the blades in the shaft.
iv. It process results to broken tubers.

Design Concept two

The second concept is the modification of the first concept. Same component parts as the first concept, except for wire brush as a peeling tool. The rotating shaft is embedded with eight wire brushes. The peeling brushes are properly positioned parallel to each other at a regular interval in the peeling chamber. In so doing, peeling can be done from both sides. This concept is designed to be continuous and not batch, making it more unique than the first concepts. It has both the inlet and the outlet unit. Also the spacing between the shafts were minimal, hence preventing the cassava from been stuck in between. Figure 3 shows the modeled view and Figure 4 shows the skeletal view of design concept two.

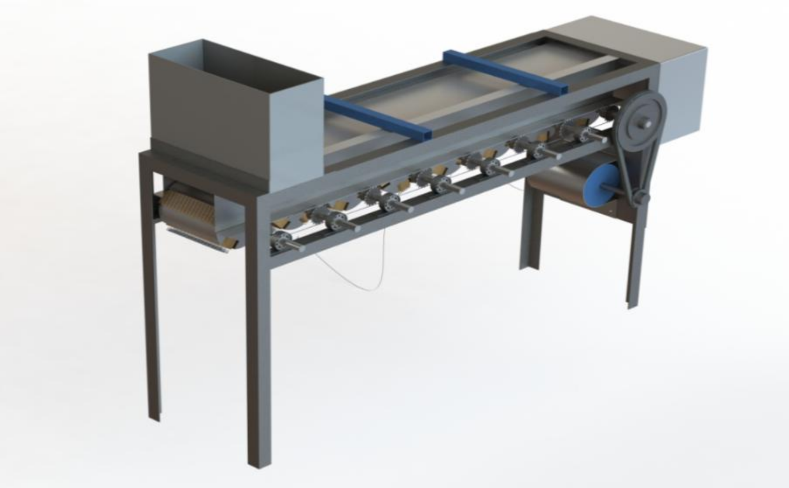
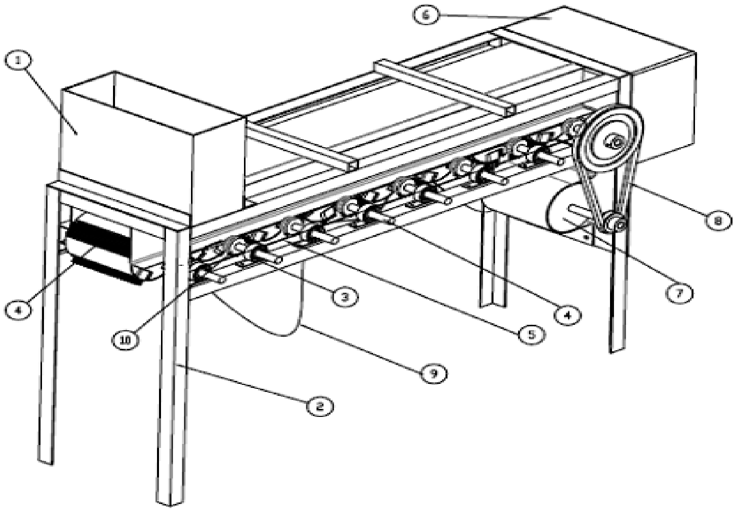


Fig. 3 Modeled View of Concept two



S/NO.	DESCRIPTION
1	Frame
2	Hopper
3	Bearing
4	Shaft
5	Chain
6	Outlet hopper
7	Electric motor
8	Belt
9	Cable
10	Sprocket

Fig. 4 Skeletal View of Concept two

Advantages

i. Loss of fleshy tuber is minimal.
ii. It is a continuous process.
iii. The machine must not be turn off before collection of peeled tuber is made.
iv. It saves time.

Selection of concept for detail design

Decision matrix (Table 1) was used to select the best concept for detail design and fabrication. A decision matrix is a list of values in rows and columns that allow an analyst to systematically analyze and rate the performance of relationships between sets of values and information. Each category is assigned a weighing factor base on believe which measures its relative importance.

Table-1. Decision matrix

Criteria	Weight	Alternatives			
		Design Concept one		Design Concept two	
		Rating	Score	Rating	Score
Functionality	0.30	6	1.8	5	1.5
Performance	0.25	2	0.5	9	2.25
Reliability	0.20	4	0.8	8	1.6
Safety	0.15	2	0.3	9	1.4
Cost	0.10	4	0.4	9	0.9
Total	1.00	18	3.8	40	*7.65

*Weight Factors from 0.10 – 0.30, Rating 1 – 10 and Score 1 – 10. ***Score = Rating x Weight

Based on the ranking, second concept was selected for detail design and fabrication.

