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CONSTRUCTION AND PERFORMANCE EVALUATION OF A DAMAGED EFFICIENT PLANTAIN SLICER FOR RIPE AND UNRIPE PLANTAIN

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1.0 INTRODUCTION

1.1 Drastically reducing wastage and plantain losses during harvest for plantain farmers, ensures timeliness and productivity in the enhancement of availability of plantain all year round. The reduction in plantain wastage will help to boost productivity and encourage the local plantain processors to engage in massive planting, keeping in view post-harvest wastage prevention due to damages and losses of harvested plantain by slicing and preserving the slices, using drying methods and frying methods. Plantain pulps hygienically processed into chips, will help to minimize post harvest waste/ losses and improve on the quality of Processed plantain into slices [1]. chipping and slicing actions help to reduce the size of plantain pulps in order to allow for uniform drying to prolong storage period of plantain to preserve the plantain crops. There is the need to design and modify existing plantain slicing machines for slicing plantains into chips to help eradicate wastage and help local farmers boost preservation in very large quantity [2].

1.2 STATEMENT OF THE PROBLEM

. Post-harvest losses increase drastically and shell life is decreased as well as storage is made difficult when Production rate is low, damage of chips is high hence high rate of slicing loss thereby increasing human drudgery associated with manual slicing of plantain pulps hence there is the need for the design and fabrication of a portable slicer with adjustable cutter blades that will be able to obtain slices of any desired thickness to cut different but uniformed chip thickness using five(5) cutter blades for spaces of 3mm, 4mm, 5mm, 6mm and 7mm thickness of plantain for greater working efficiency to cut plantains into varying shapes using varying cutter blade thicknesses. Chips damages are high hence high rate of slicing loss thereby increasing injuries associated with manual slicing of plantain pulps. shelf life is decreased due to high Post-harvest losses as a result of difficulty in storage [3].Using one cutter blade is slow, tedious, time consuming, labour intensive and characterized with the production of non-uniform chip thickness of plantain

1.3 AIM OF THE STUDY

This study is aimed at constructing a damage efficient slicer for ripe and unripe plantain by evaluating the performance for high productivity, slicing efficiency and slicing capacity of the plantain slicing machine .

1.4 OBJECTIVES OF THE STUDY

The following objectives were pursued in order to achieve the aim of this study

i. To evaluarte the slicing efficiency of the constucted plantain slicer.
ii. To evaluate the damage efficiency of slicer and obtain an optimal value of damage efficiency that will be able to eliminate losses and wastage in the constructed slicer.
iii. To evaluate the machine capacity of the slicing machine..
iv. To eradicate the non-uniformity of plantain chips thickness using varying cutter blades of diferente thickness..

1.5 JUSTIFICATION OF THE STUDY

Interchangably using different cutter blades of varying sizes to obtain different uniform chip thickness. This will help achieve machine capacity, slicing efficiency and appropriate slicing time with low losses of slices.

1.6 SCOPE OF THE STUDY

The scope of the study is limited to the following:

i. To design and constuct a damage efficient plantain slicing machine.
ii. To carry out a performance evaluation on the constructed damage efficient plantain slicer.
iii. To evaluate the constructed damage efficient plantain slicer for wastage eradication and uniformity of chip sizes for both ripe and unripe plantain pulps.

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2.0 LITERATURE REVIEW

Post-harvest losses in Plantain harvesting is a relatively complex process and cannot be determined. However, some factors like poor storage methods, wrong processing methods, poor handling, bad roads and modern preservation methods accelerate the rate of plantain losses after harvest. (Adesina et al 2015), Areas such as owan, abanikaka and uhiere in Edo state, suffer losses due to bad road network and poor availabilty of transportation of the products from farms to the farmers[4].
The bunches of plantain after harvest, are cut into chips manually dried in the open air and then stored in bags to ease transportation and carriage. plantain postharvest losses occur due to improper stoorage , poor processing and modes of transportation[5].

