Development of Yam Peeling and Slicing Machine for a Yam Processing Plant

S. P. Ayodeji*[1], B. O. Akinnuli[2], O.M. Olabanji[3]

[1, 3]Tshwane University of Technology, Pretoria, South Africa

[2]Federal University of Technology, Akure, Ondo State, Nigeria

[*1]ayodejisesantut@gmail.com

***Abstract*-Timely processing of farm products is important to prevent post-harvest losses and ensure food quality. Several processing, operation have been mechanized in the production line of yam products such as parboiling, drying, pulverizing, etc. But peeling, which is the removal of the outer layer of the yam, is one of the major problems of yam processing both for small and large scale consumption. This idea is receiving attention from design engineers in Nigeria being the largest producer of yam in the world.**

A power operated machine is developed which has two components harnessed together for peeling and slicing of yam in a pilot poundo yam flour process plant. It consists of an electric motor, the peeling chamber fitted with peeler, auger shaft to transport the yam, idle roller for clamping and aligning the yam along its course. The slicing unit and the protective hood carry the loading bay and inspection slot. The machine peels the yam at relatively high angular velocity of the rotary peeling brush. The slicer was positioned at the outlet of the feeder with high rotating speed. Machine capacity was influenced by moisture content of tubers and variations in length and diameter. Results show that auger speed resulted in higher peeling efficiencies at various peripheral speeds of the peeling brush. The design capacity of the machine is 114kg of yam per hour while the average efficiency is 91% and functional efficiency 87.86%. Adoption of this yam peeling and slicing machine would promote timely processing of fresh tubers, reduces labor input, increase productivity and hence the income of the local processors.

Keywords- Yam Peeling; Yam Slicing; Yam Process Plant

I. INTRODUCTION

Yam has an energy content of about 30billion kcal with a corresponding protein content of about 0.66 million ton. Several species of yams are grown in the tropics and the temperate zones of the world [1]. It is the second most important root/tuber crop in Africa, after cassava, with production reaching just under one third the level of cassava [2]. Some yams are grown only for medicinal purposes and others for edible purposes. Of the edible species, Dioscorea alata (greater yam), Dioscorea cayenensis (yellow yam), and Dioscorea rotundata and Dioscorea esculanta (white yam), are most common [3].

In order to minimize losses and improve quality, considerable quantities of roots and tubers are transformed into more durable products like poundo-yam flour. This involves processing yams into dry-yam tuber or slices and flour. The dry yam tubers/slices are processed by peeling, slicing, parboiling in hot water (40 °to 60 °for 1 to 3 hrs) [4]. Investing in the processing of yam into poundo yam flour for both export and local markets is not just a relatively but an enriching investment. Since yam in its natural state is both bulky and highly perishable, the storage problem is akin to all other agricultural products in West Africa, and processing into flour eliminates this. Available statistics put the yearly losses to about two million tubers due to the harvest waste [3]. [5] also reported that yam contributes more than 200 dietary calories per capital daily for more than 150 million people in West Africa, and serves as an important source of income to the people.

Initial research efforts in this area resulted in the production of several prototypes with relatively low peeling efficiencies and quality performance efficiencies [6-9]. Yams need to be processed to significant extent commercially. Up till now, dehydrated yam flours and yam flakes are being produced by sun drying. The manufacture of fried products from Dioscorea rotundata has also been attempted recently [2]. Preservation of yam in brine has also been attempted, but with little success.

[10] in his work presented detail nutritional value of varieties of yam cultivated in Nigeria as shown in Tables 1 and 2. Considering the nutritional values of yam as a staple source of carbohydrate, vitamins, dietary fibre and minerals and its economic importance being the second most important root/tuber crop in Africa, after cassava [2] the challenges and need for an effective method for the peeling and slicing of yam needs serious attention. Developing yam peeling and slicing machine provides important appropriate technology since the traditional method is tedious, raises hygiene concerns and has high risk of injury.

Pounded yam is a staple food, which is consumed by almost every tribe in Nigeria and some part of other West Africa countries. The indigenous process of production is very laborious [11], the emergence of Instant pounded yam flour (IPYF) recently brings succour to pounded yam lovers as the drudgery of pounding is eliminated. The production process according to [12] consists of simple operations as: yam selection and weighing, washing, peeling and slicing, parboiling, grating, drying, grinding, sieving and packaging.

Yam peeling remains a challenge to design engineers involved in the design of yam processing machines. Pounded yam production has been greatly limited by lack of suitable machinery for industrial scale production. Katsuyama et. al [13] listed several types of peelers used to peel a variety of fruits and vegetables such as steam peelers (for carrot and root vegetables), mechanical peelers, and chemical peelers. Also Lisa [14] listed some other peelers as rotating cage peelers, U-Bed Design, Raging Bull Peeler, while [15] designed a double action self-fed cassava peeler. Ukatu [9], designed Industrial Yam peeler but with poor efficiency, [16] worked on "An improved Rotary Peeling Machine. None of these researchers has looked at peeling and slicing machine combined for poundo yam flour production. This work looked at the development of an efficient yam peeling and slicing machine for poundo yam flour process plant.