Detail design

Power required to Peel Cassava

$$P = FV \qquad (1)$$

Where,

P = power to turn the shaft

V = speed

F= Force= mass x acceleration due to gravity

$$V = \frac{\pi DN}{60} \qquad (2)$$

Where,

V= Speed

D= Diameter

N= Speed in revolution per minute

Force = mass x acceleration due to gravity

That is,

F = Mass x Acceleration =ma (3)

Maximum number of cassava hopper can take at a time = 10tubers.

Approximate mass of cassava tuber after sorting = 0.65kg

For ten (10) cassava tubers = 0.65kg ×10 = 6.5kg

Power to peel the cassava is the power required to drive the shaft.

$$P = \frac{ma\pi DN}{60} \qquad (4)$$

$$P = \frac{6.5\times9.8\times\pi\times0.15\times1440}{60} = 720\text{watts} = 0.96\text{hp}$$

Having a factor of safety 2 gives 1.92hp

Therefore, 2hp motor would be used.

Belt design

$$2.3\log\left({}^{T_1}/_{T_2}\right) = \mu\theta \qquad (5)$$

Where,

θ = angle of wrap of an open belt

μ = coefficient of friction= 0.3 (Khurmi and Gupta, 2013)

T_1 = Tension in the tight side of the belt

T_2 = Tension in the slack side of the belt

For cross belt,

Angle of contact is given by;

$$\sin\alpha = \frac{R+r}{x} \tag{6}$$

For open belt,

Angle of contact is given by:

$$\sin\alpha = \frac{R-r}{x} \tag{7}$$

Angle of wrap;

$$\theta = 180 \pm 2\sin^{-1}\left(\frac{R-r}{x}\right) \tag{8}$$

Where,

r = radius of small pulley

R = radius of big pulley

x = distance between the two pulleys

But for open belt, angle of contact is given by,

$$\text{Sin } \alpha = \frac{75-25}{160} = 0.3125$$

$$\alpha = sin^{-1}0.3125 = 18.21°$$

$$\theta = 180° - 2 \propto = 180° - 2 \times 18.21° = 143.58^{\circ} = 2.51\text{rad}$$

$$V = \frac{\pi DN}{60} == 3.142\text{x } 0.15\text{x}1440/\ 60 = 11.31\text{m/sec}$$

$$P = (T_1 - T_2)\ V \tag{9}$$

Therefore,

$$T_1 - T_2 = \frac{P}{V}$$

$$T_1 - T_2 = \frac{1500}{11.31}$$

$$T_1 - T_2 = 132.62\text{N} \tag{10}$$

Calculating the belt ratio for an open belt

From equation (5)

$$2.3\log[\frac{T1}{T2}] = \mu\theta$$

$$2.3\log[\frac{T1}{T2}] = 0.3 \times 2.51$$

$2.3\log[\frac{T1}{T2}]=0.753$

$\mathrm{Log}[\frac{T1}{T2}]=\frac{0.753}{2.3}$

$\mathrm{Log}[\frac{T1}{T2}]=0.3274$

$\frac{T_1}{T_2} = e^{0.3274}$

$\frac{T_1}{T_2} = 1.387$

Therefore,

$T_1 = 1.387T_2$ (11)

Equating equation (10) and equation (11)

$1.387\ T_2=132.62N + T_2$

$1.387\ T_2 - T_2=132.62N$

$0.387\ T_2=132.62N$

$T_2 = 342.71N$

$T_I = 475.33N$

Design for velocity ratio for belt drive

Velocity ratio for belt drive is the ratio between the velocity of the driver and the follower (driven). It may be expressed mathematically as:

$$\frac{N_2}{N_1} = \frac{d_1}{d_2} \qquad (12)$$

Where,

d_1 = diameter of the driver = 50mm

d_2 = diameter of the follower = 150mm

N_1 = speed of the driver = 1440rpm

N_2 = speed of the follower

$$N_2 = \frac{50mm \times 1440rpm}{150mm} = 480\text{rpm}$$

N_1:N_2 = 1440:480 = 3:1

Shaft design

$$d^3 = \frac{16}{\pi \times S_u}\left[\sqrt{(ktMt)^2 + (kbMb)^2}\right] \qquad (13)$$