2.2 Plantain Processing

Plantain can be processed into plantain chips. processed plantain chips are more presentable when done using unripe plantain pulps[6] . Slices of unripe pulp, of about 2mm -4mm thick, can be processed into plantain chips [7]. Plantain when harvested, can be sorted out, weighed, peeled and then sliced to uniform thickness before drying.

2.3 Technology of Slicing

Plantain slicing is a size reduction process that involves the application of shearing force on plantain with the aid of a cutter blade to shear through the plantain to obtain a minimum deformation and rupture of the cell wall. The cutter blade could either be on a rotary motion [8]. Slicing action could be done using a sharp edge involving slicing and cutting action on bio-materials that result in the structural failure of the material due to shear, compression or tensión[9]. This method requires frequent sharpening of the blades. Slicing could also be by Tearing with rough serrated edge, eliminating the limitation of frequent sharpening. It operates by a combination of both slicing and sawing action to cut through bio-materials using high velocity single element impact with a sharp or dull edge. A two element scissor type action: Two knives or cutting elements move in opposite directions against one another and thereby getting the food item sliced in the process. The fracture of a material, which is a result of the interaction between the blade edge and the material, depends both on the material properties and the knife geometry [10].

2.4 Existing Plantain Slicing Machines

Previous researchers have put in lots of efforts in developing automated slicers to slice plantain pulps and other food materials with similar properties. This effort was aimed at developing slicers to meet the requirements of large scale processing industries and eradicate time wastage and other limitations associated with manual hand slicing. Yet only little of such machines have been developed to the minimum required standard [8], designed a plantain slicer for small scale industries. It had a cutter chamber, an electric motor and a discharge mechanism. The cutter chamber was made of stainless steel blade, a flywheel and a connecting rod. The feed and discharge mechanism comprised of Geneva and conveyor belt.. The machine was developed to slice a single plantain in 4 seconds during a single revolution of the input shaft. The machine efficiency was recorded at 73.8%.

The demerits of the design : Chip thickness cannot be controlled[11]. ,hence chip thicknesses were irregular due to the momentary fluctuations between the time of cut and the time the conveyor movement was made. An automated plantain slicer with an efficiency of 80% and a machine capacity of 52kg/hrwas developed. The machine uniformly sliced a single plantain for 20 seconds, depending on the plantain length, as against 600seconds for manual slicing method. The major machine parameters were; the cutter plate, a 2 horse power electric motor, belt, bearings and pulleys. Plantain was fed through the collector into the cutting chamber of the machine. The motor supplied rotary motion through the belt and pulley drive to the cutter plate. The cutting action sliced the plantain into chips of relatively uniform sizes.

Plate1: Motorized Plantain slicing machine (Adesina *et al.,* 2015)

A careful study of the existing slicers, have neccessitated the need to design, and construct a damage efficient slicer powered by an electric motor for both domestic and commercial purposes. The main objective of this study is to evaluate the slicing efficiency and the damage efficiency of the constucted plantain slicer, in order to obtain an optimal value of damage efficiency that will be able to eliminate losses and wastage in the constructed plantain slicer.

3.0 MATERIALS AND METHODS

3.1 Materials

Mild steel bars, Low carbon steel (Mild steel sheet), Mild steel angle bar, Plantain bunch, Stainless steel sheet (SS410), V-belt (A-size), Pulley (cast iron), Bolts and nuts.

