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Original Article

Design and Fabrication of a Power Rotary Slicing Machine

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Abstract *- This paper presents the design and fabrication of a power-operated rotary slicing machine that is capable of producing chips from plantain, cocoyam, cassava and other related farm produce. The machine becomes imperative to aid the preservation of these farm produce for a longer period of time, especially to make them available throughout the season. The machine is made up of a cutter mechanism, a feeder mechanism, an outlet chute and a prime mover. The operation and maintenance of the machine require little or no skill to carry out. Its availability will go a long way to boost the economy and social life of individuals as it aids small and medium-scale businesses. The production cost is ₦97,800.*

Keywords *- Rotary slicer, Cutter mechanism, Feeder mechanism.*

1. Introduction

Roots and Tuber crops are important cultivated staple energy sources, second to cereals, generally in typical regions in the world. They are among the most valuable staple food source for millions of people in the world [1] [2]. One of the major problems Root and tuber crops face is postharvest loss, which is the degradation in quantity and quality of food production from harvest to consumption. The rate of quantity losses is higher in developing centres (ACF, 2014) [3]. The causes of loss are root and tuber crops as a result of their physical and physiological condition as living organisms even after they have been harvested. This loss is associated with mechanical damage, physiological condition (maturity, respiration, water loss, sprouting), diseases and pests. [4] [5]

Ensuring proper control over these Portharvest threats that lead to the perishability of the crops has brought about the need to develop appropriate processing technology [4] [2].

Among the most valuable staple food source are cassava, plantain sweet potato, yam, cocoyam etc. Plantain is a basic food crop in developing countries, especially in Africa. It occupies a strategic position for rapid food production in Nigeria; over 70 million people derived their sustenance from it. Plantain (Musa spp.) originated from Southern Asia and is ranked third among starchy staples. Nigeria is one of the largest plantain producers in West Africa, with an annual production of 2.4 million metric tons. [6] [7] [8] [9] [5].

Cocoyams (Colocasia esculanta) are stem tubers widely cultivated in the tropical region of the world. Nigeria is the largest producer of cocoyam in the world, accounting for about 40% of the total world output of cocoyam. It ranks third in importance after cassava and yam among the root and tuber crops cultivated and consumed in Nigeria. Cocoyam is superior to cassava and yam in possession of higher protein, mineral and vitamin contents as well as easily digestible starch [10] [11] [12] [13]

Oyedele et al. worked on the design and fabrication of a dual pursed. This work focused on designing and fabricating a dual-powered slicer for raw plantain and potato chip 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 a low output. The design and fabrication of a plantain slicing machine is to solve the problems mentioned above. 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. [14]

Sonawane et al. designed and fabricated an electric power-operated plantain chipping machine for use in small and medium-scale plantain chipping industries. The machine is equipped with a feeder assembly, an electric motor, a cutter plate and a base support. The feeder assembly comprises a push plate for pushing the plantain to the cutter blade, a push rod and a spring. The cutter plate comprises three stainless steel blades powered by an electric motor rotating at a speed of 360rpm through a V-belt. [15]

Okafor and Okafor designed a plantain slicer for small-scale industries. It is made up of a cutter chamber, an electric motor and a feed and discharge mechanism. The machine was developed to slice a single plantain in 4 seconds during a single input shaft revolution. The machine efficiency is 73.8%. [16]

Adesina et al. developed an automated electric-powered plantain slicer. The machine has the ability to slice a plantain for about 20 seconds, depending on the plantain length. The major machine components are; the cutter plate, a 2-horse powered electric motor, belt, bearings and pulleys. Plantain is fed through the collector into the cutting chamber of the machine. The motor supplies rotary motion through the belt and pulley drive to the cutter plate. This performs the cutting action that slices the plantain into chips of relatively uniform sizes. [17]

M.B Usman and I.T Bello developed an automated plantain slicing machine. The machine is made up of a support mechanism, a cutter mechanism, a feeder mechanism, an outlet chute and an electric motor. The cutter mechanism comprises the blade, blade housing, connecting rod and crank. The blade is a removable 0.5mm thick stainless steel sheet, 300mm wide and 70mm high, bolted firmly to the blade housing. Its basic function is to slice plantain, loaded on the conveyor, by reciprocation. The blade housing is pair of hollow cylindrical pipes 30mm in diameter and 100mm long. The feeder mechanism consists of a conveyor belt mounted on two rollers. This act both as a feeding and discharge mechanism. The conveyor was designed to travel at a speed of 80rpm [18].

In order to make plantain and cocoyam available throughout the year, this call for a design of a slicer that will be affordable by small and medium-scale farmers and industries, making slicing easier and making preservation of plantain and cocoyam easier. This will eliminate the stress passed through during the harvesting of plantain and cocoyam. A sliced plantain and an average of 5mm thick cocoyam can be dried easily, bagged, and sold to the consumer. A sliced dried plantain serves as food for humans and can be processed into flour.

This slicer's development will relieve human labor, speed up slicing and produce uniform slices for a better end product. Therefore, This study aims to develop a motorized slicing device to produce uniform plantain, cocoyam and other farm produce sizes to enhance further processing and storage.

