DESIGN AND DEVELOPMENT OF A MODERNIZED CASSAVA GRATING MACHINE

ABSTRACT

Aim: To improve the production rate of a grating machine through careful modifications to the design specifications of the existing one.

Study design: The mesh surface area and the selection of proper construction materials were the two significant areas considered for modification. Stainless steel was chosen for fabricating the drum, perforated sheet, hopper, and shaft due to its reliability, durability, and resistance to corrosion.

Place and duration: Akanu Ibiam Federal Polytechnic, Unwana, Ebonyi State, Nigeria, between August 2020 and October 2022

Methodology: Detailed design drawings of the machine components were drawn with Solidworks 2019. The machine components were machined and assembled. We used an electric motor of 1hp and 1450rpm to transmit a torque of 4.94Nm that caused rotational motion on the shaft for effective and efficient meshing of the cassava roots.

Results: The performance analysis showed that the large mesh surface area significantly affects the pulp's production rate. The larger the mesh surface, the larger the quantity of cassava roots to mesh into pulp. The production rate of the modified grating machine was found to be 454.55kg/hr. and the time saved while meshing 100kg of cassava roots was 0.05 hours compared to the existing ones. The result showed that the machine has optimal performance and produces the intended quality in a reduced time.

Conclusion: Construction of the machine was carried out with improved design specifications. A careful selection of construction materials helps to achieve the stated objectives. We recommend this machine to all homes for domestic use because of its durability, reliability, affordability, resistance to corrosion, and ability to mesh a large quantity of cassava roots in a reduced time

Keywords: production rate, modernized, grater, cassava roots, machine drawing, machining

1. INTRODUCTION

Processing of cassava into garri needs to be done in a hygienic environment to prevent contamination of food. Cassava is more advantageous than other root crops and has high productivity when the climate conditions are favourable.

In Nigeria, the production of garri is a very tedious job in the 80s, because the majority of operations required were done manually. Technological advancement has brought leverage to all the processes involved in the production of garri.

Modern equipment makes the operations more reliable, faster, and with less human effort. The operations involved in the production of garri include harvesting cassava roots, peeling, washing, grinding, pressing, sieving, frying, and packaging. The systematic flow diagram for the garri production process is shown in figure 1

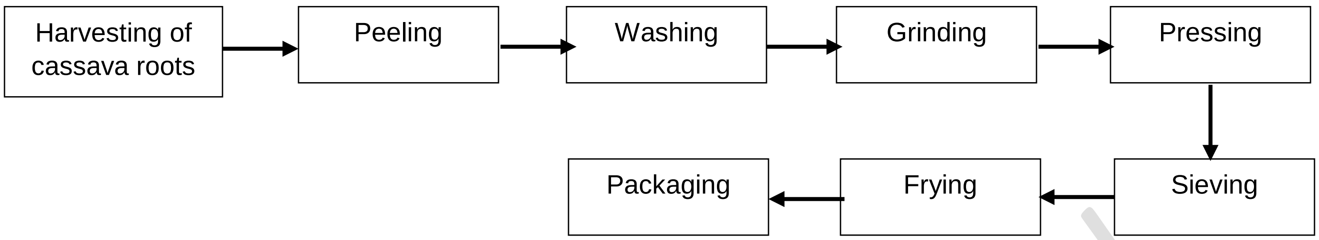

Figure 1: The systematic garri processing flow diagram

Each operation requires human effort and time for completion. Manual methods take a long time to complete and require a lot of human effort.

In this study, we considered grinding operations, which can be done using a modernized grater or traditional methods. Traditionally, cassava grinding is done either by pounding with a mortar and piston or using a hand grater made of perforated flat metal sheet. These materials have a high rate of corrosion and are difficult to clean after usage. These methods could make the by-products unsafe for consumption, require a lot of labour, and have a high production cycle. The modernized cassava grater meshed cassava into a pulp easily, packs it into bags, and is subsequently mounted on the hydraulic press to reduce the moisture content of the mashed cassava roots.

The quest to produce quality garri in a large quantity at the right time led to the innovation and invention of many cassava graters. These cassava graters are available in the market with different design concepts and development. Some of the graters available in the market include pedal power graters, dual powered (manual and electricity), manually operated graters, the International Institute of Tropical Agriculture (IITA) 202, the Jahn type grater, the GRATIS Foundation (GF) 202, and the Double-barrel cassava grating machine [1]. Kolawole et al, Quaye [2],] 3] noted that the performance of all these machines is very low as a result of poor output quality and inefficiency.

A manually operated grater was designed and developed for the interest of rural dwellers [4]. Ndaliman [5] designed and developed a dual-powered grater to reduce idle time. Adetunji and Quadri [6] worked on dimensional modification of the existing design of a grater to make it more portable and changed the wooden barrels to stainless steel and galvanized pipe. Ajao et al [7] designed and constructed a grating machine powered by a pedal. This was done to address the issues of an electric power outage, the high price of fuel, and its scarcity. Oriaku et al [8] worked on the design and evaluation performance of a grating machine with double drums for the mashing of cassava. Oriaku et al [9] worked on how to achieve high output in a grating machine with double action drums with respect to time-saving.