Table 1: Tools used

S/N	Tools Used	Purpose	Items
1	Arc welding machine	Welding	Sheets, rods and bars
2	Drilling machine	Drilling	Drill holes in sheet metal
3	Hammer and chisel	Shaping and chipping	Shaping sheet metal, chipping all weed joints and spatter
4	Electric wire brush	Cleaning	All components of the machine
5	Files/fitting machine	Dressing and cutting	All component of the machine
6	Measuring tape	Measurement	All component of machine
7	Digital Vanier Callipers	Measurement	Internal and external thickness of components
8	Spirit level	Balancing	Balancing of stands, bed and perforated plates
9	Scriber	Marking out	All component of the machine
10	Hacksaw	Cutting	All component of the machine
11	Spraying machine	Painting	External parts of machine
12	Manually operated cutter	Cutting	Sheet metals
13	Digital Weighing balance	Measurement	Plantain
14	Stopwatch	Timing	Cutter blades slicing time per load
15	Voltmeter	Measurement	The electric motor
16	Tachometer	Measurement	Cutting blades
17	Planimeter	Measurement	Plantain
18	Bolts and nuts	Fastening	For securing the cutting chamber

The materials used for the construction of the slicer were such that could make it to be easily maintained, repaired, and obtained at relatively low costs. The metallic materials used to build the machine will enable it to withstand heat, vibration, humid air, fatigue and stress without failure during operation. All the metallic parts were painted to prevent corrosion.

3.2 METHODS

The problems associated with the operation of manual methods and existing slicer due to the shortcomings in its design were identified. The necessary procedures were carried out to eliminate the causes of the shortcomings observed. Problems identified with the manual and existing design of plantain slicer include: Discoloration of the sliced chips, Longer slicing time of the chips, High noise and vibration during operation and Production of plenty broken sliced chips.

3.2.1 Description of the Plantain Slicing Machine

This design was carried out based on the problems associated with manual method of slicing plantains. The machine consists of the following major components; cutting chamber, cutting blade, cutting disc, electric motor, feed hopper, machine frame, discharge outlet, slicing blade, V-belt, pulley, ball bearings, etc. Plantains are introduced into the machine through the feed hopper. A V-belt was used to transmit the power because of the distance between pulleys; its comparative advantages of increased frictional grip with the pulley to avoid slipping of belts. A 1.5 horse power (hp) electric motor with a speed of 1440 revolutions/minutes (r.p.m) was used to power the machine. The cutting process was carried out in the cutting chamber. The cutting chamber is connected to the feed hopper. It is designed to house the cutting disc and blade and equally to collect the sliced plantains. An inclined stainless steel was welded directly below the cutting disc to receive and dispense the sliced plantains. Perforated sheet metals are put at designated places on the cutting chamber to serve as air inlets in order to avoid discoloration of the sliced plantains. The machine works on shear cutting principle and has the capacity to slice large quantities of plantains within a short period of time. Power is transmitted from electric motor to input shaft via a pulley system. The input shaft transmits power to the cutting mechanisms which consists of a disc with attached blades of varying sizes for cutting the plantain fed in vertically from the feed hopper.

3.2.2 Design Considerations

In order to produce high quality and large quantity of plantain chips, the following factors were considered in the design of plantain slicing machine;

A. Hygiene

The slicing blade must be washable so that quality chips can be obtained therefore the blade must be made of stainless steel as approved by world health organization (WHO) to guide against corrosion.

B. Aesthetics

The machine physical appearance should look good, attractive and not looking odd, this would make it attractive by choosing a streamlined frame design, choosing light but durable materials, wirings should also be done neatly and an attractive paint colour must be selected.

C. Size and Weight of the Machine

The overall size and weight of the machine is an important factor that governs the size of the selected materials and their components such as electric motor. The easy movement of the machine is an important factor, sso that anywhere the machine will be needed, it can be easily conveyed to the place.

D. Compactness

This is important when the machine is built as small as possible without removing basic components and features.

E. Ease of Operation

The machine is designed in a way that it is easy to assemble, disassemble, load, operate and off load.

F. Safety

The wires of the electric motor are all insulated and the electrical switch is carefully selected to ensure complete power cut from the mains when switch off and to prevent electric shock in case the neutral wire becomes the live when plugged to a wrongly connected socket. The casing on the electric motor was also insulated, while sharp edges were made blunt. Rotating parts were also shielded.

I. Power Supply

The plantain slicing machine uses electricity. As soon as you plug in electricity, the power firstly goes to the electric motor that transmits the motion to the pulley that makes the whole system to work.

