World Journal of Advanced Engineering Technology and Sciences

eISSN: 2582-8266

Cross Ref DOI: 10.30574/wjaets

Journal homepage: https://wjaets.com/

(Review Article)

Check for updates

Design and fabrication of improved motorized plantain slicing machine for chips production

OKOH, P. A [1], EZE, J. N [2] and ADEMIJU, T. A [2,*]

[1] *Department of Home Economics Education, School of Secondary Education (Vocational), Federal College of Education (Technical), Asaba, Delta State, Nigeria.*

[2] *Department of Agricultural Education, School of Secondary Education (Vocational), Federal College of Education (Technical), Asaba, Delta State, Nigeria.*

World Journal of Advanced Engineering Technology and Sciences, 2024, 11(01), 395–401

Publication history: Received on 17 January 2024; revised on 25 February 2024; accepted on 28 February 2024

Article DOI: https://doi.org/10.30574/wjaets.2024.11.1.0070

Abstract

The majority of small-scale food companies and shops in Nigeria are unable to meet the enormous demand for plantain chips because of a few crucial considerations. Being a semi-perishable crop, a significant number of plantains are lost to deterioration at the highest point of harvest. Adopting an efficient method for turning food into chips for year-round availability and preservation is vital to guarantee food security and minimize waste. Plantain slicing with a knife has always been a hard, time-consuming, and unclean process with poor results. Although the slicer can be used for domestic purposes, it was intended for usage in medium and small-scale industries. The plantain slicing machine's design and construction aim to address the aforementioned issues. The design parameters that have been determined are the belt and pulley size, the power requirement (P), and the shaft diameter (D). The complete apparatus consists of a slider-crank mechanism that is powered by an electric motor through a v-belt. The driven pulley is supported by two bearings on a shaft. The hopper, which holds the plantains, the guide, and the stanchion make up the slider. Two cranks, one on each side, make up the mechanism. Through the use of a connecting rod, which transfers motion to the hopper (slider), they are connected to the slider. The intended chip formation is accomplished by moving the slider back and forth along the guide's bed, which holds the cutting blade. The device, which operates on the shear cutting concept, can cut raw plantains into chips with consistent sizes in a shorter amount of time. In just two to three seconds, it can cut a raw plantain finger up to 70 mm in diameter. According to the performance evaluation results, it takes an average of 267 seconds to slice 30 plantain pieces with an average length of 260 mm, weight of 0.3 kg, and diameter of 65 mm. All that's needed for machine maintenance is appropriate cleaning after usage and lubrication of the spinning parts. Even while this plantain slicer uses less labor and is more efficient than a chip cutter, it nevertheless yields chips with a consistent thickness. This updated device is easy to use, clean, lightweight, removable, and requires less maintenance. Consequently, the aforementioned constraints will be removed with this new design's enhancement, making the processing of plantain chips quite simple.

Keywords: Design; Fabrication; Plantain; Chips

1. Introduction

In the world's tropical regions, plantains form a staple diet; in fact, they rank as the tenth most significant food staple worldwide. When the unripe fruit is cooked by steaming, boiling, or frying, plantains are prepared similarly to potatoes and have a comparable neutral flavor and texture (Okafor et al., 2013). Plantains bear fruit throughout the year, making them a dependable staple meal for all seasons, especially in underdeveloped nations with inadequate means of food preservation, transportation, and storage. Over 70 million individuals in Africa get more than 25% of their daily

* Corresponding author: ADEMIJU, T. A

carbohydrate needs from plantains and bananas. In the poor world, plantains and bananas rank among the most vital and significant fruits in terms of gross value of production (Arisa et al., 2013). Nigeria is the nation that produces the most plantains in West Africa, with a significant portion coming from the southern region of the country (Oyejide et al., 2018). Based only on bunch features, there are four primary categories of plantains that are distributed in Nigeria. These types of plantains comprise the following horn types: French type, false type, and French-horn type are all available, however the false horn type is more common in Nigeria due to its tolerance of poor soil conditions (Awoliyi, 2003).

