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DESIGN, FABRICATION AND TESTING OF A DUAL POWERED PLANTAIN SLICER

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ABSTRACT

This work focused on the design and fabrication of a dual powered slicer for raw plantain and potato chips production. Plantain is cultivated in many tropical and temperate regions. The traditional method of knife slicing plantain has proven to be laborious, time consuming and unhygienic with low output. The design and fabrication of plantain slicing machine is to solve the aforementioned problems. The design parameters determined are the diameter of the shaft (D), the power requirement (P), belt and pulley size. The machine is electrically and manually powered with a 0.7443 kW electric motor while the calculated shaft diameter is 25 mm diameter. The slicer was designed for medium and small scale industries but can also be used for domestic purpose. The slicer works on the principle of cutting to reduce plantain and potato size. The slicer used between 5-8 second to slice a finger of an average- size plantain into chips at 0.78 mm thickness. The slicer achieves 93.93%, 90.26%, and 62.90% efficiency, for slicing unripe, semi-ripe and ripe matured plantain pulps respectively. The capacity for unripe, semi-ripe and ripe was calculated to be 64.3 kg/hr, 61.5 kg/hr and 60.3 kg/hr, respectively. The percentage moisture content for unripe, moderate ripe and ripe plantain was calculated to be 48%, 50% and 56% on wet basis, respectively.

KEYWORDS: Ripe, fabrication, dual-powered, plantain, slicing.

INTRODUCTION

Plantain (Musa spp.) is a slender starchy fruit used as a staple food in many tropical countries. The fruit is used in similar ways as potatoes are used in European and North American diet (Turbana, 2001, Obayopo et al., 2014). Its origin is believed to be from South East Asia. However, a remarkable diversity of plantain exists in Sub-Sahara Africa. Total world production is estimated to be over 76million metric tons. Twelve million metric tons are produced in Africa annually (Fakayode *et al*., 2011). The raw fruit is more nutritious, with about 10 percent more magnesium, phosphorus and potassium than normal varieties. A cup of raw plantains has 27 milligrams of thiamin, a B-vitamin that helps the body's cells use carbohydrates as energy and helps ensure the proper functioning of the heart, muscles and the nervous system (Maia, 2014). According to Okafor and Okafor (2013) unripe plantain is considered a major source of iron.

In sub-Sahara Africa, Uganda is the leading producer of plantain, followed by Nigeria, Ghana, Rwanda, Cote de ivory and Cameroon (Obayopo et al., 2014, Olawuni et al., 2014). Apart from these African countries, the production of plantains and bananas cut across the tropical region of the continent. In Nigeria, for agro-climate reasons, plantain cultivation is concentrated in the southern region of the country. This crop also serves as source of income for rural farmers and substantial foreign exchange can be earned from export.

Plantain is taken in various forms such as fried plantain, boiled plantain, roasted plantain, baked plantain, and plantain chips. Although raw plantain is bitter and starchy, some people like eating them raw. It can also be processed via slicing, drying and grinding for production of plantain flour which is also consumed when baked (Maia, 2014 and Ikechukwu, et al., 2014). Considering the enormous benefits of raw plantain, slicing it can create additional benefits in terms of post-harvest processing. Plantain processed into flour can be stored for up to a maximum of two years (Arisa et al., 2013). Plantains have the potential to contribute to strengthening the national food security and decreasing rural poverty (Adejoro et al., 2010).

Processing of plantain is very advantageous because it makes storage easier due to the reduction in bulkiness and increases its shelf life. It adds value to plantain and therefore gives better return. Obayopo et al. (2014) reported that, 69.4% of plantain and other cooking bananas are used for human consumption while 8.0% are used for animal feed. Post-harvest losses and transformed quantities in the world are 11.5% and 11%, respectively. Therefore, processing has been an integral part of the utilization. Adeboye (2014) reported that, in

Nigeria over 80% of the crop is harvested during the peak period between September and February and there is much wastage during this period because the product does not store for a long period. This results in seasonal unavailability and limitations on the use by urban populations. The simplest mode of processing the plantain is conversion into chips. Slicing are carried out either manually or electrically powered machine.