3.2.3 Design Requirement

Establishing design requirements is one of the most important elements in the design process and this task is normally performed at the same time as the feasibility analysis. The design requirements control the design of the project throughout the design process. The following design requirements were drawn:

1. Design for Speed Ratio for Belt Drive
2. Determination of Angular Velocity of Cutting Disc
3. Determination of Cutting Force
4. Power required to Slice Plantain
5. Distance between the Driver and Driven Pulley
6 .Determination of Lap Angle
7. Determination of Torque
8. Design of Shaft

3.2.4 Detailed Design

This phase builds on the already developed concept, aiming to further elaborate each aspect of the project by complete description through solid modeling, mathematical modeling, working drawing as well as specifications.

3.2.4.1 Design for Speed 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:

$$\frac{N_2}{N_1} = \frac{D_1}{D_2} \qquad (3.1)$$

Where:

D_1 = Diameter of the driver = 50 mm

D_2 = Diameter of the driven = 150 mm

That is,

N_1 = Speed of the driver pulley = 1440 rpm

N_2 = Speed of the driven pulley = ?

Therefore;

$$N_2 = \frac{(1440 \times 50)}{150} = 480rpm$$

3.2.4.2 Determination of Angular Velocity of Cutting Disc

$$w = \frac{2\pi N}{60} \qquad (3.2)$$

$$w = \frac{2\times\pi\times480}{60} = 50.272\ rad/sec\text{onds}$$

3.2.4.3 Determination of Cutting Force

The cutting force of the plantain was calculated as follow.

$F = ma$ where: (3.3)

m = Mass of the cutting disc + Mass of cutting blade + Mass of Shaft = 3.05 kg

a = Linear acceleration (m/s^2)

But,

$a = rw^2$ (3.4)

where,

w = Angular velocity of rotating disc

r = Radius of the cutting disc = 30 mm = 0.030 m

Substituting Equation (3.4) into Equation (3.3)

$F = mrw^2$ (3.5)

$F = 3.05 \times 0.030 \times 50.272^2 = 254.370\ N$

3.2.4.4 Power required to Slice Plantain

$P = FV$ (3.6)

where,

P = cutting Power

V = Linear velocity of the cutting

F= Cutting Force

But,

$V = rw$ (3.7)

Thus,

$P = Frw$ (3.8)

$P = 254.370 \times 0.033 \times 50.272 = 421.994\ watts$

Considering a safety factor of 2.5

$$P = 421.994 \times 2.5 = 1054.985\ watts$$

But,

1.5 hp = 111.19kw

Therefore,

1054.985 watts $\approx 1.5\ hp$

Electric motor of capacity 1054.985 watts (1.5hp) with speed of 1440 rpm was selected based on safety and availability of the motor.

3.2.4.5 Distance between the Driver and Driven Pulley

The centre to centre distance between driver and driven pulley is given as:

$C = 2D_1 + D_2$ (3.9)

where,

D_1 = Diameter of the driver = 50mm = 0.05m

D_2 = Diameter of the driving = 150mm = 0.15m

C= Centre to centre distance between driving pulley and driven pulley

Therefore,

$$C = 2 \times (50 + 150) = 400mm = 0.4m$$

3.2.4.6 Determination of Belt Length

The belt length can be obtained as follow:

$L = 2C + \frac{\pi}{2}(D_1 + D_2) + \frac{D_1 + D_2}{4C}$ (3.10)

$$= 2 \times 0.4 + \frac{\pi}{2}(0.05 + 0.15) + \frac{(0.05 + 0.15)}{4 \times 0.4} = 1.24m$$

3.2.4.7 Determination of Lap Angle

The equation is expressed as follow:

$\alpha = 180 \pm 2\sin^{-1}\left(\frac{D_2 - D_1}{2C}\right)$ (3.11)

where,

α_1 = Angle of lap for driving pulley (rad)