Plantains are a highly perishable crop. On the other hand, Ikechukwu et al. (2014) state that it can be processed and kept similarly to flour and chips. Plantains can be consumed locally or used as a byproduct in other processes. Plantains have the ability to lower rural poverty and contribute to national food security when they are consumed locally. They also have a vital role in food and income security (Arisa et al., 2013). Plantains supply the necessary minerals that support the body's optimal functioning. They are a great source of minerals, vitamin B-6, and antioxidants. Their high soluble fiber content may also help prevent digestive issues. Ugwuoke et al. (2014) state that one cup of cooked or sliced plantain has 49 milligrams of magnesium and 716 milligrams of potassium, providing the body with 15% of the daily required consumption of each mineral. While potassium is an essential part of bodily fluids, magnesium is required by the body for appropriate neuron and muscle function. Additionally, between 5 and 10 percent of the body's required iron can be found in a cup of plantains. Iron facilitates the blood's ability to carry oxygen, which benefits the body's muscles. With roughly 10% more magnesium, phosphorus, and potassium when raw, plantains are more nutrient-dense than when cooked. Given the many advantages of raw plantains, slicing them can have additional advantages for post-harvest processing.

Due to inadequate post-harvest processing techniques and stringent quality standards necessary for the export market, the majority of Nigerian farmers are unable to achieve the export requirements for green plantains (Khurmi & Gupta, 2004). The majority of farmers offer their produce at the farm gate to middlemen for a low price in order to prevent fungal degradation and blackening of harvested plantains. Plantain chips, which are made by slicing, frying, and packing them as snack food, are a way to lessen post-harvest losses from green or maturing plantains. Plantain slicers that run on electricity can make the processing procedure easier (Ezugwu et al., 2019). Over the years, plantains have been sliced manually using tools like graters, chip cutters, and household knives. This has resulted in uneven chips that are difficult to slice, take a long time, can be harmful, are less hygienic, and are only useful for home use. The drawbacks of the manual slicers were addressed by the development of a more efficient mechanized slicer. Obeng (2004) states that a plantain finger can be sliced in five to seven seconds by a mechanical plantain cutter. Compared to the conventional technique of chopping with a sharp knife. Only a very limited scale of manufacturing can use this labor-intensive, time-consuming, injury-prone procedure, which takes 40–80 seconds per plantain finger. The utilization of a power plantain slicer is imperative to save labor costs involved in the continual chopping of large quantities of plantains with a knife, as the chips generated in this manner are never consistent in size. Plantain chips can be manufactured in larger quantities with the use of a power-operated plantain slicer, since it will take less time to slice a raw plantain finger and generate chips with consistent sizes.

Plantain slices in the shape of fried plantain chips are highly sought after by families, office workers, travelers, and schoolchildren for breakfast. Several methods have been developed to slice plantains into pieces that can then be processed into chips, flour, baked goods, or fried foods in an attempt to increase their accessibility (Okafor & Okafor, 2013). Plantain chips are cut into plain and rippled slices using a plantain slicing machine. Peeled bananas are manually fed into the slicer from the top, and the chips are guided through a guide as they are cut. It is a hand-push device with an outlet that is positioned above a frying pan. The device is a single pulley-driven form with elliptical slices that are roughly 2-3 mm in size. It is simple to handle and low maintenance. The machine is equipped with an adjustable-blade cutting plate, and its stainless-steel frame is constructed (FIIRO, 2008). The development of various motorized plantain slicers has assisted in the resolution of many slicing issues, particularly for low-scale chip producers. However, the design of a motorized plantain slicing machine that will be the most cost-effective and productive to grow their business remains a significant challenge. In light of these, a motorized plantain slicing machine will be constructed. It will have common elements such a cutting mechanism, a feeding mechanism, a base frame for support, and stability when in operation. The goal of this research is to modify an existing plantain slicing machine technology in order to increase its efficiency; fabricate new slicing blades with varying angle; fabricate a shaft pulley; fabricate an electric motor for the slicer with a power rating of 140 W and fabricate a hopper with cover. This is done to lower cost, better, and more efficient that can make it easier to slice bulk plantains hygienically into chips.