2. Methods and Materials

2.1. Materials Selection and Component Parts Description

2.2. Design Analysis

2.2.1. Design Consideration

In the Design and Fabrication of a power Rotary Slicing Machine, these factors were considered:

1. Material selection
    a. Cost
    b. Machinability
    c. Durability
    d. Availability
2. Aesthetics
3. Ergonomics
4. Operationability
5. Maintainability of the machine
6. Compactness
7. Weight of the machine
8. Safety
9. Hygienity
10. Retainability of the product colour

2.2.2. Design Calculation

Belt Calculation

Factors considered when selecting a belt drive

1. Speed of the driving and driven shaft
2. Speed reduction ratio
3. Power to be transmitted
4. Center Distance between the shafts
5. Positive drive requirement
6. Shaft Layout
7. Space Available
8. Service Conditions

Length of an Open Belt Drive

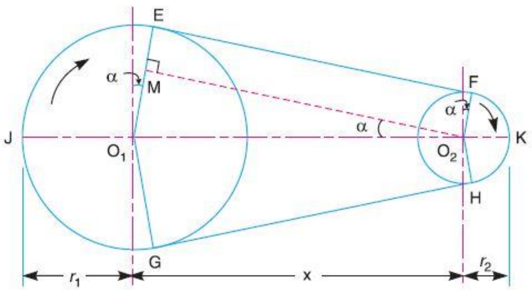


Fig. 1 Open Belt Drive (Khurmi R.S & Gupta J.K. (2004)

In terms of pulley radii

$= \pi(r_1 + r_2) + 2x + \frac{(r_1 - r_2)^2}{x}$

In terms of pulley diameter

$= \frac{\pi}{2}(d_1 + d_2) + 2x + \frac{(d_1 - d_2)^2}{4x}$

Where

r is the radius of the pulleys
d is the diameter of the pulleys
x is the distance between both pulleys

Values: x= 247mm; d_1=52; d_2=52

→ π/2(52+52) + 2(247)+0
→ 3.142/2(104) + 594
→ 1.571 x 104 + 594
→ 163.38 + 594
= 757.38mm

Velocity Ratio of Belt Drives

$$\frac{N_2}{N_1} = \frac{d_1}{d_2}$$

Where: N is the Speed

d is the diameter of the pulley

N_1 = 1440

$d_1 = d_2 = 52$

$$N_2 = \frac{d_1 N_1}{d_2}$$

$N_2 = 1440$ (Assuming no slip)

Speed on Shaft

Angular Velocity

$$\omega = \frac{2\pi N2}{60}$$

N= Speed in RPM

$$\omega = \frac{2 \text{ x } 3.142 \text{ x } 1440}{60} = 150.82 \text{ rad/s}$$

Linear Velocity

$v = \omega r$

Where r= radius of the shaft = 12.5mm

$v = 150.82$ x 12.5 =1885.25m/s

Torque and Force Required

$$T = \frac{60P}{2\pi N}$$

Where

P = Power to be transmitted by the shaft =0.75kw

N= Rotating Speed of the Shaft in RPM = 1440

T= Allowable torque on the shaft

$$T = \frac{60 \ x \ 0.75}{2 \ x \ 3.142 \ x \ 1440} = 0.004973 \text{N/m}$$

T=F x r

Where

F= Force required

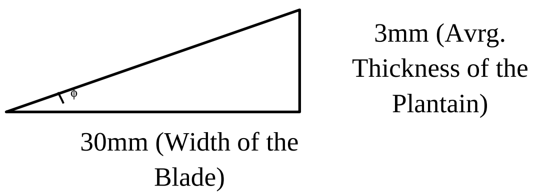
r= Radius of the Shaft =11mm= 0.011m

T = Torque on the shaft

F =T/r

0.004973/0.011 = 0.4521N

Rake Angle of the blade is calculated by



$$Tan\emptyset = \frac{Opp}{Adj}$$

$$Tan\emptyset = \frac{3}{30}$$

$$Tan\emptyset = 0.1$$

$Tan^{-1} = 0.1$

Rake Angle = 5.7^0 (At both blades)

3. Machine Description

The machine is made up of a frame, a cutter mechanism, a feeder mechanism, an outlet chute and an electric motor. The support mechanism comprises 25mm by 25mm mild steel square pipe, fabricating the frame and seats for an electric motor and a rotary cutter. The frame is welded firmly together with an electric arc welding machine using a gauge 12 electrode.

The frame was designed for high strength, rigidity and vibration resistance. The cutter mechanism comprises the blade, casted aluminum plate and shaft. The cutter can be detached easily from the shaft. The cutter is designed in two various forms; a cutter's function is basically to slice banana/plantain, and the other cutter is to slice cocoyam and cassava.

The shaft connects the cutter to the rotary motion of the pulley. The pulley receives the motion from the belt connected to the pulley of the electric motor. The outlet chute is the discharge point of the machine where sliced plantain/banana, cocoyam, and cassava are collected. It is made up of a stainless steel sheet inclined at an angle of 30^0 to the horizontal such that sliced plantain falls by gravity to the collecting tray.

The electric motor is the prime mover that supplies power to the entire system. It is a single-phase motor rated 0.5Hp and a speed of 1440rpm.