α_2 = Angle of lap for driven pulley

C = Centre to centre distance between driving pulley and driven pulley

However, for open belt, angle of lap is given as;

$\alpha = 180 - 2\sin^{-1}\left(\frac{D_2 - D_1}{2C}\right)$ (3.12)

Therefore,

$\alpha = 180 - 2\sin^{-1}\left(\frac{0.15-0.05}{2\times0.4}\right) = 165.64^0$

Converting the angle from degree to radian,

$165.64° \times \frac{\pi}{180°}$

= 2.89rad

3.2.4.8 Determination of Torque

The torque is obtained from the Equation (3.13)

$$T = Fr \quad (3.13)$$

where,

T = Torque

F = Force

r = $\frac{d}{2} = \frac{33}{2} = 16.5\ mm = 0.0165\ m$

Therefore;

$T = 12.927 \times 0.0165\ m = 0.2133\ Nm$

3.2.4.9 Determination of Belt Tension

The belt tension can be calculated as follow:

$$2.3log\left(\frac{T_1}{T_2}\right) = \mu\alpha \quad (3.14)$$

where,

α = angle of wrap of an open belt

μ= coefficient of friction = 0.4

T_1= Tension in the tight side of the belt

T_2= tension in the slack side of the belt

Also;

$$P = (T_1 - T_2)V \quad (3.15)$$

$$P = (T_1 - T_2)rw \quad (3.16)$$

Where T_1 and T_2 are tension on the tight and slack sides respectively (N)

Therefore;

$1054.985 = (T_1 - T_2)1.6589$

$T_1 - T_2 = \frac{1054.985}{1.6589} = 635.954$

$$T_1 = 635.954 + T_2 \quad (3.17)$$

Also;

$2.3log\frac{T_1}{T_2} = 0.40 \times 2.89$

$log\frac{T_1}{T_2} = \frac{0.40 \times 2.89}{2.3} = 0.503$

$\frac{T_1}{T_2} = e^{0.503} = 1.654$

$$T_1 = 1.654T_2 \quad (3.18)$$

Equating both Equation (3.17) and Equation (3.18),

$1.654T_2 = 635.954 + T_2$

$1.654T_2 - T_2 = 635.954$

$0.654T_2 = 635.954$

Therefore;

$T_2 = \frac{635.954}{0.654} = 972.407\ N$

Hence;

$T_1 = 1.654 \times 972.407 = 1,608.36\ N$

3.2.4.10 Design of Shaft

$$d^3 = \frac{16}{\pi S_S}\sqrt{(K_bM)^2 + (K_tT_d)^2} \quad (3.19)$$

Where,
M=Bending moment
For suddenly applied load (heavy shock), the following values are recommended for K_b and K_t
K_b= 2 to 3
K_t= 1.5 to 3
Selecting material of shaft SAE 1030
S_{ut}= 527MPa
S_{yt}=296MPa
K_L= Load factor=1.75 for line shaft
$\tau_{max \leq 0.30 S_{yt}}$
$\tau_{max \leq 0.18 S_{ut}}$
S_{ut}= Ultimate yield strength
Thus, for diameter of shaft

$$d^3 = \frac{16}{\pi \times 2{,}103.61} \sqrt{(3 \times 1{,}262.17)^2 + (3 \times 21.757)^2}$$

$$\approx 20\ mm$$

3.2.5 FABRICATION OF THE PLANTAIN SLICING MACHINE
The following manufacturing processes were used for the fabrication of the plantain slicing machine.

3.2.5.1 Cutting process
Cutting machining method was used for all components and machine elements that requires cutting. Such components include the frame, frame housing, feed hopper etc. and hacksaw, hand grinding and cutting machine were used.

3.2.5.2 Welding process
Welding of the slicer involved the joining of two or more metals together and this was achieved using gas welding as well as arc welding which is the most common welding operation. Electric arc welding was used in joining some the machine components in this study. s

3.2.5.3 Grinding and Filling Operation
A surface finishing process, grinding process was used to provide smooth surface for the machine and it components parts. However, filling was used to remove unwanted parts and metals and this brought about a good surface finish.

