Global Journal of Engineering and Technology Advances

eISSN: 2582-5003

Cross Ref DOI: 10.30574/gjeta

Journal homepage: https://gjeta.com/

GJETA

(Research Article)

Check for updates

Development and testing of Plantain (M*usa paradisiaca*) chips pulverizing machine

Elizabeth Ayodele ONIPEDE, Olufemi David OYEBANRE and Fuwad Olanrewaju BASHIRU *

Department of Agricultural and Bio-Environmental Engineering, Institute of Technology, Kwara State Polytechnic, Ilorin, Nigeria.

Global Journal of Engineering and Technology Advances, 2023, 15(03), 067–075

Publication history: Received on 10 April 2023; revised on 02 June 2023; accepted on 05 June 2023

Article DOI: https://doi.org/10.30574/gjeta.2023.15.3.0091

Abstract

A plantain (*Musa Parasidiaca*) chips pulverizing machine was developed in the department of Agricultural and Bio-Environmental Engineering, Institute of Technology, Kwara State Polytechnic, Ilorin, Nigeria. The machine consists of the following components parts: hopper, main frame, rotary hammers/beaters, shaft, screen, suction blower, bearing, cyclone/outlet, electric motor, belt and pulley. The design of the machine was based on the engineering properties of plantain chips and the quantity of the plantain to be pulverized in an hour while making use of locally available materials for the fabrication. The machine was tested for its performance while using a five horse power (5hp) electric motor to power it. The machine has the highest throughput capacity and efficiency of 493 Kg/h and 95 % respectively at a feed rate of 15 Kg/min and machine speed of 3500 rpm while the least capacity and efficiency was observed to be 300 Kg/h and 83 % respectively at a feed rate of 5 Kg/h and machine speed of 2500 rpm. The machine is therefore recommended for adoption by small and medium scale processors. The total cost of the machine is two hundred and twenty-one thousand seven hundred naira only (₦221,700).

Keywords: Plantain; Pulverizer; Chips; Machine; Size Reduction; Testing

1. Introduction

Plantain *(Musa paradisiaca*) is a staple food grown throughout the tropical and subtropical regions of the world. Banana and plantain (*Musa spp*.) are ranked globally as the fourth most important food crop in the world after rice (*Oryza sativa*), maize (*Zea mays*) and wheat (*Triticum spp.*) (Frison and Sharrock, 1999). In Nigeria, it ranks third after yam and cassava (Ayodeji, 2016). The country which produces the largest amount of plantain in West Africa is Nigeria (Ibrahim, 2013).

For millions of people in Africa, the Caribbean, Latin America, Asia and Pacific, plantain serves as one of the major sources of carbohydrate (Ayodeji, 2016). Plantain is usually processed into durable products like chips and flour for being a highly perishable food crop attributed by its very short shelf life (Ibrahim, 2013).

Plantain can either be used for domestic consumption or used as input by other producers. Plantain flour, apart from been used as a substitute for cassava flour especially for diabetic patients, it also serves as a raw material used in the production of cakes, chips, puff-puff, biscuit, bread and pancakes (Ayodeji, 2016). The nutritional and medicinal values of plantain Flour makes it a high sought after product as it is a cheap source of iron, protein and vitamin A (Foramfera, 2012). The major advantage Plantain flour has over other starchy foods is its high protein, mineral and vitamins content.

In the field of medicine, plantain can be used to cure a lot of sickness among which are diabetes, sore throat, tonsillitis, diarrhoea, vomiting and it is said to be a major diet in the production of *soya-musa* which can be used in the treatment

* Corresponding author: Fuwad Olanrewaju BASHIRU; Email:fuwadbashiru@gmail.com

Department of Agricultural and Bio-Environmental Engineering, Institute of Technology, Kwara State Polytechnic, Ilorin, Nigeria.

of kwashiorkor (Idachaba, 1995). Plantain flour is the product of dried and pulverized unripe plantain pulp. It is called "*elubo agbagba*" in Yoruba speaking areas of Nigeria, where it is normally made into a dough called "*amala*", having being reconstituted in boiling water (Ibrahim, 2013; Oyedele, 2013). The processes involved in plantain flour production are separation into fingers from bunch, peeling, washing, slicing, drying, milling and packaging.

The traditional methods of processing plantain into flour takes a lot of time, requires a lot of energy and attention from one stage to the other. This paper therefore aims at the development and testing of a plantain (*Musa paradisiaca*) chips pulverizing machine for plantain flour production to solve the problem of hygiene, drudgery, poor quality associated with the present methods of producing plantain flour.