2. Materials and Methods

2.1. Design Consideration

The motorized plantain slicing machine for chip production was designed with a few considerations, including the use of abrasive force to de-hull the plantains, the separation of the unconformable, and the placement of the unripe, ripe, and overripe plantains in various sections. The plantain slicing machine was also regarded as having a simple design, being simple to construct, easy to operate, and adaptable enough to meet the performance requirements. The equipment was able to swiftly and easily slice the required amount of plantains, ensuring user ease. Due to the plantain's strong acidity, great care was taken when selecting building materials to ensure that none could contaminate it and that it wouldn't corrode easily. The size and weight of the machine as a whole have a big impact on the size of the selected materials and their constituent parts, including electric motors. To ensure that it can be relocated to any place where it may be needed, the machine's mobility is essential. The device is an appropriate tool for small-scale plantain processors and was designed to be easily used by anyone without technical expertise or experience. In order to ensure that the machine does not get wet after the plantain has been cut and prevent rusting, the machine was designed to be easily maintained by routine or weekly cleaning, tightening of bolts, and lubricating of key elements, such as bearing and joints.

2.2. Materials for Fabrication

The selection of the fabrication materials was done with careful thought in order to guarantee high quality standards that will increase the functional needs and durability of the machine. Standard components that have a proven track record of dependability and longevity were used to ensure engineering feasibility. The design and construction would make use of locally obtained materials. The machine is made of engineering materials that come in different thicknesses, like mild steel and stainless steel. The hopper is composed of stainless steel, which resists corrosion, because it comes into contact with the plantains. The machine weighs less overall because the crank is constructed of mild steel, which has a thinner coating than the other metal components. All parts are created and put together to form a unit using basic engineering production techniques like marking out, cutting, welding, and fastening. Table 1 lists the materials required to assemble the motorized plantain slicing machine.

Table 1 Material Selection and Specification

Material / Component	**Material Specification / Description**
Stainless steel sheet	30 mm x 60 mm, 3.5 mm thick
Stainless Cutting blade	2 mm thick x 5 mm wide x 15 mm long
Shaft	20 mm thick x 400 mm long
Pulley	Cast iron
Stainless plates	1.2 m x 2.4 m x 3 mm & 1.2 m x 2.4 m x 6 mm ASTM A223 (225/L)
Electric motor	2HP BM19-12.5mpa
V –belt	16009 x 180019

2.3. Design Analysis and Calculations

The machine operates using the shear cutting principle. The plantain's cylindrical surface is cut by shearing along a plane when the cutting blade strikes it.

2.3.1. Determination of the Shearing Force for the Raw Plantain

Considering the shear strength of the raw plantain and the area under shear, the impact force required to shear the raw plantain may be obtained from the following equation:

$$F_p = A_p \times t_p$$

Where
FP = Force required for shearing the raw plantain
AP = Area under shear
tP = Shear stress of the raw plantain

The area under shear can be determined using the following equation:

$$A_p = \pi (D_p^2)/4$$

Where
DP = Diameter of raw plantain

According to Obeng (2004), an average force of 33.15N is needed to shear raw plantains with diameters ranging from 30 to 70 mm. As plantains soften and ripen, this power decreases. The raw plantain had an average diameter of 50 mm and a measured range of 30-70 mm.