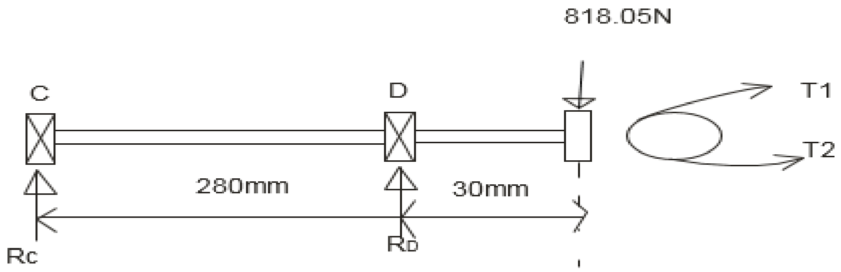
Where;

d = Shaft diameter

Kt = Stress combine shock and fatigue factor for torsion

K_b = Stress combine shock and fatigue factor for bending

S_u= Ultimate tensile strength of steel is 56MPa, K_b = 1.5, k_t=1.0 (Khumi and Gupta, 2013)



$R_C + R_D = T$

Upward reaction (forces) = Downward reaction (forces)

Where,

$T = T_1 + T_2$ = 475.33N + 342.71N = 818.05N

That is,

$R_C + R_D$=818.05N

Taking moment about point C

818.05N× (30mm + 280mm)-R_D×280mm=0

818.05N×310mm = 280mmR_D

$$R_D = \frac{818.05N \times 310mm}{280mm} = 905.7N$$

R_C =818.05N-905.7N = -87.65N

The negative sign shows that the force is actually acting downward

Therefore,

R_C =87.65N↓

Selection of Bearing

$$L_{10} = \frac{60 \times L \times N}{10^6} \qquad (14)$$

Where,

L_{10} = basic dynamic life of the bearing (million rev.)

L = Life of the bearing

$L = 18000 \leq L \leq 22000$

N = 1440rpm

Also,

$$F_e = (xC_rF_r + C_tF_t)\ sf \qquad (15)$$

Where,

F_e = Equivalent dynamic load

x = Rotational factor

C_r = Radial factor

F_r = Radial load

C_t = Thrust factor

F_t = Thrust load

S_f =Safety or service factor

x=1 (inner raceway)

$S_f = 1.1 \leq S_f \leq 1.5$ (for rotating part)

If,

$$\frac{f_t}{xFr} \leq 0$$

$C_r = 1$ and $C_t = 0$

Also,

$$\frac{f_t}{xFr} > 0$$

C_r=0.56

And C_t is interpolated or extrapolated.

Deep groove ball bearing was selected considering cost and maintenance and a shaft diameter (d) of 20mm used

RESULTS AND DISCUSSION

Table 2 and Table 3 show the results and analysis of results obtained with the designed continuous cassava peeling machine. The following data and equations were used:

$$\%WPC = \frac{W_5}{W_1} \times 100 \tag{16}$$

$$\%WP = \frac{W_2}{W_1} \times 100 \tag{17}$$

$$\%WFL = \frac{W_4}{W_1} \times 100 \tag{18}$$

$$\%WUP = \frac{W_3}{W_1} \times 100 \tag{19}$$

$$PE = \frac{W_2}{W_2+W_3} \tag{20}$$

$$THC = \frac{W_1}{PT} \tag{21}$$

$$MD = \frac{W_4}{W_4 + W_5}$$

W_1 = Weight of cassava tubers fed into the machine

W_2 = Weight of peeled cassava tubers

W_3 =Weight of peeled cassava by hands after machine peeling

W_4 = Weight of useful flesh removed

W_5 = Weight of completely peeled cassava tubers by machine

%WPC= Percentage weight of properly peeled cassava tubers by machine

PT = Peeling time

%WP = Percentage weight of peels cassava tubers by machine

%WFL = Percentage weight of flesh loss

%WUP = Percentage weight of unpeeled cassava tubers by machine

PE = Peeling efficiency

MD = Mechanical damage

THC = Throughput capacity (kg/sec)

PT = Peeling time

Table-2 Results obtained with the machine

S/N	W_1	W_2	W_3	W_4	W_5
1	5.25	4.21	1.01	0.03	3.20
2	5.50	4.33	0.59	0.58	3.74
3	5.90	4.99	0.64	0.27	4.35
4	6.45	5.46	0.43	0.56	5.03
5	6.58	5.99	0.55	0.04	5.44