TABLE 1: NUTRITIONAL VALUE OF 1KG OF YAM

S/N	Constituent	Composition
1	Calories	4186 Joules
2	Protein	20g
3	Calcium	150mg
4	Iron	10mg
5	Vitamin A	Traces
6	Thiamin	1mg
7	Riboflavin	0.3mg
8	Nicotinic Acid	4mg
9	Vitamin C	50mg

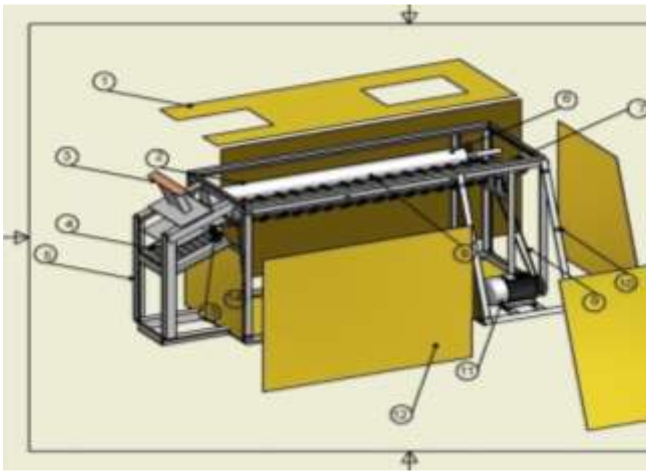
TABLE 2: NUTRIENTS PRODUCED PER ACRE OF YAM VARIETIES CULTIVATED IN NIGERIA

S/N	Variety	Protein(lb)	Carbohydrate (lb)	Oil (lb)	Minerals (lb)	TDN* of Peels only	Total Calories/ 1000g
1	White Yam	335	6973	26	190	974	13161
2	Yellow yam	411	6957	13	196	1250	13317
3	Water Yam	556	6622	44	381	1445	12882
4	Trifoliate Yam	890	6425	92	179	760	13510
5	Chinese Yam	586	6820	4	184	420	13322
TDN* - Total Digestible Nutrients							

II. MATERIALS AND METHODS

A variety of factors were considered in the design process of the machine, some of which are:

1. The equipment was designed to be relatively cheap and be within the buying capacity of small scale processors.
2. The equipment was designed to able to handle different varieties, shapes and size of yams.
3. The integration of the peeling and slicing machine to the poundo yam flour processing plant.
4. Suitable material properties used for the fabrication were mostly locally sourced.
5. The maintenance and repair of the machine can be carried out with ease.
6. There is high strength and rigidity in the construction of the machine.
7. The safety and satisfactory performance of the machine was considered.



S/N	Part List	Qty
1.	Protective hood	1
2.	Rear cover	1
3.	Slicer handle	1
4.	Slicers	1 set
5.	Slicing unit frame	1
6.	Idle roller	1
7.	Pulley	4
8.	Peeler shaft	1
9.	V-belt	2
10.	Motor house frame	1
11.	Electric motor	1
12.	Front cover	1
13.	Slicing unit	1
14.	Auger shaft	1

Fig.1: An Exploded View of the Yam Peeling and Slicing Machine

The component parts of the yam peeling and slicing machine are the frame, peeling shaft, auger shaft, idle roller shaft, electric motor, bearing, and slicer. The electric motor powers the auger shaft and the auger shaft powers the peeling shaft at the same speed. The peeling shaft is in form of a metal brush. The peeling shaft, auger shaft, and the idle roller shaft are fitted to the frame of the machine with the aid of a bearing. The function of the shaft is to produce the required peeling effect. The oval elongated shape between the peeling and auger shaft can accommodate the irregular average diameter of yam. The auger shaft moves the yam tuber linearly. An exploded view of the machine is presented in Fig. 1

A. Power Transmission System.

Power is transmitted from the electric motor to the auger shaft with the help of V-belt at an angle of 60° to the ground, using a small and big pulley. The auger shaft powers the peeling shaft at the same speed. The weight and volume of big and small pulleys on auger shaft (Wp1) were determined using equations (1) and (2). The schematic diagram of the power transmission system is presented in Fig. 2