2.3.2. Determination of the Power Required by the Cutter for Slicing the Raw Plantain

Another crucial factor in the slicing process is cutter velocity. According to Ugwuoke et al. (2014), the ideal cutter velocity needed for slicing is 2.65 m/s. The following expression can be used to determine how much force the cutter needs to slice the raw plantain:

$$P_c = F_p \times V_c$$

Where,
PC = Power required by the cutter
VC = linear velocity of the cutting blade = 2.65m/s

From equation, we get

$$PC = 31.25 \times 2.65 = 82.81 \text{ W}$$

2.3.3. Determination of the Power Required by the Electric Motor

The power required by the electric motor may be obtained from the following equation:

$$P_M = P_C \times P_F$$

Where,
PM = Power of electric motor
PF = Power factor = 1.5

From equation, we get

$$PM = 82.81 \times 1.5 = 124.22\text{W}$$

Selected capacity of electric motor = 0.37kW (0.5Hp) Speed = 1400rpm

2.3.4. Determination of the Driving Pulley Diameter

For a belt velocity of 4.98m/s, the driving pulley diameter is calculated using the relation below:

$$D_1 = (V_1 \times 60)/(\pi \times N_1)$$

Where,
D1 = Driving pulley diameter
V1 = Peripheral velocity of the belt on the driving pulley
N1 = Speed of driving pulley = 1400rpm

From equation (5), we get

$$D1 = (4.68 \times 60)/(\pi \times 1400) = 63.8\text{mm}$$

2.3.5. Determination of the Driven Pulley Diameter

The following represents the relationship between the driven pulley diameter and the driving pulley diameter:

$$\pi x\ D_1 N_1 = \pi\ x\ D_2 N_2 \rightarrow D_1/N_1 = D_2/N_2$$

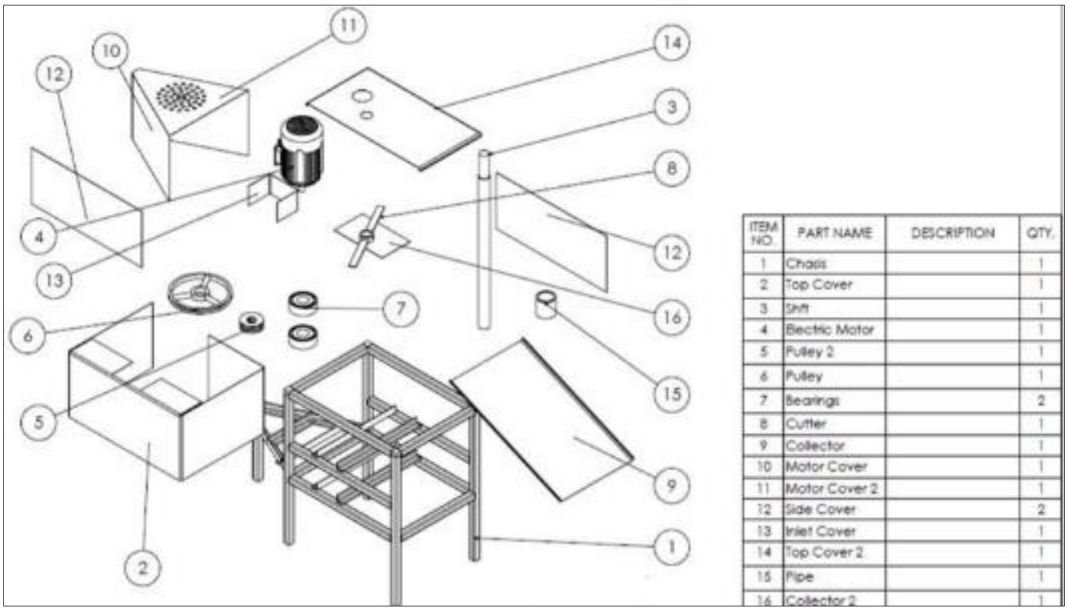
Where;
N_2 = Speed of driven pulley
D_2 = Diameter of driven pulley