2. Material and methods

2.1. Description of the Machine

The plantain (*Musa Parasidiaca*) chips pulverizing machine shown in figure 1 consists of the following component parts: hopper, main frame, rotary hammers/beaters, shaft, screen, suction blower, bearing, cyclone/outlet, electric motor, belt and pulley. The hopper is the part of the machine that allows the plantain chips to be fed into the machine. It was made from 3mm mild steel sheet and made in the form of a rectangular orifice. It also has a control gate which prevents the materials been pulverized from spilling out from the machine. The main frame is the base on which all the components of the machine rests on. It was made from 100mm 'H' iron so as to withstand the vibration of the machine during operation.

The rotary hammers, shaft and screen in conjunction forms the pulverizing unit. The hammers were made from 6mm flat bars and were arranged in three rows on top of the shaft which in turn is rested on the pillow bearing. The pillow bearing allows for smooth running of the shaft and also prevents friction. The screen forms a semicircular structure below the hammers which determines the particle size of the pulverized materials. The suction blower consists of a suction fan enclosed in within a housing which sucks the fine particle materials from the pulverizing unit and passes it through the cyclone where it is collected.

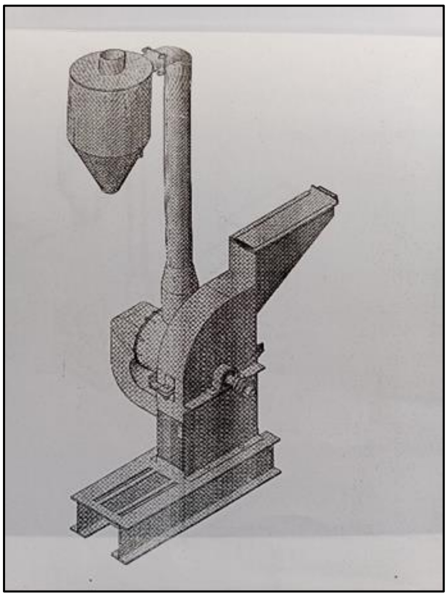

Figure 1 Plantain (*Musa Parasidiaca*) Chips Pulverizing Machine

2.2. Design Consideration

The design of the plantain (*Musa Parasidiaca*) chips pulverizing machine was based on the engineering properties of plantain chips. The quantity of the plantain to be pulverized in an hour, suitability of the material for the fabrication work, power requirement of the machine should commensurate the required output of the machine. Portability of the plantain (*Musa Parasidiaca*) chips pulverizing machine was equally considered and affordability by the end users. Finally, the ergonomics and aesthetic of the machine was also taken into consideration.

2.3. Material Selection

The materials used for fabrication of the plantain (*Musa Parasidiaca*) chips pulverizing machine were carefully selected based on the following factors:

- Availability of the material: the material used were locally sourced and could be gotten from nearby market even in the case of maintenance or replacement of worn out parts.
- Strength of the material: the materials used were strong enough to withstand the stress which would occur from the operation of the machine.
- Ease of fabrication: the materials used were those which could be fabricated with the locally available techniques or technologies for fabrication.
- Cost effectiveness: the materials used were also relatively affordable to ensure affordability by the end users.
- Maintainability of the material: the materials used were those which does not require special requirements to be maintained.

2.4. Design Analysis and Calculations

The design analysis and calculation is necessary to determine the parameters of all the component parts of the plantain (*Musa Parasidiaca*) chips pulverizing machine.

2.5. Design for the Hopper

The hopper was designed to allow easy flow of the plantain chips into the pulverizing unit. The shape of a rectangular orifice which opens directly into the pulverizing unit allows the plantain chips to fall by gravity unto the pulverizing unit. A lid was also considered necessary to prevent spilling of materials during operation. The hopper was designed to take 5Kg of plantain chips using the relation given by Uthman *et al;* 2022 below:

$$\text{Volume of plantain chips}, V = \frac{mass\ of\ \text{plantain chips}}{bulk\ density\ of\ \text{plantain chips}} \quad \text{.........(1)}$$

2.6. Design for Shaft

The shaft which is the rotating element of the plantain (*Musa Parasidiaca*) chips pulverizing machine was designed for to prevent structural failure during operation. The diameter of the shaft was designed based on Maximum direct stress of 1.2 x 10^8pa using ASME code equation given below:

$$d^3 = \frac{16}{\pi S_S} M_b + \sqrt{(K_b M_b)^2 + (K_t M_t)^2} \quad \text{.............(2)}$$