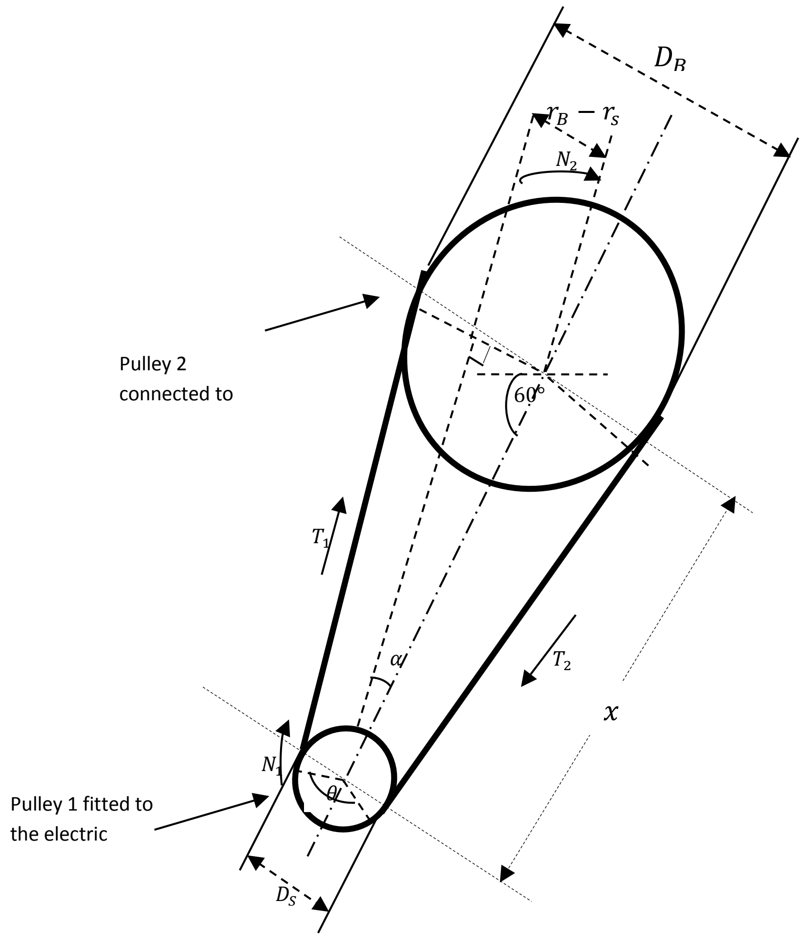


Fig. 2 Power Transmission system in the Peeling and slicing machine

Volume of big pulley $=\pi D_B^2 T_B/4$ …...... (1)

Weight of small pulley= D_S x volume x g ……… (2)

Where; DB and DS are the diameters of big and small pulley respectively, TB and TS are thickness of big and small pulley respectively, and g is acceleration due to gravity.

Belt and Pulley design were done using equations (3) – (8) according to [17]. V-belt class A type was used because of its advantages.

$$N_1/N_2 = D/b \text{ ………… } (3)$$

$$V=\frac{\pi d N_1}{60} \text{ ………. } (4)$$

$$\alpha = 180^0 + 2\sin^{-1} - \frac{(R_B - R_S)}{C} \ldots \quad (5) \text{ (for open belt)}$$

$$L = 2C + \frac{\pi}{2}(D+d) + \frac{(D-d)^2}{4C} \text{ ……. } (6)$$

$$\frac{T_1 - mv^2}{T_2 - mv^2} = \ell^{\mu\alpha} \ldots\ldots\ldots \quad (7)$$

$$P = (T1 - T2) \times V \ldots\ldots\ldots \quad (8)$$

Where L = length of open belt; N1 = speed of motor pulley; N2 = speed of Auger shaft pulley; D = diameter of Auger pulley; d = diameter of motor pulley; v = belt speed; μ= 0.25 for rubber belt running over metal pulley; T1= belt tension on tight side; T2 = belt tension on slack side; C = Centre distance; α = Angles of wrap of the belt; m = mass of belt; and density of rubber belt =970kg/m^3.

B. The Auger Spirals and Shaft:

The auger shaft moves the yam tuber linearly by means of a rotating helical flights whirled round it. The flights are whirled round a cylindrical structure which is fitted permanently to the shaft by means of welding. The kinematic design for the auger shaft is presented in Fig 3. The weight of auger spirals per unit length (WA) was determined using equations (9) to (11)

Area of spiral (A_S) $=\pi r_B^2 - \pi r_C^2$ ……… (9)

Volume of spiral (V_S) =A_S x T_S ……… (10)

The weight of the auger spiral per unit length of auger shaft with 9 spirals is therefore given as:

$$W_A = {}^{totalweightofspirals}/_{0.90} \cdots\cdots\cdots \quad (11)$$

The weight of galvanized mild steel hollow cylinder per unit length, WH is given as:

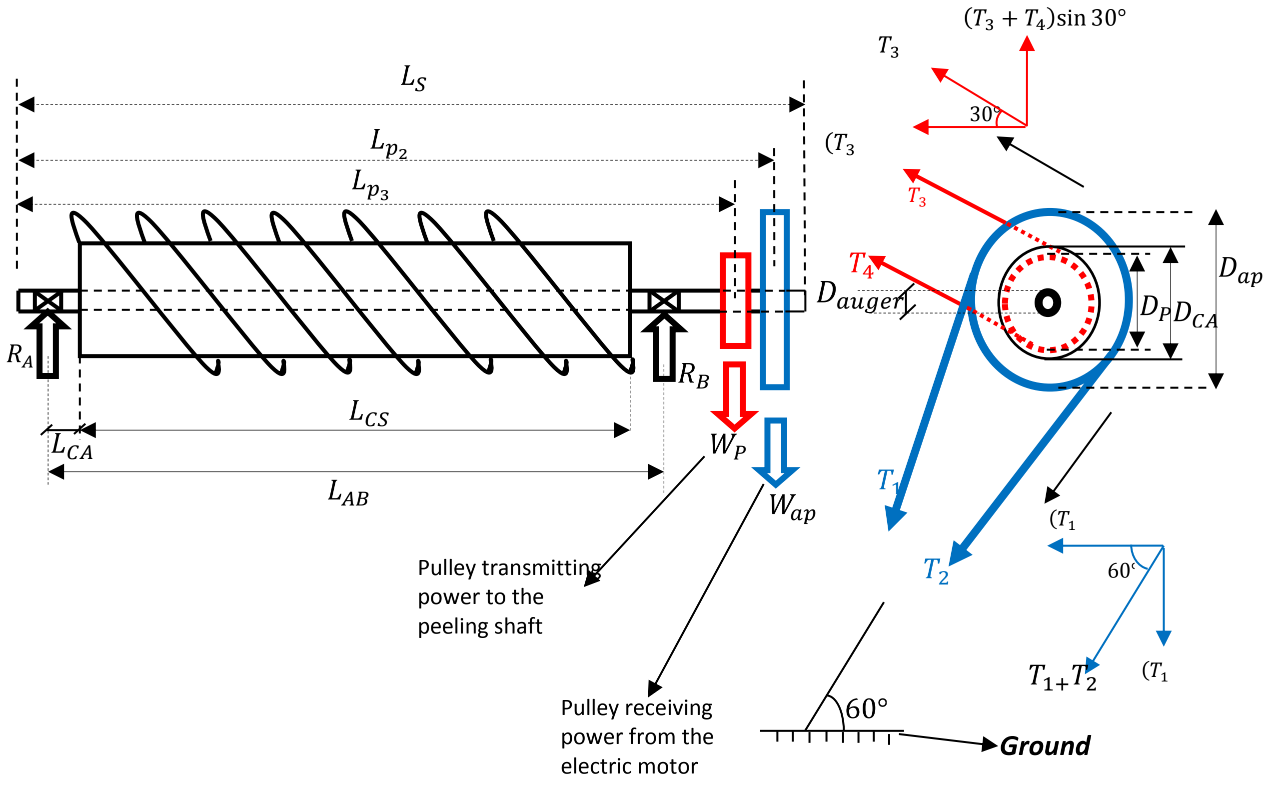


Fig. 3 Kinematics of the Auger shaft

W_H= density x volume x g / length and

Area of hollow cylinder=$\frac{\pi}{4}(D_a^2 - D_b^2)$ ……… (12)

The weight of material fed (yam) per unit length (W_M) is given as:

$$W_M = {}^{weightofmaterial(yam)}/_{0.90} \cdots\cdots \quad (13)$$

Therefore the total weight, W_T, on the auger shaft per unit length was determined using equation (14)

$$W_T = W_A + W_H + W_M \ldots\ldots\ldots \quad (14)$$

C. The Auger Shaft:

The auger shaft is supported by two bearings, each one at the end of the peeling section.

It is subjected to both torsional and bending loads. Diameter of the auger shaft is determined using equations (15) according to [18].

$$d^3 = \frac{16}{\pi S_s}\left[(M_b K_b)^2 + (M_t K_t)^2\right]^{1/2} \ldots\ldots\ldots \quad (15)$$

Where; Mb = maximum bending moment; Mt = maximum torsional moment; Kb = combined shock and fatigue factor applied to bending = 3; Kt = combined shock and fatigue factor applied to torsion = 3; Ss = maximum allowable shear stress for steel $=40 \times 10^6 \mathrm{N/m^2}$; and d = diameter of shaft. Since the power transmission to the auger shaft is a belt drive, then the torsional moment is a function of the total torque acting on the pulley, and the number of revolution of the pulley.

D. Selection of the Electric Motor:

The selection of the electric motor for the parboiling machine was based on the following factors: the motor duty (continuous); the power rating and speed required and the type of enclosure (closed). The speed of the motor was determined from equation (16) [19] where Dm is the diameter of the motor pulley, DA is the diameter of the pulley on the auger shaft, and Nm represents the speed of the electric motor in r.p.m. Also, total power required, P in Watts of the electric motor, which is the addition of power required to drive the pulley and the auger shaft, was determined using equations (17) – (19).

$$\frac{D_A}{D_m} = \frac{N_m}{N_A} \ldots\ldots\ldots\ldots \quad (16)$$

$$P = \frac{2\pi T N_m}{60} \ldots\ldots\ldots \quad (17)$$

Angular velocity, ω = $2\pi N_m$ ……... (18)

Linear velocity, v =rω ……..... (19)

Where T in equation (17) represents the torque on the driving (electric motor) pulley in N-m.

E. The Screw Conveyor:

Equation (20) was used to design the Screw Conveyor according to [20].

$$Q = 47.2\,(D^2 - d^2) \times A \times n \ldots\ldots\ldots \quad (20)$$

Where Q = conveyance capacity; D = Screw diameter; d = Hollow Cylinder diameter; A = Screw pitch; and n = Pulley speed.

F. The Volume of the Hopper and Peeling Chamber:

The chamber is circular in shape. The volume of the hopper (v) and Peeling Chamber was determined using equation (21) and (22) respectively.

$$V = \pi r^2 L \ldots\ldots\ldots\ldots\ldots\ldots \quad (21)$$

Where;

$$Vc = \pi r^2 L \ldots\ldots\ldots\ldots\ldots\ldots \quad (22)$$

Where L = Loading bay length; and R = Loading bay radius in equation (21) while Vc = Volume of peeling chamber; V = Radius of cylinder; and L = Length of the drum in equation (22).