For N_2 = 400rpm. Substituting into equation and simplifying, we get

$$D_1 = (63.8 \times 1400)/ 400 = 223.3mm$$

2.4. Mode of Operation

A cutting tool, a feeding mechanism, a support frame, and an electric motor serving as a power source make up the plantain chip-slicing machine that was built, shown in Figure 1. The components of the cutting mechanism are the flywheel, pulleys, guide frame, connecting rod, and stainless-steel blades. On the plantain tubers, the blades were oriented perpendicularly. The primary component of the feeding and discharge systems was the Geneva drive, which is intended to give the conveyor intermittent motion and cause it to move in a start-stop pattern. The feeding and discharge processes are both under the control of the conveyor. The conveyor is in charge of both the feeding and discharge procedures. The conveyor consists of iron pieces that are spaced equally, soldered at both ends, and coated with a thin layer of aluminum sheet. It is fastened by sprockets and chain. Chains are fastened to the opposing sides of the conveyor to produce a continuous cyclic motion. The base construction suspends and firmly supports the machine. The driving shaft is supported by two ball bearings that are mounted on the base frame and which withstand both thrust and radial loads.



ITEM NO.	PART NAME	DESCRIPTION	QTY.
1	Chasis		1
2	Top Cover		1
3	Shft		1
4	Electric Motor		1
5	Pulley 2		1
6	Pulley		1
7	Bearings		2
8	Cutter		1
9	Collector		1
10	Motor Cover		1
11	Motor Cover 2		1
12	Side Cover		2
13	Inlet Cover		1
14	Top Cover 2		1
15	Pipe		1
16	Collector 2		1

Figure 1 Design View

2.5. Performance testing

The machine was properly constructed and positioned before testing, as shown in figure 2. Additionally, lubrication was applied to the parts to reduce friction among the rotating members. The electric motor and pulley were linked to the belt. To analyze the machine's behavior, an electric engine was used to supply the machine with power. The machine was then tested for 10 minutes without a load. After that, the electric motor was turned on, and the machine was tested for ten minutes to observe its behavior. Throughout this operation, the blade was observed to rotate steadily. After that, the machine was tested under load. Slicked plantains, or chips, were discharged from the discharged outlet as the peeled plantains, which had been handled by hand, were fed vertically into the feeding chute through the hopper and covered with a lid. Here, cutting a finger of raw plantain took two to three seconds, depending on its length. Four (4) times, the slicing procedure was carried out while the average value of each was ascertained. At the output, plantains were weighed both sliced and unsliced. We noted and assessed the outcomes. The weight of the plantain output, sliced or not, was expressed as a function of time to determine the machine's capacity (Usman & Bello, 2017). The following equation was used in determining the machine's quality performance efficiencies and machine: (Onifade, 2016)

Figure 2 Assembled Improved Motorized Plantain Slicing Machine

2.6. Operating capacity

The following equation was used to determine the improved plantain slicing machine's operational capacity (g/s):

$$c = w/t$$

Where
w = total weight of the sliced plantain (g)
t= time to slice the plantain (s)

2.7. Slicing efficiency

The following calculation was used to determine the improved plantain slicing machine's slicing efficiency (%):

$$\aleph = (w_{RSP} - w_{BSP})/w_{BSP} \times 100$$

Where,
Ɲ = Slicing efficiency
WRSP = weight of round sliced plantain
WBSP = weight of broken sliced plantain

3. Discussions

In the crop processing lab, some plantain fingers were chopped in the early phases of the slicer development. To guarantee the machine's functional requirements for its intended application, a number of corrective measures were implemented. The design analysis results indicated that an average of 33.15 N of force is needed to shear a raw plantain finger. The rotating disk has an angular speed of 29.5 rad/s. The belt that ran from the electric motor to the cutting disk was 1600 mm long. The efficiency and operating capacity were 93.37% and 102.88 g/s, respectively. A fresh plantain finger took two to three seconds to slice, compared to thirty to forty seconds for manual and other existing machines.