Where;
d= diameter of the shaft
S_S = 1.2 x 10^8pa
M_b= maximum bending moment
M_t= torsional moment
K_t= 1.5
K_b=1.5

2.7. Design for the Power Requirement of the Machine

The power requirement of the machine was derived by the equation given by Khurmi and Ghupta, 2005 below:

$$P = \frac{2\pi NT}{60} \text{..............(3)}$$

Where;
T = Fr
P is required power
N is machine speed
T is torque
F = weight of shaft
r = radius of shaft

2.8. Design for Belt Drive

The belt drive was designed using the relation given by Khurmi and Ghupta, 2005 below:

2.9. Determination of belt tension

$$P = (T_1 - T_2)V \text{.............}(4)$$

Where;
P = Design power in watts
T_1 = Belt tension at tight side in Newton
T_2 = Belt tension at slack side in Newton
V = Speed of belt in M/S

$$\text{Also, } N_1 D_1 = N_1 D_2$$

Where;
N = Speed
D = Diameter of pulley
1 = Electric motor
2 = Machine

2.10. Determination of Angle of Wrap

$$\vartheta = [180 - 25\, in^{-1}\, x\,] \frac{\pi}{180} \text{...............}(5)$$

Where;
ϑ - angle of wrap in rad
$2.3\, log \left[\frac{T_1}{T_2}\right] = \varphi\vartheta cos\beta$
ϑ - frictional coefficient of belt
β - frictional coefficient of pulley

2.11. Determination of Length of Belt

$$L = 2x + \frac{\pi}{2}(D_1 + D_2) + \frac{(D_1 - D_2)^2}{4x} \text{............}(6)$$

Where;
L = Length of belt
C = Centre distance between two pulley
D_1& D_2 = Diameter of driver & driven pulley