The reviewed literature showed that all the researchers had a common goal, which was to design and develop grating machines mainly for garri production at lower production costs and with high efficiency. They also aimed to develop a modernized grater that will aid in the meshing of cassava roots into pulp to meet specific standards and customers' demands. The reviewed literature also showed that much was not said about the choice of construction materials and the dimensions of the grating drum. The grating drums (perforated mash), discharge chute (outlet), and hopper have direct contact with the cassava roots and should be constructed with materials that cannot contaminate the output. The grating drum, with a relatively small surface contact area, meshed a smaller quantity of cassava roots into pulp in one stroke.

We embarked on this study to develop and improve on the existing design of a modernized cassava grater such that it can produce pulp with less human effort, at a minimum time, and at a high-performance rate. To achieve our main objective, proper material selection and dimensional modification of the grating drum will be carried out. The combination of these specifications will help to develop a modernized cassava grating machine with a high-performance rate and high-quality output. The 3D model drawing of the grater will be done using the SolidWorks 2020 application.

2. MATERIALS AND METHODS

2.1. Materials

The following materials were selected based on some vital criteria to be used for the fabrication of the machine

2.1.1.. Material selection

Material selection is of utmost importance to ensure that the components to be fabricated have the desired performance requirements. Since different components of the machine would be subjected to varying forms and the degree of stresses strains, torque, and the frictional effect, therefore materials like Mild Steel, Stainless Steel, Alloy Rubber and Cast Iron were selected because they possess the appropriate engineering properties required for the project.

Table 1: Materials selected for the fabrication of the machine

S/No.	Component	Material & Dimension
1	Frame (structural base)	Angle iron 55mm x 55mm
2	Plummer block	Cast Iron Ø40mm
3	Bolts & Nuts	Bolts & Nuts (stainless)
7	Hopper and discharge chute	2mm Sheet of stainless steel
8	Drum	Ø300mm x400 stainless disc
9	Electric motor Cast Iron	1.HP, 1450rpm
10	V belt	Polyester fibre
11	Pulley	9" and 3” pulleys
12	bolts & nuts	17 Mild steel
13	Shaft	Ø50mm x 600mm Stainless shaft
14	Perforated sheet plate	2x200x400mm

2.1.2. Material Selection Criteria

The materials to be used for fabrication was selected after a careful study of the desired physical, mechanical and chemical and even aesthetic characteristics of a number of proposed materials. For this project, due to economic considerations and availability of raw materials, high and medium carbon steel would be mostly used for body parts and chuck materials while cast iron was chosen for the pulleys.

2.2. Methods

In order to achieve the stated aims the following methods will be adopted

2.2.1. Machine Drawing

This is the graphic representations of the machine components or machine assembly by lines. It gives all the dimensional details of the machine component from which it can be fabricated. This will be done using Solidworks.

2.2.2. Machining

This is the process of removing unwanted material from a work piece using machine tools to get the desire shape or an intended design specifications. This can be done using drilling machine, lathe machine, milling machine, grinding machine, bending machine etc.

The various components of the machines would be machined to the needed design specification

2.2.3. Choice of assembly and procedures

This is the process of assembling or coupling of the machine parts together. However, for a good finish, arc welding and fixing have been chosen for assembling of the project.

2.2.3.1. Welding

This is a metal joining process which is an act of joining two metal parts permanently in such a way that the joints are equivalent in composition and characteristics to the type of material used.

2.2.3.2. Fixing components with bolts and nuts

This is a coupling process that can be used in joining component parts that can be removed or changed in case of wear or damage.

2.2.4. Testing of the Machines

The machines having been completed, in terms of the design and fabrication, would be tested to verify if the efficiency of the machines is satisfactory. In fact, all the design concepts and calculated results would religiously be followed and arrived at with little or no variations.

2.2.5. Performance Evaluation

Series of test would be conducted using the machines. Cassava tubers would be obtained from a farm peeled automatically, thoroughly washed, and weighed using a weighing balance scale. The machine would be operated for some minutes to allow speed to stabilize, peeled cassava would be introduced into the machine through the hopper, and the process will continue until the final output product is obtained. The time taken to obtain the required output will be noted and recorded.

2.2.6. Installation of the Machines

This is the stage at which all the fabricated machines are reassembled, realigned, connected to essential services and then tested exhaustively to ensure it works at peak operating efficiency when it finally goes into production.