3.2.5.4 Drilling and Boring Operation
Drilling and boring operation were mainly applied in machine operation for making holes for temporary joints on the slicer. On the other hand, boring was used to enlarge the drilled holes on the slicer to the required dimension. Both machine processes were applied in fabrication of the plantain slicing machine especially in the parts/components were bolt and nuts were required.

3.2.5.5 Fastening
Fastening a temporary joining process was used to bring two or more separate parts of the slicer together. This was done in such a way that the joint can be disassembled and maintain. For this study, bolts and nuts, screw, washers and keys were the fasteners used.

3.2.5.6 Painting
The entire assembled machine (both inner and outer) was thoroughly painted (coating) not only to provide good surface finish but most importantly for the purpose of protecting the metals against corrosion.

3.2.5.7 Assembly Process
The assembly process involved the joining of the different parts of the machine. The joint can be temporary or permanent. Some parts/components of the plantain slicing machine was assembled temporarily while other parts/components were done permanently.

3.2.5.8 Safety Precaution Taken
Hazard is being posed during and after fabrication. For safety use of the machine domestically and commercially,. The following neccessary safety precautions were taken;

i. Operator of the machine should be familiar with the mode of operation of the machine.
ii. The machine should be switch off when not in use.

Plate.2: Picture of the constructed damage efficient Plantain Slicing Machine

4.1 Performance Evaluation

The rotating parts of the machine were lubricated to reduced friction. The belt was connected to the pulley and the electric motor. Testing of the machine with fresh pulps of plantain was then carried out. The electric power was supplied to the machine through electric motor and test run for thirty (30) minutes so as to study the behaviour of the machine. It was observed during this process that blade rotated without wobbling. The fresh plantain pulps were peeled with a knife to remove its pericarp and pave way for the endocarp. The peeled plantain pulps were feed into the machine through the feed hopper and covered with a lid, during this process, sliced plantain (chips) passed through the discharged outlet. In this study, twenty (20) pulps of fresh plantains were measured to be 4.24 kg using a weighing balance. The plantain pulps were sliced for 30.2 seconds using machine and 600 seconds using manual/tradition method; the weights of the properly sliced fresh plantain pulps and broken sliced plantains were 4.01 kg and 0.23 kg respectively.

4.2 Machine Capacity

The machine throughput capacity was calculated using Equation (4.1).

$$M_C = \frac{Wsp}{Ts} \qquad (4.1)$$

where,

Wsp = Weight of fresh plantain pulps (kg)

Ts = Slicing time (seconds)

A. For Plantain Slicing Machine

$M_C = \frac{95.05\ kg}{0.153} = 636.9\ kg/hour$ for unripe plantain

$M_C = \frac{47.49\ kg}{0.747} = 641.7\ kg/hour$ for ripe plantain

4.3 Efficiency of the Machine

The efficiency of the machine is calculated using Equation (4.2).

$$\text{Slicing } Efficiency = \frac{W_1 - W_2}{W} \times 100 \qquad (4.2)$$

where,

W_1 = Weight of properly sliced fresh plantain pulps

W_2 = Weight of broken sliced fresh plantain pulps

$Slicing\ Efficiency = \frac{95.05 - 0.995}{95.05} \times 100 = 98.9\ \%$ for unripe plantain

$$Slicing\ Efficiency = \frac{47.49\ - 0.8965}{47.49} \times 100 = 98.1\ \%$$

Damage efficiency:

$$Damage\ \ Efficiency = \frac{Wd}{Twp} \times 100 = \ \%$$

Wd=Weight of damaged sliced plantain

Twp = Total weight of properly sliced plantain

$Damage\ \ Efficiency = \frac{0.995}{95.05} \times 100 = 1.05\ \%$ for unripe plantain

$Damage\ \ Efficiency = \frac{0.8965}{47.49} \times 100 = 1.88\ \%$ for ripe plantain

4.4 RESULTS:

A set of ten (10) trials was carried out on the modified plantain slicing machine for unripe plantains and the following values were recorded.

