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DESIGN AND FABRICATION OF YAM SLICING MACHINE

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ABSTRACT

. A power operated machine is developed for slicing of yam, consists of an electric motor, the chamber fitted with auger shaft to transport the yam. The slicer is positioned at the outlet of the feeder with rotary cutter. Machine capacity was influenced by moisture content of tubers and variations in length and diameter. A multi-crop slicing machine was designed, fabricated and evaluated for performance. The major components of the machine include the hopper, mainframe, conveying disc, slicing unit, slicing shaft, idler shaft, pulley, bearing, electric motor base and outlet. Performance of the device was evaluated using the following parameters: slicing efficiency, throughput and percentage of non -uniform slices. The slicing efficiency, throughput and non–uniform slices obtained was 52.3 %, 315 kg/hr. and 47.65 % respectively. Making the chute adjustable to different tuber thickness would eliminate wobbling and further reduce the percentage of non–uniform slices. The design capacity of the machine is 25kg of yam per hour while the average efficient is 91%, the summary of the cost is equivalent to one hundred and fifty thousand naira and function efficient 87.86%.

Key words: Efficiency, Performance evaluation, Slicing device, Yam tuber.

INTRODUCTION

Yams can be processed into flour for making bread, biscuits and for preparing beer (Grenand, 1980). They are also fed to domestic animals either fresh or boiled and as a result, they serve as a valuable food for the conversion of such animal product as milk, meat and eggs. Some species have chemical, pharmaceutical and cultural values for making insecticides, steroid and for social events. The world production of yam is 3.9 tones and West Africa accounts for 90-95 % of total production (FAO, 2005) reported that Nigeria is the single largest producer of yam, accounting for about 71 % of total world production.

Yams, being a perishable crop, need to be processed into a more suitable form such as chips, flour, starch and glue so as to improve their shelf life, reduce or eliminate toxic alkaloid and improve the palatability of the food products. To achieve this and reduce bulkiness, losses, cost of transportation and drudgery in production, high moisture content of yam tuber could be maximally reduced with appropriate technologies, especially for Nigerian small-scale yam farmers who produce most of these yams. Drying is an appropriate option for preserving yam. Drying of yam could be enhanced by increasing the surface area of the tubers. Slicing involves using sharp blades to reduce the yam tuber into smaller thicknesses purposely meant to increase the surface area of the product for faster drying. .Olukunle (2007) Some experts stated that sharp knife could be used during slicing to reduce damaging the yam tissue. The physical properties of yam tuber relevant to slicing are shape, size, length, weight and moisture content.

In recent times, some slicers have been developed for reducing the size of agricultural products such as electrically operated ginger slicer; rotary draw banana slicer; Cassava Chipper; Potato slicer (FAO, 1991) and foot operated yam slicer. The above technologies are for different applications except the foot operated yam slicer, which uses human energy. It is slow and labor intensive. The development of a motorized yam slicer will provide a relief of human labor speed up slicing and produce uniform slices for a better end product.

Timely processing of farm products is important to prevent post-harvest losses and ensure food quality. Several processing, operation have mechanized in the production line of yam products such as parboiling, drying, pulverizing, etc. (Babajide et al 2008). 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 engineering in Nigeria being the largest producer of yam in the world**.** Shape and length, depend on their variety, genetic make-up and species. Environmental factors such as soil structure. soil density, presence or absence of rocks and roots, also affect the physical characteristics of yam tubers,

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determines the shape of yam tubers by taking linear measurements at various points on the tuber. Most yams are more or less cylindrical in shape with pointed or round lower end. The weights of yam tubers depend on their moisture content, reported that yam tubers contain less than 40% dry matter (Babaleye, 2003). This paper is limited to the design and fabrication of a yam slicing machine that will use a single electric motor and will also slice two different ways. The machine has a cylinder that will move the yam through the slicing chamber and return afterward.

Problem Statement.