G. Determination of Peeling Force, Permissible Angle of Twist for Peeler and Auger and Arial Deflection of the Shafts:

Peeling force, permissible angle of Twist for peeler and auger and arial deflection of the shafts was determined using equations (23), (24) and (25) respectively. The peeling force is a centripetal force produced by the metal brush, which acts on the surface of the yam in contact.

$$F = M\,\omega\,r^2 \text{ -------------} \quad (23)$$

$$\text{Ø} = 584\, M_t L / G d^4 \text{ -------------} \quad (24)$$

$$\delta = FL/AE \text{ ---------} \quad (25)$$

Where M = average mass of yam tuber = 2.5kg; r = radius of peeler; ω = angular speed; n = speed of peeler in rev/min; L = Length of shaft; Mt= torsional moment; G = torsional modulus of rigidity; d = Shaft diameter; F = Force acting on the shaft; L = Length of shaft; E = Modulus of Elasticity; δ= arial deflation of the shafts and A = Area of Shaft

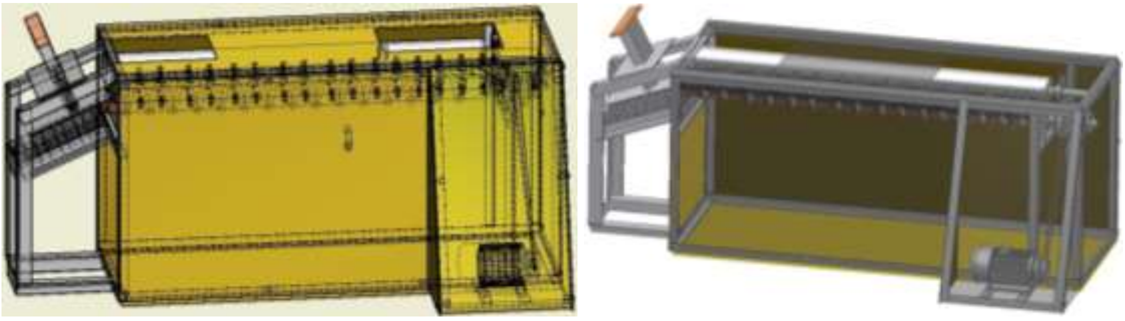
Fig. 2 shows the detail drawing of the developed machine.

H. Designed Capacity of the Machine:

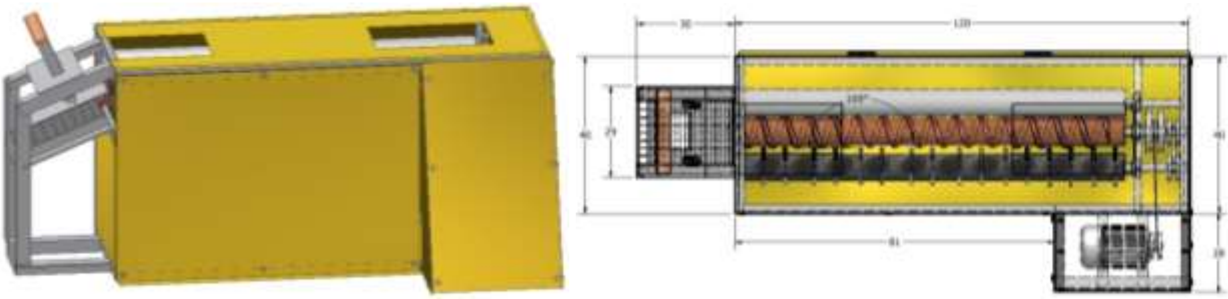
According to [21], the designed capacity Cd is a measure of the total volume of washed yam, the machine could handle per unit time as shown in equation (26)

$$C_d = \frac{V_t}{T_t}\ldots\ldots \quad (26)$$

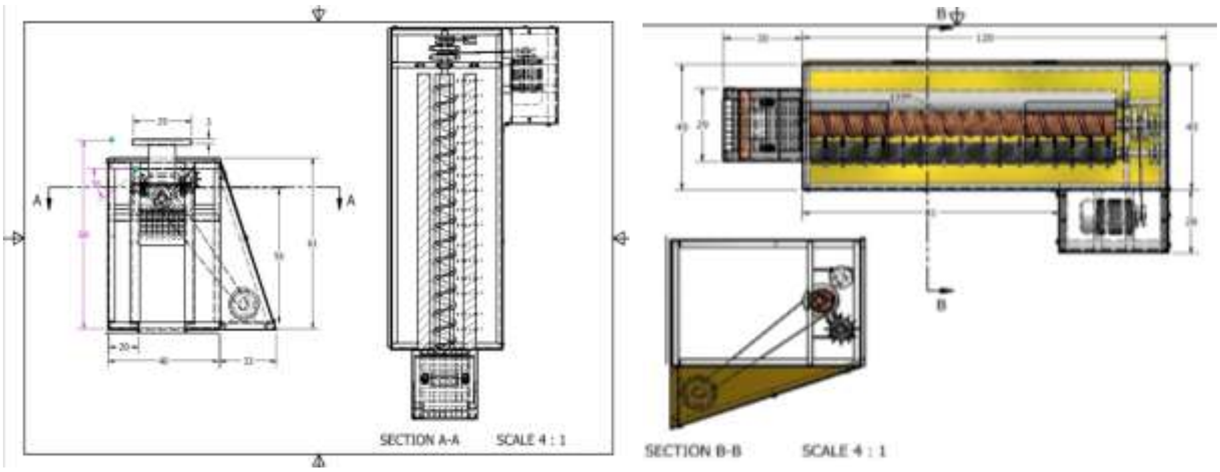
Where Vt and Tt represent the volume of washed yams in a full hopper size of the machine and total time required to peel and slice a full hopper size of the washed yams respectively.



