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DEVELOPMENT OF A SIMPLE PLANTAIN SLICER FOR SMALL SCALE PLANTAIN-CHIPS PRODUCERS

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Abstract

This study looked into developing a simple plantain slicer for small scale plantain chips producers, using locally sourced materials. Manually operated slicing platforms and methods are slow methods commonly used in small scale industries, hence the need for a more advanced design. The developed machine was designed with an electric motor of a power capacity of 746 W and it slices at a speed of 1.8 m/s, with a cutting force of 414 N. It was able to slice plantain conveniently and faster than crude slicing methods. The developed machine had the highest throughput capacity of 46.5 kg/hr and an overall average throughput capacity of 45.61 kg/hr. The slicer had a maximum efficiency of 87 % and an overall average efficiency of 83.25 %. It was observed that time spent influences the throughput capacity as the throughput increases as time increases while there is no direct relationship between the time to slice and the efficiency of the machine for the considered speed in this study.

Keywords: Slicing, Plantain, Throughput capacity, Efficiency.

INTRODUCTION

Plantain is a type of banana which is common in tropical regions. It is starchier and less sweet when compared to bananas. Plantains are usually served steamed, boiled or fried, although ripe plantains can be eaten raw. They are a rich source of antioxidants, vitamin B-6 and minerals, and their soluble fiber content may help ward off intestinal problems (Maia Appleby, 2014). Plantain for local consumption plays an important role in food and income security and has the potential to contribute to national food security and reduce rural poverty (Arisa, 2013). Plantains provide the essential minerals that help the body to function efficiently. A cup of sliced or cooked plantain has 49 milligrams of magnesium and 716 milligrams of potassium, giving the body 15 percent of the recommended daily intake for each of these minerals. The body needs magnesium for proper muscle contraction and nerve function, while potassium is a crucial component in the body fluids. A cup of plantains also contains 5 to 10 percent of the iron need of the body. Iron helps to carry oxygen through the bloodstream which serves as a benefit to the muscles of the body.

Although raw plantain is bitter and starchy, some people like them raw. They are more nutritious raw, with about 10 percent more magnesium, phosphorus and potassium. 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. A cup of cooked plantain has less than 1 milligram of thiamin (Maia Appleby, 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, 2013). The purpose of the machine is to make slicing process less laborious especially for medium scale industries and for domestic purposes. When compared with the traditional method of cutting with a sharp knife, the traditional method took 40-80 seconds per finger of plantain.

In some parts of Africa such as Nigeria and Ghana, plantains are also dried and made into flour; banana meal forms important food stuffs with the following constituent water 10.62% protein 3.55%, fat 1.15%, carbohydrate 81.67% and ash 3.01% (Arisa *et al.,* 2013). Also plantain is a popular staple in Africa and in many other countries of the world. Although many Western consumers consider it a mere super-market bought, millions of people especially in Africa, see plantain as a starchy staple of major importance. Unripe plantain is also considered a major source of iron. Plantain is taken in various forms such as fried plantain, boiled plantain, roasted plantain, baked plantain, and plantain chips. It can also be processed via slicing, drying and grinding for production of plantain flour which is also consumed when baked. There is high demand for plantain slices in form of fried plantain chips by travelers, office workers, school children, and families as part of breakfast. In an effort to make it readily available, several means have been devised in slicing plantain into pieces which is further processed into chips, flour, baked or fried.

Plantain slicing methods

1. Manually operated wooden platform … this is a slow method employed in small-scale industries. The plantain is pressed and moved across the sharp blades of the machine. The major risk is that when it misses a cut, the machine operator gets his finger cut by the exposed sharp blades. It is also time consuming since the operator will be operating in a slow rate to avoid injury. The manually operated wooden platform plantain slicer is a slow method commonly used in small scale industries as reported by Okafor (2013

2. Manually operated cutting knives … in this method, the plantain tuber is placed on top of a sharp blade on the base frame of the machine, and the upper handle which also contains sharp blades pressed down thereby slicing the tuber into chips. The major problem here is that when off-loading, one gets his hands injured because of the chips stocked in-between the sharp blades. It is also time consuming because of the slow nature in off-loading and to avoid injury (Nwanekezie and Ukagu, 1999). Commonly, the process of manual peeling and slicing using knife is time consuming (Awoluyi, 2008; Obeng, 2004).

In view of these, there exists the need to develop a plantain slicing machine of commercial quality. Developing a motorized slicing machine will contribute to food security, export earnings and economic growth. Farmers are faced with post-harvest losses since the plantain perish or get rotten easily when ripe, for this reason, many methods of processing (roasting and frying) are being introduced to reduced losses for human consumption, after harvest.

As regard these, it is necessary to design and construct a plantain slicing machine which will slice a finger of raw plantain within a short period of time (FIIRO, 2007).

Benefits of a plantain slicer

With the development of the machinery in the kitchen, knife is not required anymore. The plantain slicer solves a major problem among small scale plantain chips producers in Nigeria. Therefore some of the benefits include;

- Increased slicing efficiency
- Enhance timeliness

- Slicing process becomes more hygienic
- Slicing becomes less laborious

MATERIALS AND METHOD

Methodology

Design consideration … the design considerations for this study includes the design criteria and the design functions.