Several types of cutting machines are available. These include knives with one cutting edge, shear with two cutting edges, saw with man cutting edges (Zakpaa et al., 2009). They may be operated manually or electrically. As reported by Fellow and Hampton (2003), some cutter consists of rotating or reciprocating blade which cut the food as it passes beneath. The purpose of the slicer is to make slicing process less laborious especially for medium scale industries and for domestic purposes. According to Okafor and Okafor (2013) the kitchen knife method remains a primitive way of producing plantain chips in large quantities in small, medium and large scale industries. In this method, a sharp knife is used to slice the plantain usually placed on a wooden cutting board. The problems associated with this method are fatigues, low speed which leads to poor output and low income generation, too many staff are needed, hand injury, non-uniformity of plantain chip thickness, and energy consumption.

The processing of plantain needs to increase to boost farmer's income, reduce spoilage and other avoidable deterioration of the crop in the farm made it imperative to develop some post-harvest processing equipment like the slicer which will go a long way in reducing spoilage, elongating shelf life and eventually increasing farmer income. In view of the injury involved in using the primitive method of producing plantain and potato chips, coupled with epileptic power supply in Nigeria which makes usage of electric slicer ineffective the need to develop a dual-powered plantain and potato slicer is imperative. The design is to improve on the existed manual and electrical operated slicers.

The objectives of this research are to design a portable slicer for plantain that uses two sources of power, fabricate the designed slicer, and test run the plantain slicing machine.

MATERIALS AND METHODS

The machine consists of five major components which are the loading unit, slicing chamber, frame, electric motor, and discharge outlet.

Materials

Components of the machines such as loading unit, slicing chamber shaft, discharge outlet and the cutting blade were made of stainless steel because the parts are always exposed to wet environment during operation.

Some of the machine components and parts that are not exposed to the food directly, especially the frame were made of mild steel.

Fabrication Procedure and Finishing Operation

The operations explained below were carried out in the fabrication of the slicer.

Cutting disc

This is the part of the machine that does the actual slicing. The cutting disc, (Figure1) was cut with shear cutting machine and fabricated from a stainless steel plate with dimensions of, Ø230 mm held in position by a permanent joint, with 5 mm space between the cutting disc housing and the cutting disc. The blade was then sharpened with grinding machine.

Cutting disc housing

As shown in Figure 2, this is the part that serves as the cutting blade compartment. It also has a covering unit that keeps the cutting disc in place and consists of an output opening for the processed plantain pulp.

To fabricate it, the disc diameter was marked out using metal scriber on the stainless plate. Using sheet metal shearing machine, the disc housing was cut out from a stainless steel plate of 2 mm thickness and 242 mm diameter. The centre position of disc through which shaft passes was located and a centre hole of 25 mm diameter was drilled. An opening was made on this covering plate to guide the plantain pulp towards the cutting blade. The parts that were cut out were thereafter welded together.

Shaft

This is the part of the machine that provides the rotary motion required for the cutting. The Facing of shaft to the length 500 mm was done using lathe machine, the tailstock of a lathe machine was used for drilling with the aid of a drilling chuck attachment and the drilling of the key way was done with milling machine.

Frame

This unit carries other component and holds to maintain stability during slicing operation. It supports and provides rigidity for the machine. The length, breadth and height were marked with scriber. The metal sheet was cut with shear cutting machine into required size. The sheet metal was joined together using electric arc welding.

Housing cover for shaft

This is the part of the slicer that covers the shaft, (Figure 3). The required size and radius were measured with measuring tape and mark with scriber. The sheet metal was folded to the required shape with folding machine. The cover was then bolted unto the frame.

Assembly of machine

The assembly of the component parts were carried out in the following order

1. The frame/stand was constructed by welding the appropriate side to each other.
2. The two pillow bearing was fixed on the top of the frame and covering the bearing with the housing which was bolted to the angle bar (Frame).
3. The cutting chamber was fixed at the end of the shaft which was bolted with the cutting disc.
4. Fixing the pulley through which the shaft was inserted.
5. The electric motor stand was constructed and welded to the supporting frame. It was situated underneath the supporting frame.