3.1. Designed Drawings

Fig 2-10 present the designed drawings for the sieving machine

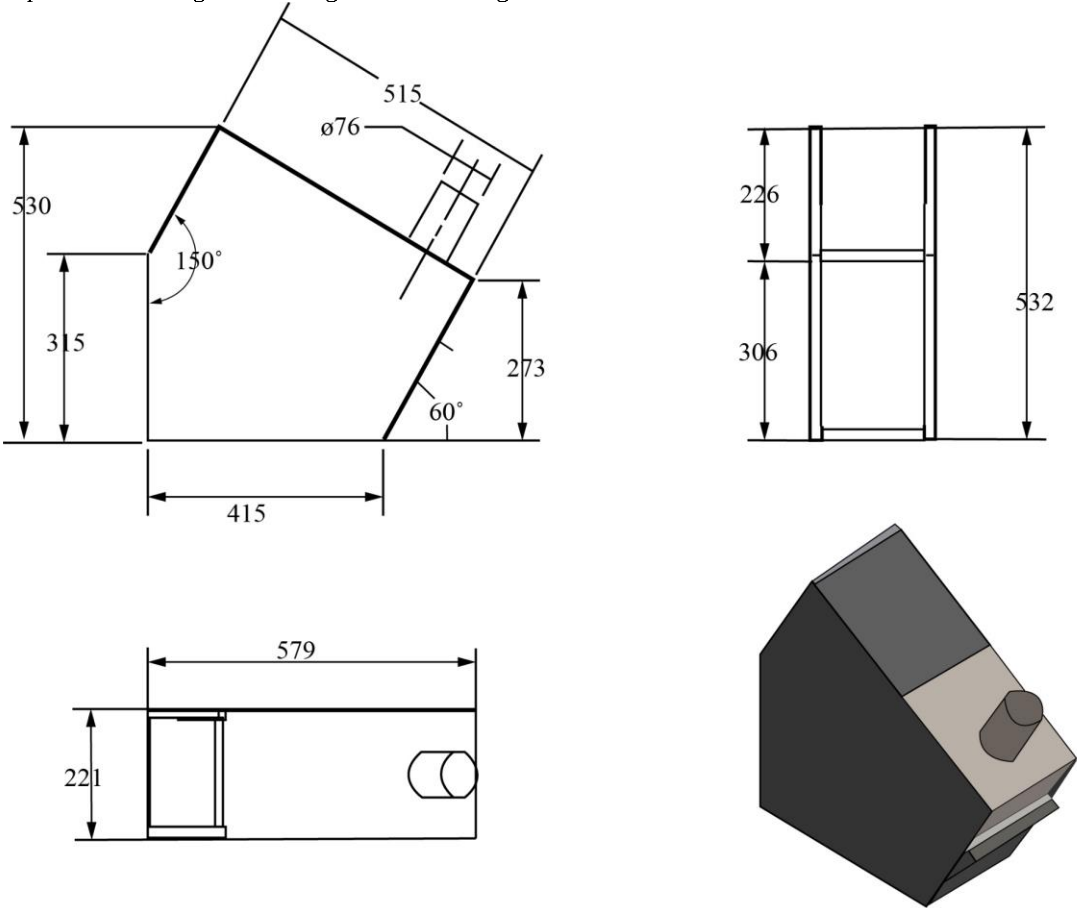
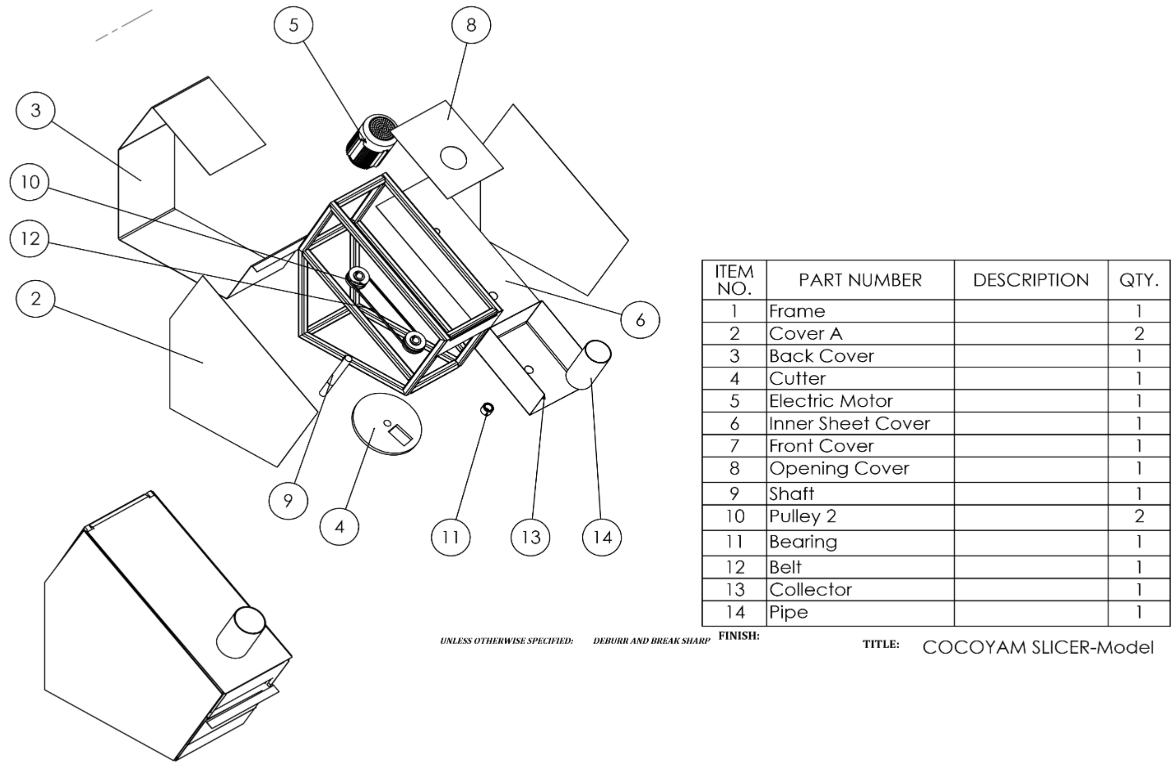