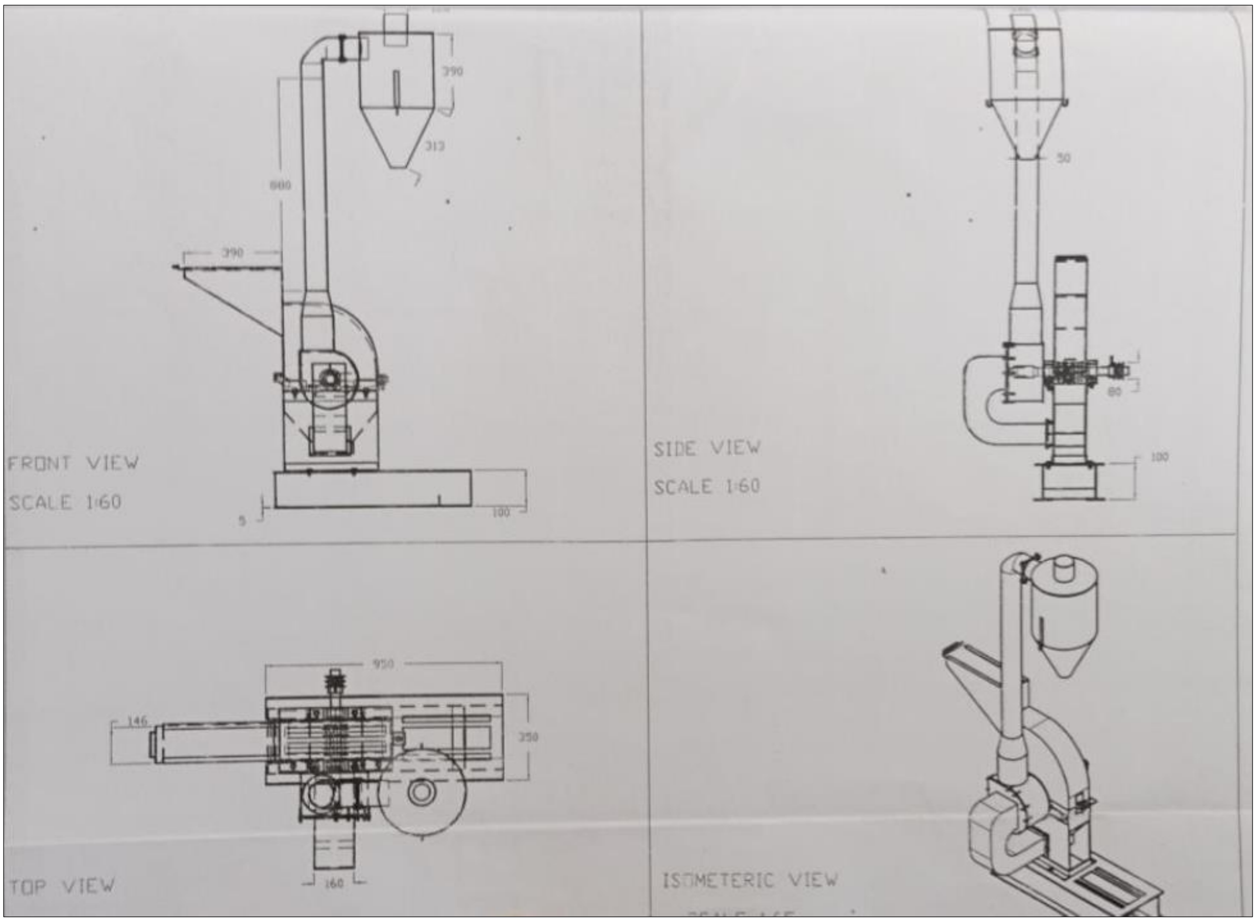

Figure 2 Orthographic Projection of the Plantain (*Musa Parasidiaca*) Chips Pulverizing Machine

2.12. Fabrication Procedure and Assembly

2.12.1. Fabrication of Hopper

The hopper was made from mild steel sheet of 2.5mm thickness. It was cut with a guillotine shears according to the size and bent to the shape with a manual bending machine. It was welded with an electric arc welding machine using gauge 12 electrode as a joining medium.

2.12.2. Fabrication of Main Frame

The mainframe of the machine was made from 100mm 'H' iron. The length and breadth was marked and cut to the required size using an angle grinder. It was then joined using an electric arc welding machine using gauge 12 electrode as a joining medium.

2.12.3. Fabrication of Shaft

The shaft was made from 30mm mild steel machine rod. It was machined on the lathe to the appropriate size while the key way slot was cut with a vertical milling machine.

2.12.4. Fabrication of Rotary Hammers/Beaters

The rotary hammers were made from 50mm X 6mm mild steel flat bar. It was marked and cut using an angle grinder. The hammers were arranged on a flange which has been attached to the shaft through a hole drilled at one end of the flat bar with a pillar drilling machine. The hammers were then welded fully to the flange at the end to enable swinging while in rotation.

2.12.5. Fabrication of Screen

The screen of the machine was selected to have a fine aperture. The screen was marked and cut with a guillotine shears and then rolled to the shape of a semicircular hemisphere with a manual rolling machine. It was attached to the base of the pulverizing unit with bolt and nut fastening.

2.12.6. Fabrication of Suction Blower

The suction blower was made from 3mm mild steel sheet. The housing was cut with a guillotine shears and rolled with a manual rolling machine. The fan was formed to a centrifugal type and enclosed into the housing. It was attached to the shaft by bolt and nut fastening.

2.12.7. Fabrication of Cyclone/Outlet

The cyclone was made from 2.5mm mild steel sheet. It was marked and cut with a guillotine shears and then rolled with a manual rolling machine to form a cylindrical shape. The outlet from the blower was connected to the cyclone with a 75mm mild steel pipe.

2.13. Principle of Operation of the Machine

The plantain (*Musa Parasidiaca*) chips pulverizing machine use the principle of shear and impact in the reduction of the size of the dried plantain chips. The machine is coupled with a 5Hp electric motor and its power is transmitted to the machine via belt drive. The plantain chips are fed into the machine via the hopper into the pulverizing unit where it comes in contact with the rotary hammers/beaters. The hammers apply both impact and shear action against the plantain chips until the size has been reduced to pass through the sieve. The reduced material is then sucked by the blower to the pneumatic unit where the fine particles were carried in the air stream through the pipeline to the outlet for collection.

2.14. Cost Analysis

Table 1 Bill of Engineering Measurements and Evaluation (BEME)