Majority of the existing slicing machines are imported, expensive and sophisticated which are not easy to operate and maintain by the local farmers. Also, some of these machines are designed for a particular type of crop and cannot be used for other crops. The project was therefore conducted to achieve the following objectives:

i) To design and fabricate a prototype multi-crop slicing machine.

ii) To evaluate the performance of the machine in slicing carrot, onion, yam and potato by determining its slicing efficiency and throughput capacity at different speeds of operation.

The design and fabrication of a multi-crop slicing machine is expected to lead to the following

i. Reduction of human drudgery associated with the manual method of slicing root and tuber crops.

ii. Reduction of slicing losses and infection of root and tuber crops when compared with the existing slicing machines.

iii. . Generation of rural employment through widespread cultivation, increase in farmer's productivity

Yam tubers loose most of these weights during storage especially in an open-air traditional barn. Tubers stored in barns usually lose 50% of their weight. This affects the appearance and texture of the yam tuber, hence requiring more force for slicing. (Ukatu 2002) Yams can also be processed into flour for making bread, biscuits and for preparing beer.

Slicing and size reduction slicing is a form of size reduction and the general term "size reduction" includes slicing, cutting, crushing, chopping, grinding and milling. The reduction in size is brought about by mechanical means without change in chemical properties of the material

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and uniformity in size and shape of individual units of the end product. Ajiboshin et al (2005). Such processes as cutting of fruits or vegetables for canning, shredding sweet potatoes for drying, slicing onion for salad, chopping corn fodder, grinding grain for livestock feed and milling flour are size reduction operations. Reducing the size of food raw materials is an important operation to achieve a definite size range.

2.0 METHODOLOGY

Machine Description: The assembly and orthogonal drawings of the multi-crop slicing machine is shown in appendix. The machine consists of the following components, namely; hopper, upper housing, feed channel, conveying disc, slicer shaft, outlet, slicing unit, frame, idler shaft and idler frame

2.1 Components of the yam slicer

Find below the components of a typical the yam slicing machine.

(i) **Feeding Chute**: The chute serves as the hopper and provides means of feeding yam tubers to the device. It is made of galvanized steel. Its length and diameter were based on average length and diameter of the tuber. The reason for this is to prevent wobbling.

(ii) **Blades:** The blades are made of galvanized steels coated with aluminum. They are used for effecting slicing. To prevent tuber damage, easy maintenance and replacements, the blades were sharpened and bolted to the bearing shaft.

(iii) **Blade Housing**: The blades housing shields the rotating blades during and after operation to prevent accident. A door way was provided to facilitate easy access to the blades by the side of the housing

(iv) **Bevel Gears**: Bevel gears were angled at angle 90˚to each other so as to transfer the horizontal speed of the driving gear to the driven gear.

(v) **Pulleys**: Larger pulley was used to reduce electric motor speed in the design.

(vi) **Bolts and Nuts Selection**: For all the attachments made, 5 mm bolts and nuts were used. The thickness of the slices considered was 7 mm. This was essential in determining the speed of the blades.

2.2 Mode of Operation of Yam Slicer

The yam slicer reduces tubers of yam into smaller thickness for faster drying. It consists of powered shaft, bevel gears, blades and feeding chutes. The powered shaft is of diameter 30 mm and 130 mm long with 8-tooth bevel gears (Ø 60 mm) at its end. The blades are 270 mm long and 40 mm wide. Each of the blades has holes of Ø 5 mm at one end to facilitate bolting it to the blade's bearing shaft of diameter 30 mm. Olukunle et al (2006). Blade's bearing shaft with bevel gears at its end was angled, 90˚ to that of power shaft.