ISOMETRIC INTERIOR VIEW 1 OF MACHINE **ISOMETRIC INTERIOR VIEW 2 AND PERSPECTIVE**



4D VIEW OF THE MACHINE **REALISTIC PLAN VIEW OF THE MACHINE**



SECTIONAL VIEWS OF THE MACHINE

Fig. 4: Showing Detail Drawing Of The Yam Peeling And Slicing Machine.

The approximate volume Vy of a yam tuber is calculated based on initial survey done on yam selection and size giving yam average diameter (d) as100mm and average length (Ly) as250mm. Therefore, the cross sectional area (A) and volume Vy of a yam tuber were found from equations (27) and (28).

$$A = \frac{\pi d^2}{4}\ldots\ldots\ldots \quad (27)$$

$$V_y = AL_y \ldots\ldots \quad (28)$$

Consequently, the approximate number of yam tuber in a full hopper is defined as hopper volume divided by volume of a yam tuber. Practically, the average number of sliced yams in a tuber is approximately 12. Then; the total number of sliced yams from a full hopper (Nt) is given as;

Number of yam tuber in a full hopper $\times 12$

An average of 2washed yams enters the peeling chamber at a time, and the time (Td) for them to move from the hopper feeding end to the delivery end was found (see equation 29).

$$T_d = \frac{L_c}{V_a} \text{……….} \quad (29)$$

Therefore, the estimated total time taken to peel and slice a full hopper size of washed yams is

$$T_t = \frac{N_t}{4} T_d \text{……..} \quad (30)$$

I. Peeling Efficiency (PE) and % Material Loss of the Peeling (MLP) Machine:

The peeling efficiency of the machine was determined using equation (31). This is the ratio of the weight of yam tuber after peeling (WA) to the weight of the tuber before peeling (WB) expressed as a percentage while percentage material loss in peeling is a measure of the effectiveness of the peeling chamber and was determined using equation (32). Total weight of yam before peeling, WBT = 3.85kg and total weight of yam after peeling, WAT = 3.5kg (Table 4)

$$P_E = \frac{W_A}{W_D} \times 100\% \text{.........} \quad (31)$$

$$M_{LP} = \frac{W_{BT} - W_{AT}}{W_{BT}} \times 100 \text{.........} \quad (32)$$

J. Determination of Machine Functional Efficiency (FE)

Machine functional efficiency (F_E) is a measure of the number of cubes product to the number of chips expected to be produced. If N_c is the number of cubes produced and N_t is the expected total number of cubes per operation which is the ratio of length of sliced yam to expected thickness of cubes. The functional efficiency, F_E is therefore determined from equation (33).

$$F_E = \frac{N_c}{N_t} \times 100\% \text{..........} \quad (33)$$

K. Determination of Slicing Efficiency (S_E) and Percentage Material Loss in Slicing (MLs):

Slicing efficiency is the ratio of the total weight of sliced cubes (W_C) to the total weight of yam before slicing (W_D) expressed as a percentage as expressed in equation (34). Percentage material loss in slicing is a measure of the effectiveness of the slicing chamber. If W_D is total weight of yam before slicing and W_C is the total weight of yam after slicing, then it is as expressed in equation (35).

$$S_E = \frac{W_C}{W_D} \times 100\% \text{…..…..} \quad (34)$$

$$M_L = \left(\frac{W_D - W_C}{W_D} \right) \times 100\% \text{……..} \quad (35)$$

L. Determination of Average Machine Efficiency (M_E) and Average Machine Percentage Material Loss (ML):

Average Machine efficiency, M_E is given by the average of the peeling and slicing efficiencies as shown in equation (36). The average Machine Percentage Material Loss, M_L is given by the average of the percentage material losses in peeling and slicing as indicated in equation (37).

$$M_E = \frac{1}{2}(P_E + S_E) \text{……..} \quad (36)$$

$$M_L = \frac{1}{2}(M_{LP} + M_{LS}) \text{……..} \quad (37)$$

III. MATERIALS SELECTION

The cost, availability, properties and weight of the materials were some of the factors considered for the selection of appropriate material for each machine component. Table 3 presents the summary of the material selected for each machine component.