S/N	Material Specification	Quantity	Rate(₦)	Amount (₦)
1.	2.5mm mild steel sheet	1	30,000.00	30,000.00
2.	50 x 50 x 5mm 'L' iron	2	10,000.00	20,000.00
3.	100mm 'H' iron	¼	70,000.00	17,500.00
4.	30mm shaft	1m	10,000.00	10,000.00
5.	50mm X 6mm flat bar	1	5,000.00	5,000.00
6.	M10 Bolts And Nuts	2dozen	750.00	1,500.00
7.	Pillow bearing	2	5,000.00	10,000.00
8.	75mm mild steel round pipe	1.5m	4,000.00	6,000.00
9.	200mm pulley	1	4,000.00	4,000.00
10.	50mm pulley	1	2,000.00	2,000.00
11.	5hp motor	1	75,000.00	75,000.00
12.	Gl2 electrode	1pack	3,500.00	3,500.00
13.	Cutting disc	1	1,200.00	1,200.00
14.	Grinding disc	1	1,000.00	1,000.00
15.	Machining	Lump	10,000.00	10,000.00
16.	Painting	Lump	5,000.00	5,000.00
17.	Transportation	Lump	5,000.00	5,000.00
18.	Workmanship	Lump	15,000.00	15,000.00
	Total			221,700.00

2.15. Testing of the Machine

2.15.1. Sourcing of Test Materials

Unripe plantain (*Musa Parasidiaca*) was purchased from Oja Oba Market in Ilorin West Local Government Area, Ilorin, Kwara State, Nigeria.

2.15.2. Sample Preparation

The unripe plantain was cleaned and sorted to remove all the foreign materials. The plantain was soaked in hot water for five minutes for easy removal of the skin and then sliced into 4mm chips with a manual plantain slicer. The plantain slices were then loaded into a mixed mode solar dryer for drying until the moisture content is around 4% dry basis. The dried plantain chips were then measured into samples of 5, 10 and 15 Kg in triplicates using a digital weighing scale of accuracy ±1g.

2.15.3. Output Parameters

The output parameters were determined using the following equations:

Machine Throughput Capacity (Kg/h): $$M_c = \frac{m_s}{T} \times 3.6 \text{............(7)}$$

Machine Efficiency (%): $$M_e = \frac{m_p}{m_s} \times 3.6 \text{ ....(8)}$$

Where;

M_c: $Machine\ througput\ capacity$
M_e: $Machine\ efficiency$
m_s: $mass\ of\ sample\ before\ milling$
m_p: $mass\ of\ milled\ sample$
T: $time\ taken\ to\ mill\ the\ sample$

2.16. Experimental Procedure

The plantain (*Musa Parasidiaca*) chips pulverizing machine was cleaned and dried prior to its usage. The electric motor was connected to 240V A.C electric supply and the switch was put on. The machine was allowed to run for a minute before the samples were then introduced into the hopper. The samples were collected at the outlet below the cyclone and time taken for each sample to be milled was taken with a stopwatch and recorded accordingly. The procedure was repeated for all the samples while operating the machine at a speed of 2500, 3000 and 3500 rpm respectively for each of the samples.

3. Results and discussion

The summary of the result obtained from the testing of the plantain (*Musa Parasidiaca*) chips pulverizing machine are presented in table 2 below while the graphical representation of the results for the machine throughput capacity and machine efficiency was presented in figure 3 and 4 respectively.

From table 2 below, the result of the test carried out on the plantain (*Musa Parasidiaca*) chips pulverizing machine was presented. It was observed that the machine has the highest throughput capacity and efficiency of 493 Kg/h and 95 % respectively at a feed rate of 15 Kg/min and machine speed of 3500 rpm while the least capacity and efficiency was observed to be 300 Kg/h and 83 % respectively at a feed rate of 5 Kg/h and machine speed of 2500 rpm. The result obtained is an indication that the machine tends to perform best at a higher feed rate and machine speed and this could be attributed to higher kinetic energy of the hammers resulting from high rotational speed and higher collision between the molecules of the plantain chips at higher feed rate. Figure 3 and 4 below depicts the graphical representations of the results.

Table 2 Summary of Results Obtained from the plantain (*Musa Parasidiaca*) chips pulverizing machine

S/N	Feed Rate (Kg/min)	Machine Speed (rpm)	Machine Throughput Capacity (Kg/h)	Machine Efficiency (%)
1.	5	2500	300	83
2.	5	3000	345	89
3.	5	3500	372	94
4.	10	2500	425	84
5.	10	3000	462	91
6.	10	3500	480	95
7.	15	2500	430	86
8.	15	3000	475	91
9.	15	3500	493	95