Table-3 Analysis of results obtained from testing machine

S/N	%WP	%WPC	%WFL	%WUP	PE (%)	MD	PT (Sec)	THC(kg/sec)
1	80.19	60.95	0.57	19.24	60.95	0.0093	55.60	0.094
2	78.73	68.00	10.55	10.73	68.00	0.134	59.05	0.093
3	84.58	73.73	4.58	10.85	73.73	0.058	62.50	0.094
4	84.65	77.98	8.68	6.67	77.98	0.100	65.60	0.098
5	91.03	82.67	0.61	8.36	82.67	0.0073	70.00	0.094
∑	419.18	363.33	24.99	55.85	363.33	0.3086	312.75	0.473
A	83.84	72.67	4.99	11.17	72.67	0.0617	62.55	0.095

The analysis of results showed that an average percentage weight of peeled cassava tubers was 83.84%. However, the average percentage of cassava tubers properly peeled without re-peeling with hand was 72.67%. This simply means an average percentage of 11.17% was the percentage weight of unpeeled cassava tubers by machine, thus, it was re-peeled with hand manually. To know the percentage of useful cassava flesh loss, the weight of flesh of cassava removed in the process of peeling and the weight of cassava tubers fed into the machine were evaluated. The results realize showed that an average 4.99% of useful cassava flesh was lost in the process of peeling. Figure 5 shows the chart of peeling efficiency and percentage weight of peels cassava tubers by machine against peeling time. From the chart, there was an increase in both peeling efficiency and percentage weight of peels cassava tubers by machine as peeling time increases. Moreover, an average peeling efficiency of 72.67 (Table 3) was obtained and this shows that the continuous cassava peeling machine was efficient. Also, in evaluation of the machine, the throughput capacity and mechanical damage were calculated for. An average value of 0.0617 and 0.095 were obtained for the throughput capacity and mechanical damage. This is a confirmation that minimal mechanical damage was recorded by the continuous cassava peeling machine.

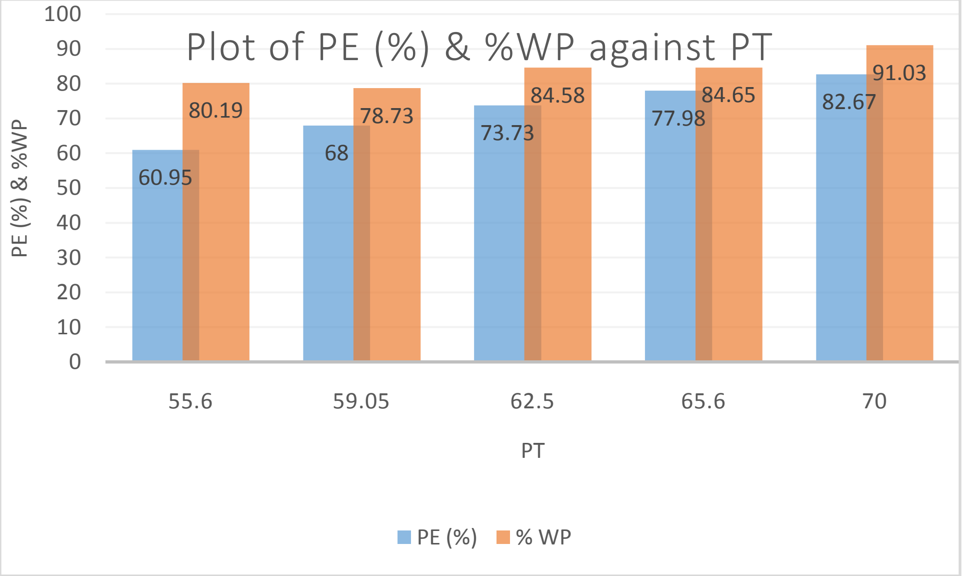


Fig. Peeling efficiency and percentage weight of peels cassava tubers by machine against peeling time.

CONCLUSION

This research work is focus on the design and development of an improved continuous cassava peeling machine. The machine was successfully design, fabricated and test performance was carried on the machine to evaluate it. The results obtained showed that the machine was not only efficient but minimal mechanical damage and minimal useful cassava flesh lost were obtained. Therefore, the machine can replace manual method (traditional method) of peeling of cassava tubers.

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