Design criteria

1. Improvement on local plantain slicing methods
2. Low cost plantain slicer with considerable efficiency
3. Easy operation and control
4. Simple design and ease of fabrication

Functional requirement

1. To help get the uniform measurement of plantain chips.
2. To improve on timeliness during slicing
3. To increase the level of production
4. To slice varieties of plantain.

Description of machine parts

The plantain slicer was designed to work on the principle of shearing or slicing, due to the sudden contact from the rotating slicer on the plantain. It is made up four units namely: iron framework, power unit, the slicing chamber and the outlet.

***The framework*:** it is made of low carbon iron; the stand forms a square shape of 350mm by 400mm height. The stand support and holds the machine component and gives it a compact design and study outlook.

***The power unit*:** it comprises of an electric motor of 0.75W with a speed of 1440 rpm and a capacitor. The motor powers the machine as soon as it is connected to an electric source.

Plantain slicing unit: The slicing unit is made up of stainless steel of size 75mm and has a cover of size 325mm at both front and back and it in circular shape. The slicing unit has a slicer blade of size 250mm long by 50mm within it and is responsible for the slicing of plantain.

Plantain cones*:* These were welded at the frontal cover of the chamber. They were made up of stainless steel pipe which was cut into U shape of size 50mm and 38mm form, and welded on the frontal cover of the chamber. These cones help to hold the plantain of different sizes to be sliced.

Outlet unit: This is constructed at the bottom of the chamber and it is of size 200mm in which the sliced plantains are been led out.

Materials used for fabrication

Angle iron	Measuring tape
Grinding and cutting machine	Electrodes
Bolt and Nut	Stainless steel
Hollow pipe	Welding machine
Hack saw	Hammer
Drilling machine	

Plate 1: Front view **Plate 2: Side view**

Different views of the slicing machine

Mode of operation

The engine consists of an electric motor which is used to power source for the machine. It is placed vertical in its chamber which allows plantain to be sliced in a vertical rotation which comes in through a cone. The slicer serves as a knife or cutter which cuts plantain pulp into various sizes and dimensions. The slicer is connected to an electric motor through a shaft and pulley assembly. It slices plantain pulp into various thicknesses and discharges it through the outlet. The slicer has dimension of 250mm by 50mm**.** The cone has a circular shape, which allows various sizes of plantain pulp to be sliced. The dimensions of the cone are 40mm, 35mm and 30mm respectively.. The cone can also be referred to as the feeding chute.

Evaluation parameters

These include; shelling power, shelling speed, shelling force, throughput capacity and the efficiency of the machine.

Shelling speed (V) … this is the rate at which plantain is sliced.

$V = \omega r$

where

ω ... *speed of motor*

r … radius of the slicing blade

Shelling force (F) … this is the force exerted to slice plantain per time

$F = p/v$

Throughput capacity (Kg/h) … Throughput is the rate of slicing; it is the quantity of sliced plantain divided by the time taken.

$Throughput = weight/t$ (Kg/h)

Where

Weight … weight of sliced plantain

t … total time taken to slice

Efficiency (%) … The efficiency of the machine was calculated using the equation below:

$$Efficiency = \left[\frac{\{W_1 - W_2\}}{W_1}\right] x \ \ 100$$

where

W1... Total weight of plantain

W2 … weight of damaged plantain

Performance test

The machine was properly assembled and bulk quantities of plantain were purchased from a local store. The lengths and diameters of plantains were measured and recorded before being fed into the slicing machine. The electric motor was allowed to run for few minutes to study the behavior of the machine, before the fruits were into it for slicing. The time for complete mass of fruit fed into the machine were recorded and evaluated.

A bulk quantity of plantain was weighed before slicing; these varieties of plantains had sizes that ranged between 200 - 250 mm. They were sliced using the machine and the slicing process was repeated four (4) times, while each average value was determined. Both sliced and unsliced plantains were collected at the output and weighed. The results were recorded and evaluated.

RESULTS AND DISCUSSION

Power capacity of electric motor (P) = 1HP = 746W

Speed (N) of motor = 1440rpm

Radius(r) of slicer = 12mm

Shelling speed (V) = ωr

But $\omega = 2\pi N/60$

$$\omega = 2\,x\,3.142\,x\,1440/60 = 150.82\,rad/sec$$

Therefore, $V = 150.82\,x\,0.012 = 1.8\,m/s$

Shelling force (F) = p/v

$$F = 746/1.8 = 414\,N$$

The results of the throughput capacities and slicing efficiencies are summarized in tables 1 and 2 respectively below. Table1 shows that the developed machine was able to slice the selected ranges of plantain. The highest throughput capacity was 46.5 kg/hr and was obtained for the long plantain sizes. The average throughput value for the machine was 45.61kg/hr. Table 2 shows that maximum efficiency of 87% was obtained at the third replicate and an average efficiency of 83.25% was obtained for the overall test.