Table 2: Experimental results for Unripe plantain

Experimental runs	Number of Plantains	Initial weight of plantain before slicing(kg) A	Weight of chips produced(kg) B	Weight loss=C A-B=C	Slicing Time (Hr) (D)	Throughtput capacity (B/D)
Test 1	67	13.45	7.81	5.34	0.1250	62.48
Test 2	72	15.38	10.17	5.21	0.1760	57.78
Test 3	77	16.57	11.46	5.11	0.1710	67.02
Test 4	81	16.26	10.25	6.01	0.1500	68.33
Test 5	76	15.26	10.10	5.16	0.1700	59.46
Test 6	65	13.19	8.12	5.07	0.1510	53.77
Test 7	73	14.82	9.81	5.01	0.1600	61.31
Test 8	75	15.11	9.91	5.20	0.1800	55.05
Test 9	74	15.02	9.72	5.32	0.1531	74.76
Test 10	64	13.01	7.70	5.31	0.100	77.00
TOTAL	Total number of plantain pulps=724 plantains	Total Weight=148.07kg Average weight=148.07/10 =14.8kg	Total=95.05kg Average=9.51kg	Total=47.74 Average=4.7 74	Total=1.5351 1hr53min Average=0.153	Total=636.96 Average=63.69 Kg/hr

Table3 : Experimental results for ripe plantain

Experimant Runs	Initial Weight(kg)	No of plantains slicced	Weight of chips produced(kg)	Weight loss(kg)	Slicing Time	Throughput capacity (kg/hr)
Test 1	12.26	61	4.84	7.42	0.091	53.187
Test 2	10.51	50	4.26	6.89	0.075	56.80
Test 3	13.59	68	5.09	8.50	0.071	71.69
Test 4	10.83	54	4.69	6.14	0.065	72.15
Test 5	10.76	53	4.91	5.85	0.072	68.19
Test 6	10.74	53	4.90	5.84	0.073	67.12
Test 7	10.61	52	4.85	5.76	0.081	60.62
Test 8	10.69	53	4.81	5.88	0.082	60.12
Test 9	11.38	56	4.91	6.47	0.080	61.38
Test 10	10.15	50	4.23	5.92	0.06	70.51
TOTAL	Total=111.16kg Average=11.12kg	Total=550 Average=55 plantains	Total=47.49kg Average=4.75kg	Total=64.67kg Av=6.47kg	Total=0.747 Ave=0.075hr	Total=641.77 Average=64.17kg/hr

4.5 BILL OF ENGINEERING MEASUREMENT AND EVALUATION
Table 4 shows the bill of engineering materials used and the evaluation.

Table 4: Bill of Engineering Measurement and Evaluation

S/N	Component	Material	Dimensions (mm)	Qty.	Unit Cost (₦)	Total Cost (₦)
1	Electric motor	Cast iron	1.5hp	1	15,000	15,000
2	Ball Bearing	Stainless Steel	Dia: 20mm	2	1000	2000
3	V-Belt	Rubber	A37	1	500	500
4	Pulley	Cast iron	Dia. 50 mm	1	1500	1500
			Dia. 100 mm	1	2000	2000
5	Solid Shaft	Stainless Steel (ASTM A36)	Length: 3feet Dia: 20mm	1	3000	3000
7	Angle bar	Mild Steel (ASTM A36)	Length: 4800 40x40x3mm	2	3500	3500
8	Stainless Plate	Galvanized metal	1440x710x2mm (SS410)	1	50000	50000
11	Bolt & Nut	Mild Steel (ASTM A36)	11	12	50	600
12	Electrode	Guage 14	14	1 packet	1650	1650
13	Electric cable	1.5 x 3 cores	4 yards	4	200	800
14	Cutting disc	Mild steel	3	3	400	1200
Total						81,750