TABLE 3: A SUMMARY OF THE MATERIAL SELECTION PROCESS

S/N	Machine Component	Material Used	Reason for Selecting the Material
1	Body frame	Mild Steel	• Good tensile properties • Low cost • Readily available
2	Auger Shaft	Mild Steel	• Good tensile properties • Low cost • Readily available
3	Protective hood, Rear and front cover, Motor house frame,	Mild Steel	• Good tensile properties • Low cost • Readily available
4	Slicer handle	Mild Steel	• Good tensile properties • Low cost • Readily available
5	Slicers and Slicing unit	Stainless Steel	• Excellent corrosion resistant • Good for food processing • Good tensile properties • Readily available
6	Slicing unit frame	Mild Steel	• Good tensile properties • Low cost • Readily available
7	Idle roller	Mild Steel	• Good tensile properties • Low cost • Readily available
8	Peeler shaft	Mild Steel	• Good tensile properties • Low cost • Readily available
9	Motor house frame	Mild Steel	• Good tensile properties • Low cost • Readily available

IV. RESULTS AND DISCUSSIONS

A. *Operational Principle of the Developed machine*

When operated, yam tubers are fed through the loading unit into the peeling chamber. The idle roller helps in pressing the tubers on the peeler as it passes through the chamber while the peels are collected through the chute to the machine base. The peeler, carrying wire-brush peeling bits incorporates an auger as well as an idle roller to monitor the yam tuber movement in the peeling chamber. The peeler and auger shafts rotate in the same direction at the same speed and impacts a rotary and linear motion on the tuber. The relative motion between the peeler and auger shafts and the rotary motion of the tuber produces the required peeling. The peeled yam tubers are then passed into the slicing unit where slicing takes place. The sliced yam cubes are then passed on to the next stage in the poundo yam process plant.

B. *Results*

The yam peeling and slicing machine was tested using pulleys as a speed reducer to a peeler/Auger speed of 490.91rpm considered adequate for the operation of the machine. It was run on no load for about 5 minutes with a one-phase 1410 rpm, 2Hp electric motor before it was loaded with washed yam tubers. The weight of the yam before peeling and the time taken for the peeling to be completed were recorded. Also the weight of the peeled yam before slicing and after slicing and the time taken for the slicing process were recorded. The test was carried out on the machine five times using several tubers of yam randomly selected. Table 4 shows a summary of the results obtained for the various tests performed on the machine, while Table 5 presents the summary of the results of the similar tests using the domestic hand peeling and slicing method and the two results were compared. The peeling efficiency is taken as the ratio of the yam after peeling to its weight before peeling.

TABLE 4: SUMMARY OF THE RESULTS OBTAINED FOR THE VARIOUS TESTS PERFORMED ON THE MACHINE

No of Tuber	**Weight before peeling (kg)**	**Weight after peeling (kg)**	**Peeling time (sec.)**	**Peeling efficiency (%)**	**%Material loss in peeling**	**Weight after slicing (kg)**	**Slicing time (sec.)**	**Slicing efficiency %**	**%Material loss in slicing (kg)**
1	1.1	0.90	3.71	81.82	18.18	0.87	6.42	96.67	**3.33**
1	0.95	0.90	3.85	94.74	5.26	0.88	6.51	97.78	**2.22**
1	0.65	0.60	2.75	92.31	8.33	0.56	6.05	93.33	**6.67**

1	0.60	0.57	3.09	95.00	5.00	0.54	6.01	94.74	**5.26**
1	0.55	0.53	3.13	96.36	3.64	0.48	6.00	90.57	**9.43**
Ave.	**0.77**	**0.70**	**3.31**	**92.05**	**8.08**	**0.67**	**6.20**	**94.62**	**5.38**

TABLE 5: SUMMARY OF THE RESULTS OBTAINED FOR THE VARIOUS MANUAL PEELING AND SLICING METHOD

No of Tuber	**Weight before peeling (kg)**	**Weight after peeling (kg)**	**Peeling time (sec.)**	**Peeling efficiency (%)**	**%Material loss in peeling**	**Weight after slicing (kg)**	**Slicing time (sec.)**	**Slicing efficiency %**	**%Material loss in slicing (kg)**
1	1.1	0.87	75.03	79.09	20.91	0.80	63.25	91.95	**8.05**
1	0.95	0.82	68.97	86.32	13.68	0.77	62.01	93.90	**6.10**
1	0.65	0.51	68.62	78.46	26.15	0.46	59.87	90.20	**9.80**
1	0.60	0.53	63.33	88.33	11.67	0.47	58.62	88.68	**11.32**
1	0.55	0.50	59.75	90.90	9.09	0.44	55.00	88.00	**12.00**
Ave.	**0.77**	**0.65**	**67.14**	**84.62**	**16.30**	**0.59**	**59.75**	**90.55**	**9.45**

C. Discussion

The percentage of material lost has also been drastically reduced while the total processing time gives the machine a great advantage over the laborious and time consuming hand processing. Peeling time was also fairly constant for all the tubers used. The orientation and size of tubers however affects the effectiveness of peeling to a great extent. It was also noted that despite the variation in the weight of the tubers used during the testing, the peeling time remained fairly constant. This shows that weight of tubers had no effect on peeling time.

The average efficiency of YPSM was 87.86%. The average time it takes YPSM to peel and slice a tuber of yam is 12.2 seconds. The design capacity C is calculated to be 1.2kg of yam/Sec.