The weights of thirty fingers of raw plantains and whole, broken, sliced plantains were 3502.3 g and 90.5 g, respectively, according to the results. Additionally, thirty plantain fingers produced 2145 plantain slices, and 1925 of those slices showed a uniform slice thickness of 2.89–3.25%. Of the 2145 slices, 129 slices (6.01%) and 91 slices (4.25%) were half broken, and quarter broken, respectively. The machine made no noise while it was operating, and there was no noticeable vibration. The motorized slicer produced pretty encouraging results and saved time as the slicing blade rotated steadily. This suggests that the plantain's mass and the machine's capacity to slice it efficiently are related. The plantain was sliced perfectly by the slicing mechanism, which accomplished its intended purpose. The physical characteristics of the sliced plantain produced indicated that the plantain's color was not adversely affected by the slicing blade or the cutting chamber, suggesting that there was no contamination and that uniformly sized, round plantain chips were produced. This suggests that the functional need of the machine was met. The resulting slices exhibited consistent thicknesses, as determined by weighing the damaged ripe plantain pulps and using a vernier caliper. Due to improvements made to the scraper on the cutter blade, very little plantain pulp was lost or damaged from the outcomes of the damaged plantains.

4. Conclusion

This plantain-slicing machine is an innovative design and development with an enhanced turn rate, 93% total efficiency, and a remarkably low time, labor, and production cost. It can operate at 0.24/second. The issues related to plantain quantity, quality, and safety that were present with manual slicing and other plantain slicers have been resolved with this innovative machine. Locally sourced materials were used in the fabrication process. Although this machine was intended for use in medium-sized plantain chip producing enterprises, it can also be utilized for household uses. In just two to three seconds, the machine can slice a finger-sized piece of raw plantain, with a maximum diameter of 70 mm. The machine only has to have its rotating parts lubricated and cleaned properly after each usage for maintenance to be easy to understand. It is an easy-to-use, portable, detachable, and hygienic machine.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Arisa, N.U., Adelekan A.O., Alamu, A.E. and Ogunfowora,E. J. (2013).The Effect of Pretreatment of Plantain (Musa Paradisiacal) Flour on the Pasting and Sensory Characteristics of Biscuit. International Journal of Food and Nutrition Science, 2(1), 10-12.

[2] Awoliyi, O.O. (2003). Design and Construction of Plantain Slicer. Unpublished Thesis Dissertation in Department of Design and Fabrication. Federal Institute of Industrial Research, Oshodi, 20-21.

[3] Ezugwu, C. A., Osueke, C. O., Onokwai, A. O., Diarah, R. S., Olayanju, T. M. A., Braimoh, S. O., Olawale, O. and Nnaji, F. C. (2019). Motorized/ Power Operated Plantain Slicer for Optimum Chips Production. International Journal of Mechanical Engineering and Technology (IJMET), 10 (1), 1485–1495.

[4] Khurmi, R.S. and Gupta J.K. (2004): A text book of machine Design, Eyrasia Publishing House (put) LTD. Ram Nagar, New Dehil.pp 1096.

[5] Obeng, G. Y. (2004). Development of a Mechanized Plantain Slicer. Journal of Science and Technology, 24(2), 126-133. 10.4314/just.v24i2.32925

[6] Okafor, B.E. and Okafor, V.C. (2013). Design of a Plantain Chips Slicing Machine. International Journal of Engineering and Technology, 3(10), 928-932.

[7] Onifade, T. B. (2016). Design and Fabrication of a Three-Hopper Plantain Slicing Machine. American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS),17 (1), 61-80.

[8] Ugwuoke, I. C., Ikechukwu, I. B. and Muazu, Z. O. (2014). Design and Fabrication of an Electrically Powered Rotary Slicer for Raw Plantain Chips Production. American Journal of Engineering Research (AJER), 3 (4), 38-44.

[9] Usman, M. B. and Bello, I. T. (2017). Development of an Automated Plantain Slicing Machine. International Journal of Scientific & Engineering Research, 8(10), 1390-1408.