The slicer is operated by an electric motor and power transmitted to the blades through the shaft via the pulley's v-belt. It is manually fed with one tuber at a time through the chute. The whole tuber falls vertically as it is manually fed by the operator against the rotating blades and become sliced. The thickness of the slices is predetermined by the feed rate pressure on the yam tuber and this is greatly enhanced by the rotating speed of the blade. The slices are collected through the channel into the receptacle below the blades housing

2.3 DESIGN CALCULATION

(a) Determination of the feeding chute of the slice

The weigh (kg), length (L) and circumference (C) of different sizes of yam tuber were taken. The mean of the circumference was used to determine the average diameter (d) of the yam tubers as:

$\pi d = C$ (i)

And,

$d = \frac{C}{\pi}$

where, C = mean circumference of yam tubers: d = diameter of the yam tubers.

$\pi = \frac{22}{7}$

The diameter (d) becomes the diameter of the slicer chute.

(b) Determination of dynamic frictional coefficients (blades and yam)

When two bodies in contact move relatively to each other, resistance occurs between them. This is due to friction that opposes their motion. Different sizes of yam slices were individually placed on a neat weight-carrying pan. Weight (F) was added to the pan until the slices to move at

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uniform velocity. The thickness and weigh of each slice (R) were measured using micro-meter screw gauge and weighing balances respectively to determine the coefficient of dynamic friction as shown below.

$$\mu = \frac{F}{R} \qquad \text{(ii)}$$

The knowledge of the coefficient of dynamic friction helps to obtain the dynamic frictional force which is important in determining the shear force that must be applied to the blades to effect shearing of tubers.

Therefore. the shear force (P_t) of the device is given as:

$$P = \frac{T}{R} \qquad \text{(iii)}$$

Where, P_t = shear force; T = torque; R = resistance.

(c) Determination of the number of revolution of the shaft

Linear velocity (*V*) is equal to the angular velocity

$V = R\dot{\omega}$

Linear velocity (V^2) = $U^2 + 2as$ (iv)

$U = 0$

$V^2 = 2as$

$V = \sqrt{2as}$

But, $\dot{\omega} = \frac{2\pi N}{60}$

$\sqrt{2as} = \frac{2\pi RN}{60}$

$N = \sqrt{\frac{60^2 aS}{2\pi^2 R^2}}$

where; S = thickness of the yam slices; R — length of the blades; a = acceleration due to gravity.

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2.4 Bending Moment of the Shaft

The bending moment was calculated by taking into account load acting on the disc. Assuming that the Mass of the peeling disc = 25 kg, Mass of yam to be peeled = 20kg per batch, Total Mass = 45 kg. Mass of the peeling disc and yam was considered as uniformly distributed load acting over a span of length 1 m. This was converted into equivalent point load acting at the center of the shaft. Considering that the shaft is simply supported, maximum bending moment occurs at the center of the shaft, and is calculated as

$M_b = \frac{PL}{4}$

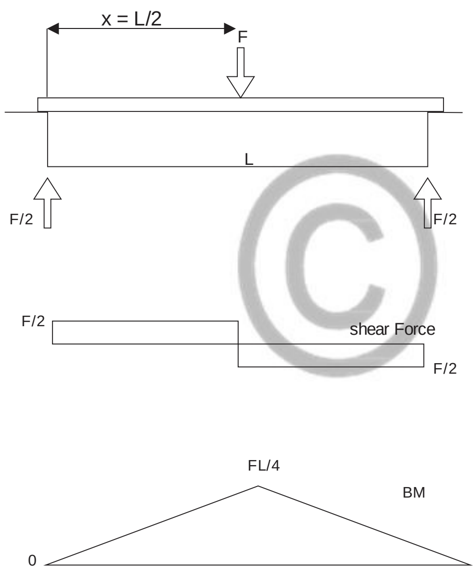

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Fig 1: Bending moment of the shaft

Torque is nothing but twisting moment.