V. CONCLUSION

The yam peeling and slicing has been designed, fabricated and evaluated. The performance evaluation gave the michnic the efficiency of 87.86%, with designed capacity of 1.2kg of yam/sec. This was achieved with very low cost of production will promote timely processing of fresh tubes, reduces labour impact, and increases production on the side of production area.

The yam peeling and slicing machine is a very simple and hygienic machine with safe operation. It will be very good for small scale and large scale production of poundo yam products. The system offers a sustainable approach for processing and consumption of yam in developing countries. It is expected that the modified machine will minimize the drudgery involved in yam peeling and slicing, enhance yam processing and storage, and improve the quality of processed yam products for both local and international markets.

VI. RECOMMENDATION

Despite the appreciable performance of the motor operated yam peeling and slicing machine, in terms of machine capacity, machine efficiency and lower percentage material loss, I will recommend that:

1. Automated devices that will take care of different sizes and orientation of yam tubers should be incorporated into further design of the machine to eliminate the problem of yam selection.

2. The slicing unit should be improved upon by the introduction of a fulcrum lever to reduce the amount of force exerted in slicing.

REFERENCES

[1] Innvista, Yams; History, Description and Types, 2009. www.innvista.com

[2] Food and Agricultural Organization, FAO Roots, tubers, plantains and bananas in human nutrition – Nutritive value, methods of cooking and processing, 2008. www.fao.org

[3] International Institute of Tropical Agriculture, IITA: Root and tuber systems, 2008. www.iita.org

[4] Babajide J. M and Atanda O. "Quantitative survey and anti-microbial effect of Pipiostigmathonnigil and Khayaivorensis on traditional dry-yam," *African journal of Microbiology Research*, vol. 2, pp. 078-08, 2008.

[5] Babaleye, T., "Raising the status of the yam, a major food crop in West Africa," ANBBIA SUPPLEMENT ISSUE/EDITION, no. 463, pp. 1-, 2003.

[6] Aderoba O. (2008): Design and fabrication of a yam tuber peeling and slicing machine for a poundo-yam process plant. Department of Mechanical Engineering, Federal University of Technology Akure, Ondo-state, Nigeria.

[7] Adejumo O. Design and Fabrication of a machine for slicing plantain, Department of Agriculture and Agricultural Extension, Federal University of Technology Akure, Ondo-state, Nigeria, 2007.

[8] Adetan D. A., AdekoyaL. O and Aluko O. B. "Theory of a mechanical method of peeling cassava tubers with knives," *International Agrophysics*, vol. 20, iss. 4, pp. 269-276,, 2006.

[9] Ukatu A. C., "Development of an industrial yam peeler," *Nigerian Journal of Engineering Research Development*, vol. 1, no. 2, pp. 45-

56, 2002.

[10] Coursey O., *Yams: Tropical Agricultural Series*, Macmillan Press Limited, London, 1967.

[11] Ajiboshin I. O, Daoudu M. A, Omotade S. A and Komolafe A. O (2005): Capacity Building for Instant Pounded yam Flour Production, Nigerian Journal of Information Studies, Vol. 4, No. 4, pp 1-5

[12] Oshodi, "Roots and Tubers Systems," Federal Institute of Industrial Research, Nigeria, FIIRO, 2005. www.iita.org

[13] Katsuyama A. M, Olson N. A and Rose W. W., "In-Plant Control of Food Processing Waste Water," U.S Environmental Protection Agency, Office of Technology Transfer, Washington, D. C., 1975.

[14] Lisa B., "A New Millennium Spin on Peeling Vegetables," Manufacturing Innovation Insider Newsletter, Lyco Manufacturing Inc., 2002): www.lycomfg.com

[15] Olukunle O. J, Ademosun O. C, Ogunlowo A. S, Agbetoye L. A. S, and Adesina A., "Development of a Double-action Cassava Peeling Machine," International Conference on Prosperity and Poverty in a Globalized World; Challenges for Agricultural Research, DuetscherTropentag, Germany, 2006. www.tropentag.com

[16] Ariavie G. O and Ohwovoriole E. N, "Improved Ohwovoriole's Rotary Cassava Tuber Peeling Machine," *Nigerian Journal of Engineering Research and Development*, vol. 1, no. 2, pp. 61-63, 2002.

[17] Rotimi I., "Design and Fabrication of rice polisher," undergraduate project thesis, Department of Mechanical Engineering, Federal University of Technology Akure, Ondo-state, Nigeria, 2005.

[18] Chelecha O. P., "Design and Fabrication of a multipurpose crushing machine," undergraduate project thesis, Department of Mechanical Engineering, Federal University of Technology Akure, Ondo-state, Nigeria,2003.

[19] Khurmi R. S and Gupta J. K., *Mechanical Engineering Design*, S. Chand and Company Limited, Ram Nagar, New Delhi, India, 2005.

[20] Sahay K. M and Singh K. K, *Unit Operations of Agricultural Processing*, Vikas publishing house, PVT Limited, 1994.

[21] Olukunle O. J., "Development of a Cassava Peeling Machine for Cottage Industries," Tropentag University of Kassel-Witzenhausen and University of Gottingen, Conference on International Agricultural Research for Development, 2007,www.tropentag.com