Fig. 2 Plantain/Cocoyam slicer model



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Frame		1
2	Cover A		2
3	Back Cover		1
4	Cutter		1
5	Electric Motor		1
6	Inner Sheet Cover		1
7	Front Cover		1
8	Opening Cover		1
9	Shaft		1
10	Pulley 2		2
11	Bearing		1
12	Belt		1
13	Collector		1
14	Pipe		1

Fig. 3 Cocoyam slicer model component and parts

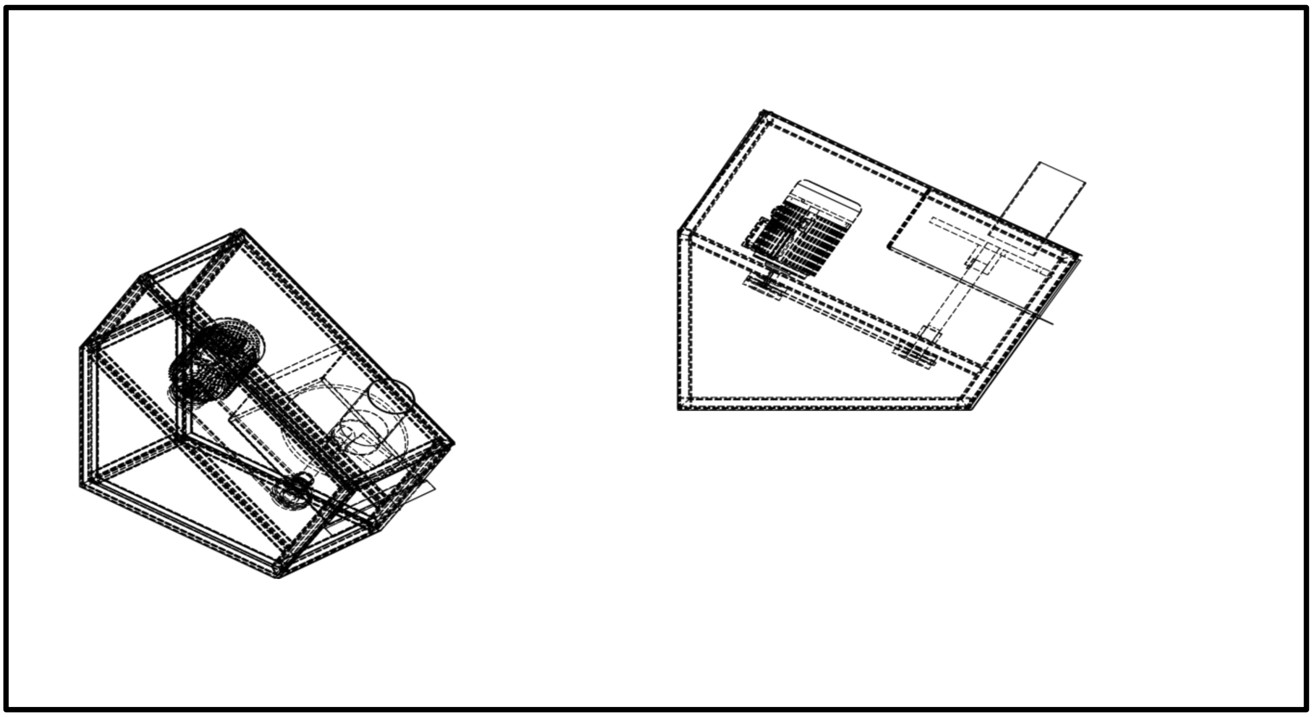


Fig. 4 Cocoyam slicer schematic

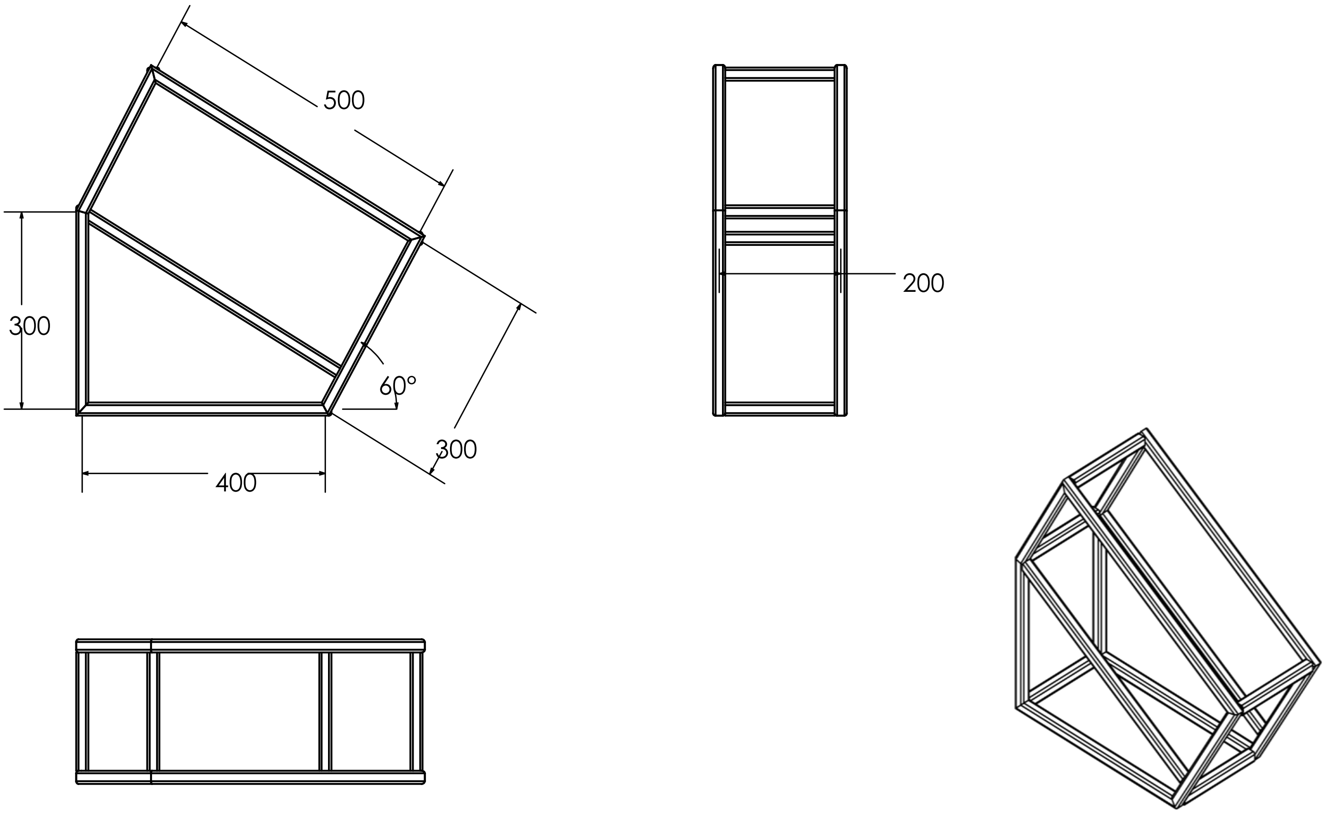