Therefore, $M_t = 110.25$N-m

Diameter of the solid shaft is determined by using the following formula

Where,

d = shaft diameter

M_t = twisting moment of the shaft, Nm

M_b = bending moment of the shaft, Nm

K_t = stress combine and fatigue factor for torsion = 1.5

Kb = stress combine shock and fatigue for bending = 1.0

S_u = ultimate tensile strength of mild steel is 67Mpa

$d^3 = \frac{16}{\pi\ X\ 67\ X\ 10^6}\sqrt{(110.25\ \ X\ \ 1.5)^2 +\ (112.5\ X\ 1.0)^2}$

$= \sqrt[3]{0.0000152}$

=0.0248m

2.5 Performance Evaluation

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 NC 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 (3).

$$F_E = \frac{N_C}{N_T} \text{ x } 100\% \qquad (3)$$

Determination of Slicing Efficiency (SE) and Percentage Material loss in Slicing (MLS):

Slicing efficiency is the ratio of the total weight of sliced cubes Wc to the total weight of yam before slicing W_D expressed as a percentage as expressed in equation (4). Percentage materials losses in slicing is a measure of the effectiveness of the slicing chamber. If W_D is total weight of yam slicing and Wc is total weight of yam after slicing, then it is expressed in equation (5).

$$S_E = \frac{W_C}{W_D}\ X\ 100\% \qquad (4)$$

$$M_L = \frac{W_D - W_C}{W_D}\ X\ 100\% \qquad (5)$$

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Determination of Average Machine Efficiency (ME) and Average Machine Percentage Material loss (ML/.):

Average Machine efficiency, M_E is given by the average of the peeling and slicing efficiencies equation (6). The average Machine Percentage Material Loss, M_L is given by the percentage material losses in peeling and slicing as indicated in equation (7).

$$M_E = \frac{1}{2}(P_E + S_E) \qquad (6)$$

$$M_L = \frac{1}{2}(M_{LP} + M_{LS}) \qquad (7)$$

3.0 RESULT AND DISCUSSION

The percentage of materials lost has been drastically reduced while the total processing time gives the machine a great advantage over the laborious and time consuming hand processing. Slicing time is fairly constant for all tubers used. The orientation and size of tubers however affects the effectiveness of slicing to a great extent. It was noted that despite the variation in the weight of the tubers used during the testing, the slicing time remained fairly constant. This result shows that the weight of tubers has little or no effect on slicing time. The table below represents the performance parameters of the yam slicer. From the table, the slicer has an average slicing efficiency of 52.3%, while the throughput and percentage of non-uniformity cutting of slices are 315 kg/hr. and 47.65% respectively. These parameters were tested with six yam tubers of varying diameter. It was observed that tubers of diameter close to that feeding chute have higher slicing efficiency than tubers of lower diameter. For example, yam tubers of diameters 89.5 mm and 87 mm have efficiency of 89.11% and 71%. The reason for this could be as a result of wobbling effect of the tubers with the chute walls, as the yam diameters are very close to that of the chute walls. Higher percentage of non-uniform slicing efficiency was observed for tubers of low diameters**.**

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Table 1.

Dia. of Yam (mm)	Wt. of yam (kg)	Wt. of sliced yam uniform (kg)	Wt. of sliced yam non-uniform (kg)	Slicing efficiency	% non-uniform sliced yam
89.5	1.01	0.90	0.11	89.11	10.86
87	1.05	0.75	0.30	71	29
78	1.25	0.50	0.75	40	60
74	1.00	0.45	0.55	45	55
68	1.60	0.45	1.15	28	72
53	1.10	0.45	0.65	41	59
Average				**52.3%**	**47.65%**

Weight or uniform and non-uniform slices, and efficiency of sliced yam

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CONCLUSION AND RECOMMENDATION

. The performance gave the machine the efficiency of 52.3%, with average capacity of 315 kg of yam per hr. This was achieved with very low cost of production will promote timely processing 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. 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.

For further study, and to enhance the performance of the motorized yam slicing machine, in terms of machine capacity, efficiency and lower percentage material loss, it is recommended that: 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;

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

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