4.6 DISCUSSION

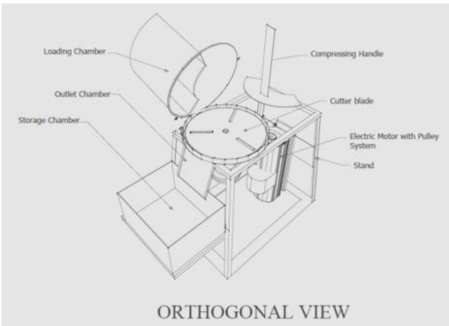
Some pulps of plantain were cut in the crop processing laboratory during the initial stages of the slicer development. Series of remedial actions were taken to ensure the machine's functional requirement for its intended use. Results from design analysis showed that force required for proper slicing of the finger of raw plantain was 254.370 N. The angular speed of rotating disc is 480 r.p.m. A 1.24 m length of belt was used for transmitting power from electric motor to the cutting disc. The distance between the driver and driven pulley, required power, lap angle were calculated as 0.4 m, 1.5hp and 2.89 rad/sec. The angular velocity of the cutting disc was recorded at 50.27 rad /secs and the Torque required was recorded at 0.2133 Nm. The slicing time of pulps of fresh plantain and manual were determined to be 567seconds for unripe plantain and 270 seconds for ripe plantain as against 600 secs for manual slicing respectively. Thus, the machine sliced faster than the manual method of using knife. Results showed that weight of sliced plantain was 47.49 kg and weight of damaged sliced plantain weighed 0.896 kg. The machine capacity for ripe and unripe platain were 641.77 kg and 636.96 kg respectively. Hence, the machine is efficient and when commercialized, as the machine efficiency for ripe and unripe plantain are 98.1% and 98.9 % respectively. it can solve the time wasting problem and inefficient manual method of slicing plantains pulps that is currently practiced in Nigeria.

The machine was noise free during operation with no vibration observed. The slicing blade rotated without wobbling, and saved time indicating that the ability of the machine to slice efficiently depends on the mass of the plantain and the power rating of electric motor used. The slicing machine sliced the plantain without stains on it showing that the slicing blade and cutting chamber had no negative effect on the colour of the sliced plantain thereby impling that there was no contamination and the plantain retained its original colour and round shape of plantain chips with uniform size obtained. The machine's functional requirement was achieved.

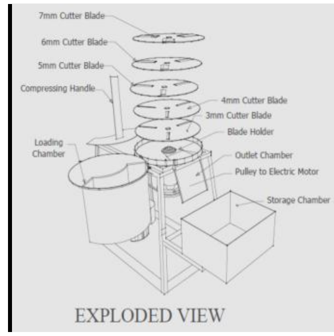
5.0 CONCLUSION

A constructed damage efficient plantain slicing machine was designed, and evaluated for performance. With this new plantain slicer, the problems of safety, quality and quantity of sliced plantain associated with manual slicing have been eliminated. The plantain slicer is environmental and user friendly and does not require any special skill to operate though it .The slicing efficiency of the machine was calculated to be 98.9% and 98.1 % for unripe and ripe plantain.. Besides, it was found that plantain thickness of sliced plantain had the most significant effect on the machine capacity. It is affected the machine speed and the feed rates for both ripen and unripen plantain. The slicing time of 567seconds obtained for slicing 95.05kg of pulps was found to be independent of chip diameter. However, to prolong the active life of the machine, the machine is required to be properly maintained and kept clean at all times. The total weight of the ripe and unripe plantain was recorded at 111.16kg and 148.07kg respectively. The Damage recorded was low. Damage efficiency for unripe plantain was recorded at 1.05% and 1.88% for ripe plantain. The machine capacity for ripe and unripe plantain were 641.77kg and 636.9 kg respectively. showing that the machine can be used for both small and large scale production..

Appendix



Orthogonal view of plantain slicing machine



Exploded view of the slicer

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