Fig. 5 Frame

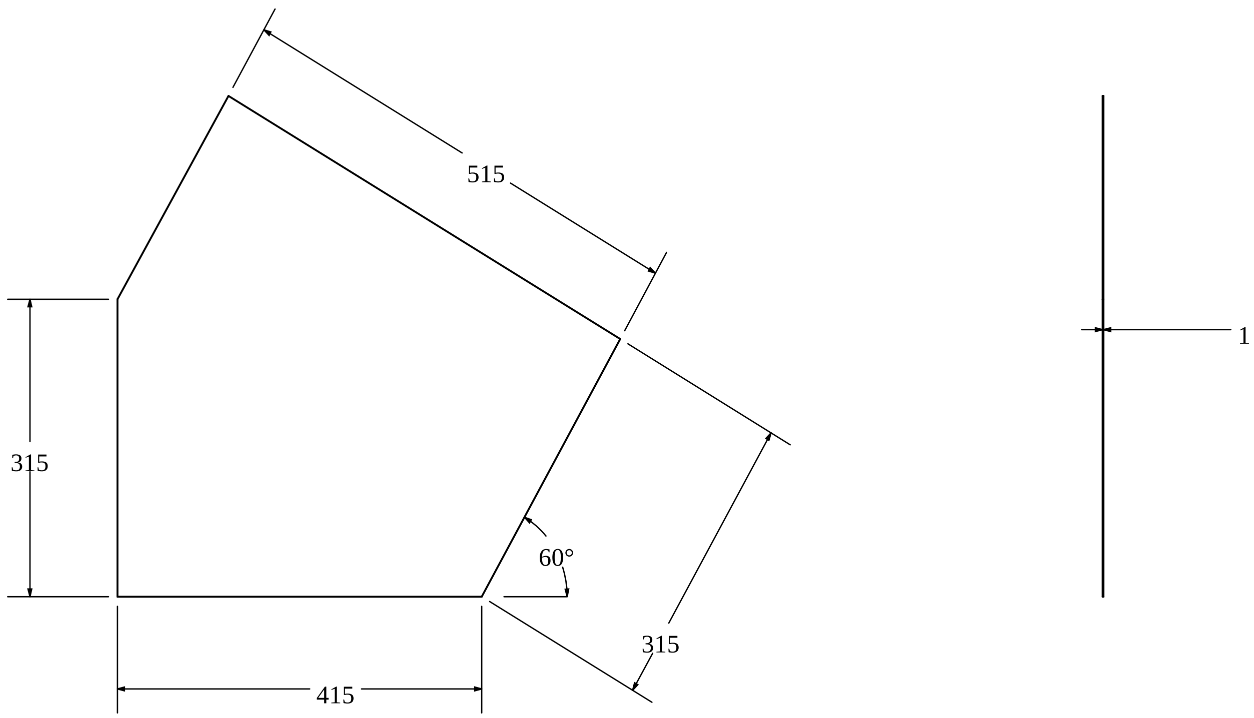


Fig. 6 Cover

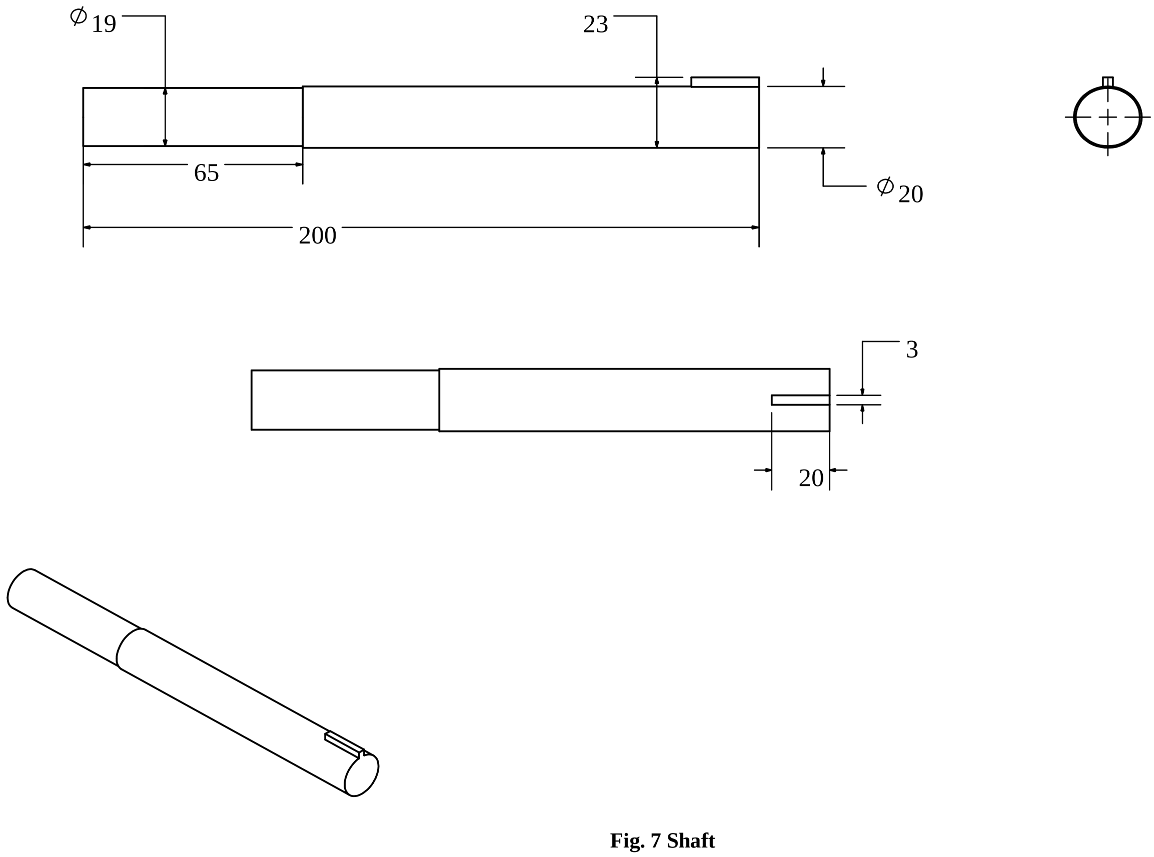


Fig. 7 Shaft

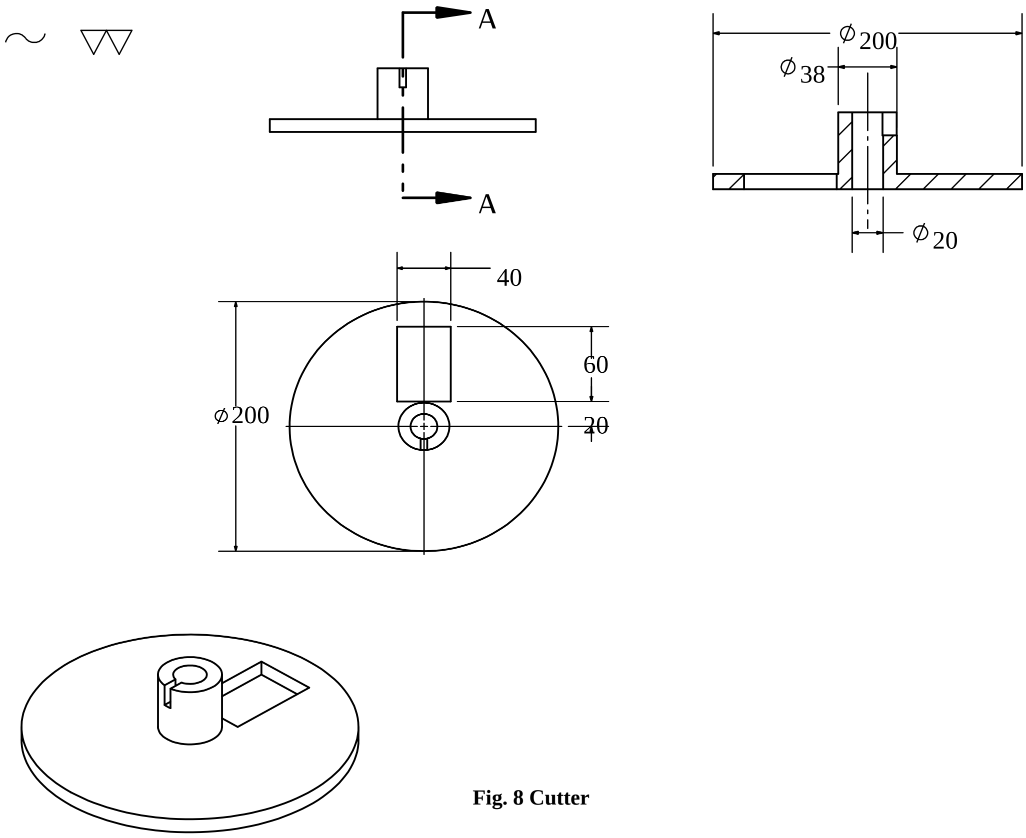


Fig. 8 Cutter

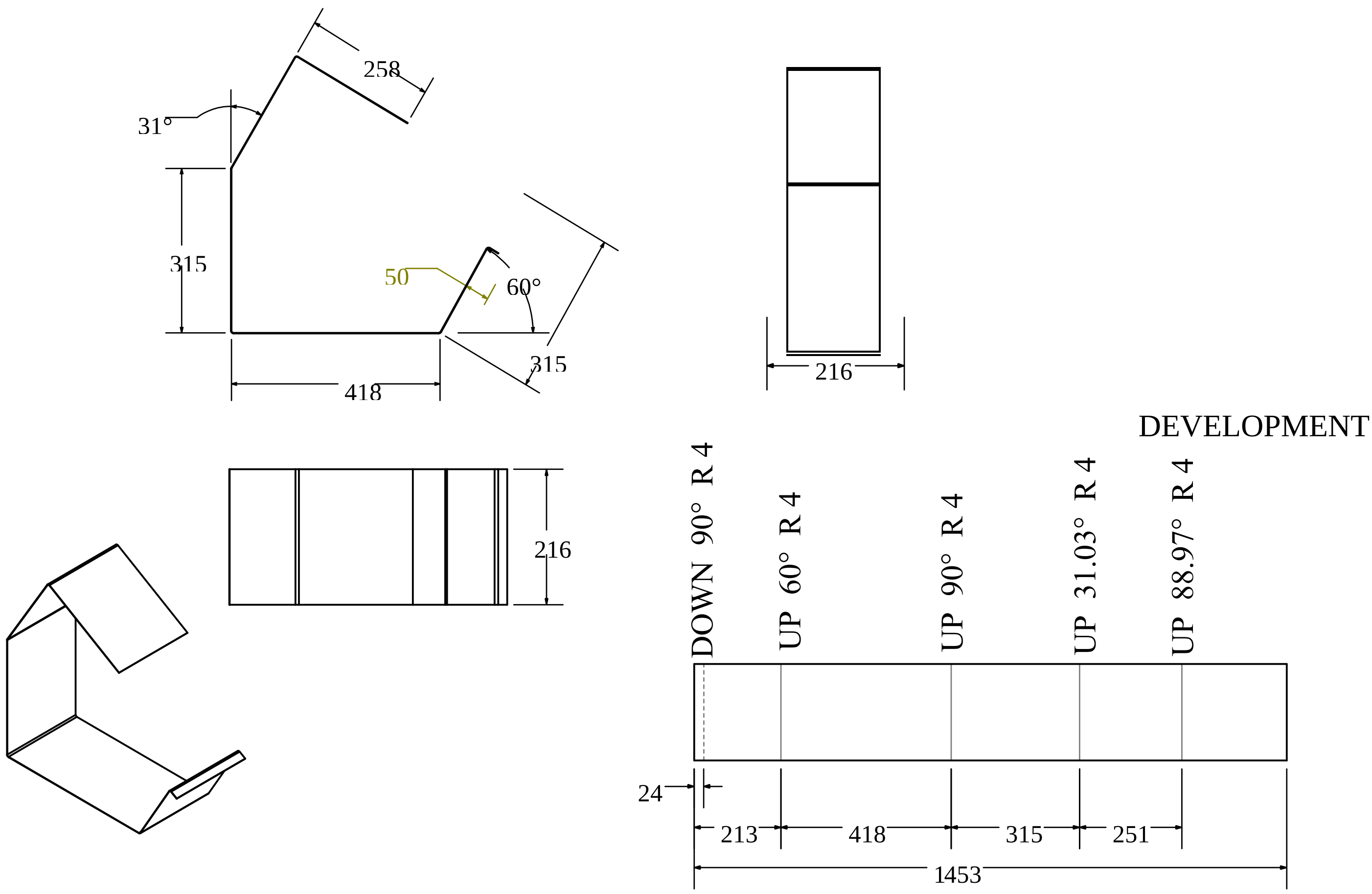


Fig. 9 End Cover

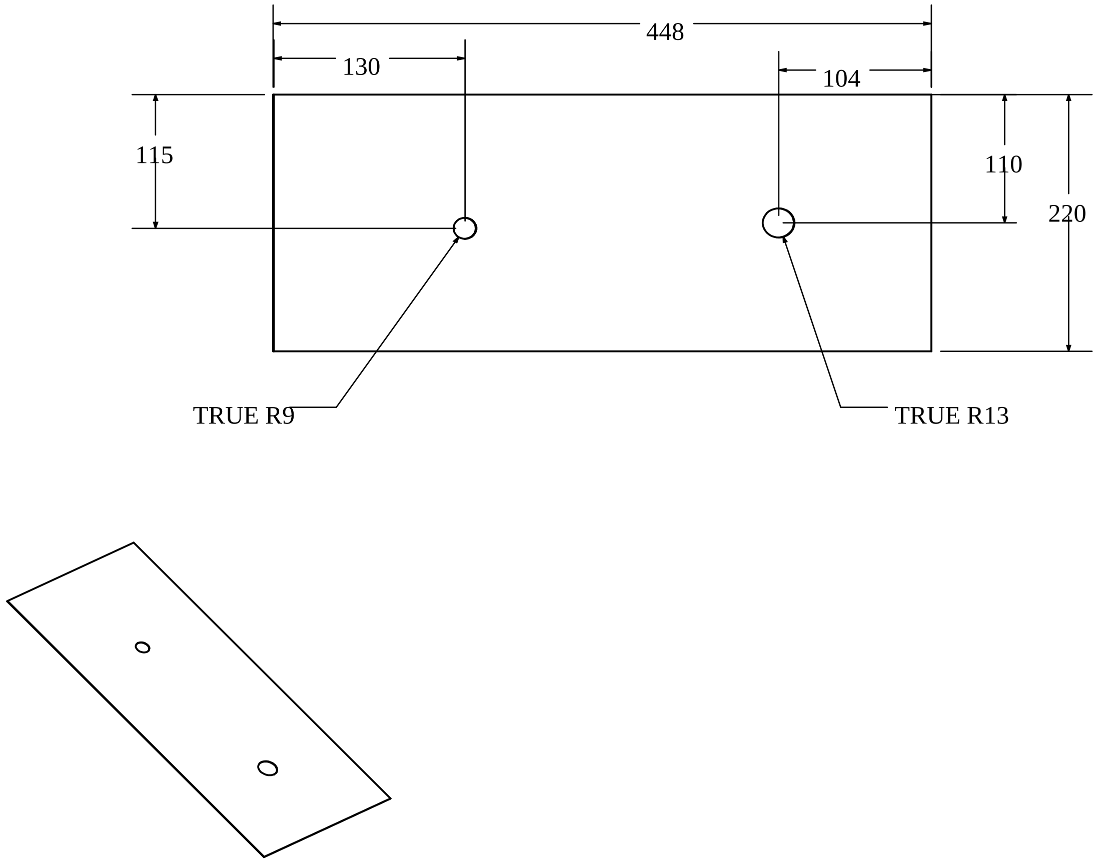


Fig. 10 Inner Sheet Metal

Table 1. Bill of materials needed for construction

S/N	MATERIAL	DESCRIPTION	QTY	RATE (₦)	AMOUNT (₦)
1.	Stainless Sheet Metal	8ft by 4ft x 1.5mm	1	25,000	25,000