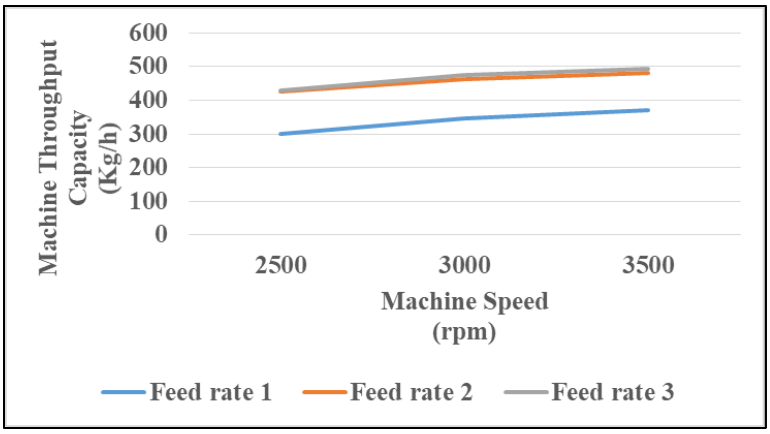

Figure 3 Effect of Machine Speed on the Throughput Capacity of the Plantain (*Musa Parasidiaca*) Chips Pulverizing Machine

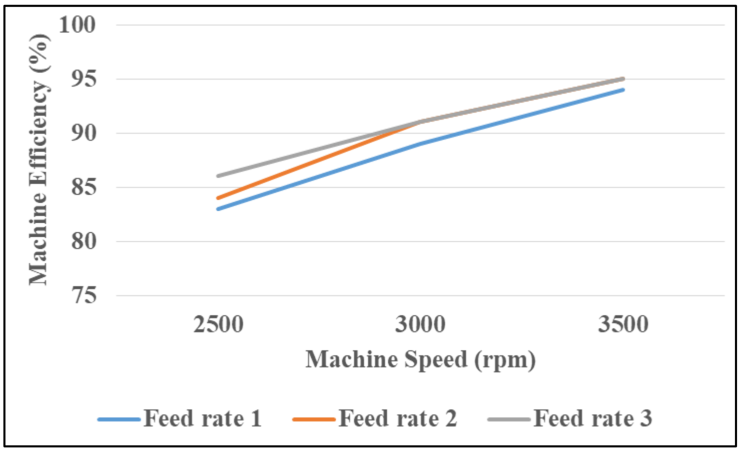

Figure 4 Effect of Machine Speed on the efficiency of the Plantain (Musa Parasidiaca) Chips Pulverizing Machine

4. Conclusion

A plantain (*Musa Parasidiaca*) chips pulverizing machine was developed in the department of Agricultural and Bio-Environmental Engineering, Institute of Technology, Kwara State Polytechnic, Ilorin, Nigeria. The machine was tested for its performance, and based on the results obtained the following conclusions were drawn:

- The machine is able to mill plantain chips into flour.
- The machine performs best at a high speed of up to 350 rpm and Higher feed rate of up to 15 Kg/min.
- The machine could be adopted by small and medium scale processors being able to process 493 Kg of plantain chips per hour at an efficiency of 95 %.

Compliance with ethical standards

Acknowledgments

We acknowledge our indebtedness and deepest sense of gratitude to all member of staff, department of Agricultural and Bio-Environmental Engineering, Institute of Technology, Kwara State Polytechnic, Ilorin, Nigeria.

Disclosure of conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

References

[1] Ayodeji, 2016: Conceptual design of a process plant for the production of plantain flour. Journal of Cogent Engineering. http://dx.doi.org/10.1080/23311916.2016.1191743

[2] Foramfera, 2012: Plantain flour production in Nigeria, the feasibility report. Retrieved from http://www.foramfera.com/index.php/market-research-reports/item/409-plantain- flour- production-in-nigeriathe-feasibilty-report

[3] Frison and Sharrock, 1999) Frison, E. and Sharrock (1999): The Economic, Social and Nutritional Importance of Banana in the World. International Network for the Improvement of Banana in the World.

[4] Ibrahim, A. H. (2013): How to start a plantain flour mill in Nigeria. Retrieved from http://constantive.com/business/plantain-flour-mill-in-nigeria

[5] Idachaba F. S. (1995): Food Policy in Nigeria towards a framework. Anal. Agricultural Res. Bull.,Volume 77, Issue 1. pp. 161-166.

[6] Khurmi R.S, Gupta JK. Machine Design, 14thEdition. S. Chand & Company Ltd. Ram Nagar. New Delhi-110055. 2005; 434-960.

[7] Uthman F., Oyebanre O.D., Bashiru F.O. and Shuaib-Na'allah B.O. (2022): Design and Fabrication of a Motorized Castor (Ricinus communis L.) Seed Decorticator. Global Journal of Engineering and Technology Advances, Vol 12(01), 064–077https://doi.org/10.30574/gjeta.2022.12.1.0103