Table 1: Throughput capacity

Length (mm)	W_1 (kg)	Time (s)	Throughput (kg/hr)
205	2.55	200	45.9
217	2.59	206	45.26
213	2.55	205	44.78
220	2.70	209	46.5
Mean			45.61

Table 2: Efficiency of the machine

Length (mm)	W_1 (kg)	W_2 (kg)	Efficiency (%)
205	2.55	0.52	80
217	2.59	0.40	85
213	2.55	0.33	87
220	2.70	0.51	81
Mean			83.25

Effect of time on throughput

As shown in table 1 above and figure 1 below, there is a direct relationship between the time to slice and the throughput; it was observed that the throughput increases as time increases, except for the first replicate that had a low throughput than expected. This could be because machine was just been used and needed time to stabilize.

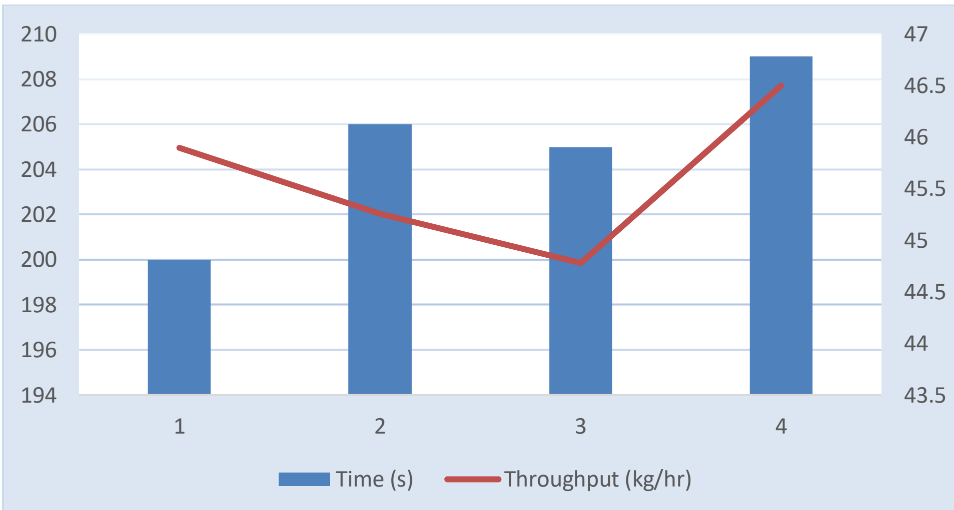

Figure 1: Effect of time on throughput

Effect of time on efficiency

As shown figure 2 below, there is no direct relationship between the time to slice and the efficiency values; it can be observed that the efficiency increases randomly to time increment. This suggests therefore that the efficiency of the machine is not a function of time under the speed condition assessed for this study. Further tests could be carried out to assess this relationship by varying the speed of the machine.

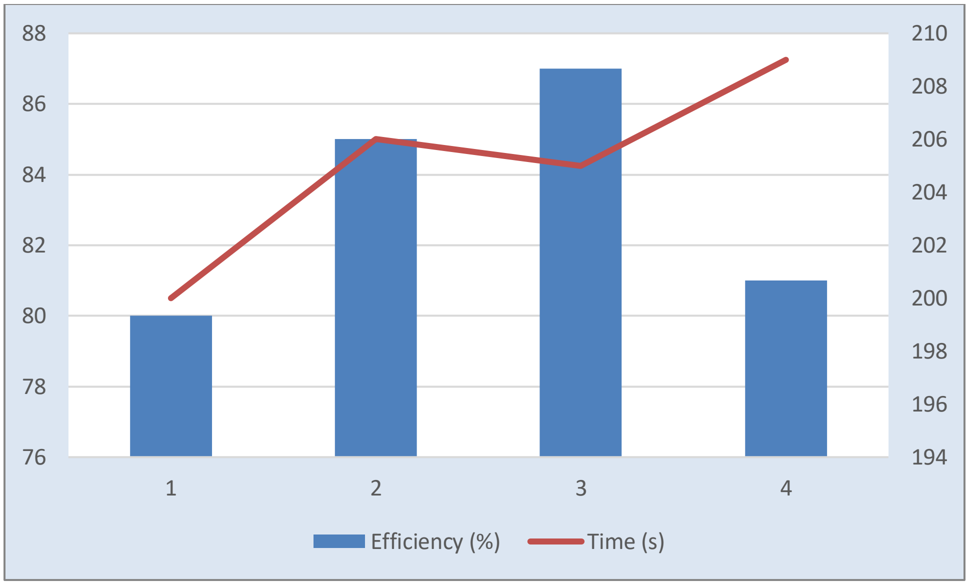

Figure 2: Effect of time on efficiency

CONCLUSION

The developed machine was designed with an electric motor of a power capacity of 746W and it slices at a speed of 1.8m/s, with a cutting force of 414N. It was able to slice plantain conveniently and faster than crude slicing methods. It had an average throughput capacity of 45.61kg/hr. The slicer had a maximum efficiency of 87% and an average efficiency of 83.25%. It was observed that time spent influences the throughput capacity as the throughput increases as time increases while there is no direct relationship between the time to slice and the efficiency of the machine for the considered speed in this study.

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