2.	Electric Motor	Flange Mounted 1HP (1440rpm)	1	35,000	35,000
3.	Galvanized square Pipe	12ft by 4mm	1	1,000	1,000
4.	Aluminum Casting/ Machining		2	2,000	4,000
5.	Cutter	Stainless	4	1,000	4,000
6.	Pulleys (casting)		2	4,500	9,000
7.	Stainless Shaft and Machining	Diameter 25mm x 300mm	1	4, 000	4, 000
8.	Belt		1	800	800
9.	Fasteners	Bolt and Nut	25	100	2,500
10.	Stainless & Mild Steel Electrode	Gauge 12	Lot	5,000	5,000
11.	Transportation				10,000
12.	Miscellaneous				5,000
TOTAL				**₦97,800**	

4. Conclusion

A power-operated rotary slicing machine was developed with locally available materials for slicing freshly harvested farm products (plantains). Though this machine was designed for medium-scale industries for raw plantain chips production, it can also be used for domestic purposes.

The developed machine, in addition to slicing peeled and unpeeled plantain, can also be used to slice other agricultural products such as; bananas, cassava, and cocoyam, among others. Based on the results of the test obtained, the machine proved to be a better design than the existing one in that the slicing time of plantain is reduced. In addition, the use of stainless materials in areas in direct contact with the product ensured that there was no discoloration of the sliced chips produced.

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