The orthographic and complete assembly of plantain and potato slicer are shown in Figure 4, and Figure 5, respectively.

Testing Procedure

The plantain and potato slicer was designed and fabricated to slice plantain and potato into chips. In testing the slicer, the following steps were followed.

Test at no load

The slicer was operated empty (with no load) for about five minutes. Unusual noise and irregular rotation were noted during this period. The following were observed during the operation at no load testing. The feeding unit was removed from the slicing unit. Excessive vibration of the whole machine was observed. This led to instability of the machine. The electric motor seat was found to tilt up as a result of the vibration, belt tension and weight of the electric motor. These anomalies were corrected and the test was repeated to ascertain the condition of the machine. When it was satisfactory, test at loading was carried out.

Test with loads

The slicer was tested under three different ripening stages of plantain and three different size potatoes. Each result was labelled A, B, C to differentiate them from one another. The slicer was on and plantains were loaded one after the other for five fingers of raw plantain. At the end cutting of each finger, the slicer was stop to collect the clogging and sliced plantain. At every turn, the number of broken, whole slice, thickness and time of cutting were observed and recorded. This was carried out for three levels of moisture content (MC_1, MC_2 and MC_3) representing level of ripeness of the plantain.

Testing Parameter

The data collected was use to analyse the machine under the following parameters.

i. Slicing efficiency (SE)= $\frac{MW-MB}{MW} \times 100\%$

ii. Broken efficiency $= \frac{MB}{MW} \times 100\%$

iii. Slicing capacity = $\frac{M_1}{t}$

Where, *MW* = Average mass of whole sliced plantain

MB = Mass of broken sliced plantain

M_1 = initial mass of the plantain input

t = time taken to slice (kg/hr)

RESULTS AND DISCUSSION

The results of the test carried out were presented in Table 1. The tests were carried out at three levels of ripeness. Moisture content was used to determine the level of ripening as indicated mc_1, mc_2 and mc_3. Five trial of slicing were carried out at each level of mc_1, mc_2 and mc_3. The average was computed and presented in Table 1.

The data were further used to calculate slicing efficiency, broken efficiency and slicing capacity of the slicer. Table 2 shows the result of the efficiencies and capacity of the slicer.

The result obtained from the test carried out shows that the machine slice best at unripe plantain followed by the semi- ripe (Table 1 and 2). Slicing efficiency of 93.9% was recorded at mc_1 (unripe), the least slicing efficiency is obtained at mc_3 (62.9%). Hence, the machine will be able to meet the required objective as unripe plantain are usually used for chip.

The thicknesses of the slice at the three levels of the ripening are equal, showing that the level of ripeness does not affect the slice thickness of the slicer (Table 1). Also the time for ripe and semi-ripe slice are not different while that of ripe plantain is by 0.6 seconds showed (Table 1).

The result also indicates that the higher the ripening the higher the clogging of the plantain. This is why the broken efficiency (Table 2) is the highest (37.1%) at ripe stage. Table 3 shows the specification of the slicing machines as derived from the test carried out.

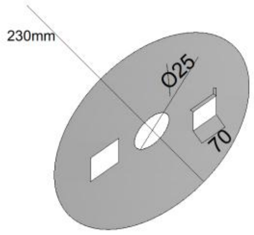

Figure 1: Cutting disc.

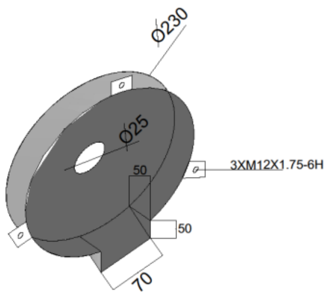

Figure 2: Cutting disc housing.

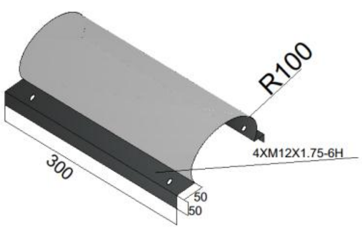

Figure 3: Shaft cover.

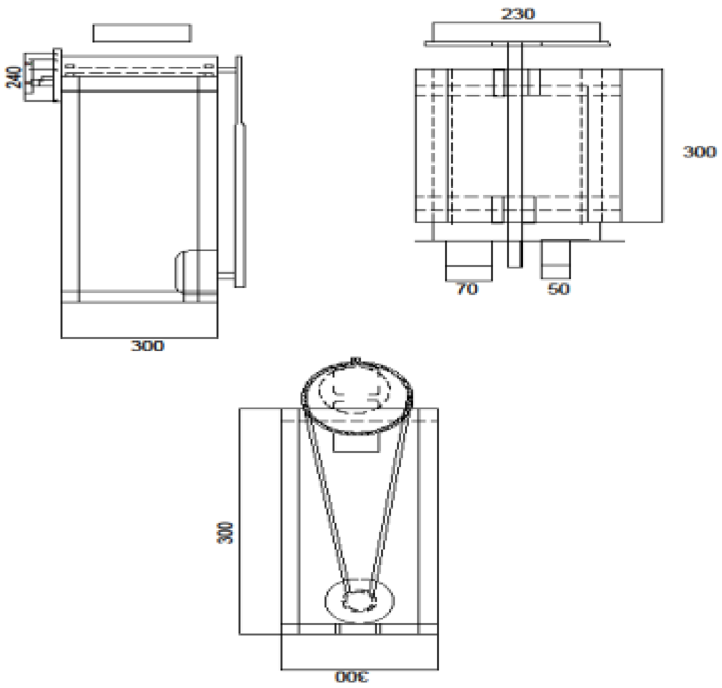

Figure 4: Orthographic drawing of the slicer.

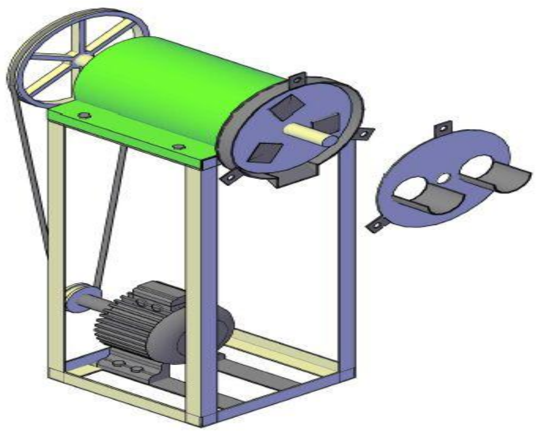

Figure 5: Complete assembly of plantain and potato slicer.

Table 1: Result of Test.

Parameter	**Mc_1 (48%) Unripe**	**Mc_2 (50%) Semi- ripe**	**Mc_3 (56%) Ripe**
Initial mass (kg)	0.1072	0.1026	0.1106
Mass from outlet (whole and broken) (kg)	0.0944	0.0876	0.0826
Whole (kg)	0.0890	0.0842	0.0744
damage sliced (kg)	0.0054	0.0082	0.00276
Time (hr)	0.001666	0.001666	0.001833
Thickness (mm)	0.78	0.78	0.77
Clogging (kg)	0.0074	0.00154	0.00198

Table 2: Result of slicing, broken efficiency & slicing capacity.

Parameter	Mc_1 (48%) Unripe	Mc_2 (50%) Semi- ripe	Mc_3 (56%) Ripe
Slicing efficiency (%)	93.9	90.3	62.9
Damage efficiency (%)	6.1	9.7	37.1
Slicing capacity (kg/hr)	64.3	61.5	60.3

Table 3: Summary of plantain and potato slicer specifications.

Parameter	Dimension
Diameter of shaft	Ø25 mm
Speed of pulley	284 rpm
Diameter of pulley	300 mm
Belt tension	643.38 N
Power requirement	744.6 w
Slicing capacity	64. kg/hr
Slicing efficiency	93.9 %
Damage efficiency	6.1 %

CONCLUSION AND RECOMMENDATION

The plantain and potato slicer was designed and fabricated. The test was carried out on the machine using unripe, semi ripe and ripe plantain The results show that the slicer can slice the plantain with minimum damage.

It is recommended that the machine should be further tested with other crops like potato and cocoyam to see the possibility of adapting the machine to other crops.

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