3. DESIGN CALCULATION

3.1. Parameters

B_{ms} Bending moment on the shaft

V_d Distributed Load on the shaft from Drum, disc and perforated sheet weight

W_p Weight of the pulley

W_D Weight of the drum

W_{ps} Weight of the perforated sheet

ρ_m Density of the drum and disc material

V_{rs} Volume of the stainless rolled sheet

V_{pm} Volume of the perforated mesh sheet

T_s Torque transmitted on the shaft

T_m	Twisting moment on the shaft
D_s	Diameter of the shaft
D_d	Diameter of the drum
h_d	Height of the drum
L_s	Length of the shaft
τ_s	Permissible shear stress of the shaft
P_s	Power transmitted to the shaft by the electric motor
D_p	Diameter of pulley on the shaft
d_m	Diameter of pulley on the electric motor

3.2 Shaft design

3.2.1. Loads and stresses on shaft

Wp = Mass of the pulley x acceleration due to gravity (1)

Where mass of the pulley = 1.45kg and acceleration due to gravity is taking to be $9.8m/s^2$

∴ W_p = 1.45 x 9.8 = 14.21N

W_D = Density of the material x Volume of the drum x acceleration due to gravity (2)

Density of the material (ρ_m) = 7850Kg/m3,

Volume of the drum (V_D) = $\pi(R_d^2 - r_d^2)h_d$ (3)

where D_d = 300mm, R_d = 150mm = 0.15m, r_d = 25mm = 0.025m hd = 400mm = 0.4m, π = 3.142

∴ $V_D = 3.142(0.15^2 – 0.025^2) \times 0.4 = 2.75 \times 10^{-2} m^3$

Then Volume of the perforated sheet = 1.6×10^{-4} m^3

Thus $W_D = 7850 \times (2.75 \times 10^{-2} + 1.6 \times 10^{-4}) \times 9.8 = 2127.88N$

∴ Distributed load on the shaft due to the drum = 2127.88N

Torque transmitted to the shaft (Ts)

This can be calculated from

$$T_s = \frac{P_s}{\omega} = \frac{P_s \, x \, 60}{2\pi N} \quad (4)$$

Electric motor power rating = 1hp = 0.75KW with 1450rpm

$$\therefore T_s = \frac{750 \, x \, 60}{2 \, x \, 3.142 \, x \, 1450} = 4.94N - m$$

Permissible shear stress of the shaft (τ_s)

The Permissible shear stress of the shaft (τ_s) is given as = $\frac{Distributed\ Load\ on\ the\ shaft}{Cross\ sectional\ area\ of\ shaft}$ (5)

Cross sectional area of the shaft (A_s) = $\frac{\pi D_s^2}{4}$ (6)

$$= \frac{3.142 \ x \ 0.05^2}{4} = 1.96 \ x \ 10^{-3} m^2$$

$$\therefore \tau_s = \frac{2127.88}{1.96 \ x \ 10^{-3}} = 1.086 \ x \ 10^6 N/m^2 = 1.086 MPa$$

Twist moment (T_w) = $\frac{\pi \tau_s D_s^3}{16}$ (7)

$$= \frac{3.142 \ x \ 1.086 \ x \ 10^6 \ x \ 0.05^3}{16} = 426.53 Nm$$

3.2.2. Bending stresses on the shaft

The shaft is subjected to bending stresses are given as

1. Bending moment

Bending Moment (M) = W_D x L_d (8)

= 2127.88 x 0.4 = 851.15Nm

2. Bending stress

Bending stress $\sigma_b = \frac{M}{Z}$ (9)

$$Z = \frac{\pi}{32} x D_s^3 \quad (10)$$

$$\therefore \sigma_b = \frac{32 \ x \ M}{\pi \ x \ D_s^3} = \frac{32 \ x \ 851.15}{3.142 \ x \ 0.05^3} = 69 MPa$$

3.2.3. Speed transmitted to the shaft

D_1 = 9" = 9 x 0.0245 = 0.2205m (diameter of the shaft pulley)

D_2 = 3" = 3 x 0.0245 = 0.0735m (diameter of the electric motor pulley)

Speed transmitted (Vs) $= \frac{\pi \ N \ D_2}{60}$ (11)

$$= \frac{3.142 \ x \ 1450 \ x \ 0.0735}{60} = 5.58 m/s$$

Speed ratio $= \frac{D_1}{D_2}$ (12)

$$= \frac{9}{3} = 3$$

3.3 Belt design

The belt length (L_b) is given as:

$$L_b = \frac{\pi}{2}(D_2 + D_1) + 2X + \frac{(D_1 - D_2)^2}{4X} \quad (13)$$

$$X = \frac{D_1 + D_2}{2} \quad (14)$$

$$= \frac{0.2205 + 0.0735}{2} = 0.147 m \ or \ 6"$$

$$\therefore L_b = \frac{3.142}{2}(0.2205 + 0.0735) + 2\,x\,0.147 + \frac{(0.2205 - 0.0735)^2}{4\,x\,0.147}$$

= 0.53m

The angle of contact on electric motor pulley (θ)

$$sin\alpha = \frac{D_1 - D_2}{2X} \quad (15)$$

$$= \frac{9-3}{2\,x\,6} = 0.5$$

$$\alpha = sin^{-1}(0.5) = 30^o$$

The angle of contact $\theta = 180 - 2(\alpha)$ (16)

= 180 – 2 x 30 = 120o or $\frac{\pi}{180}x120 = \frac{3.142}{180}x120 = 2.09rad$

3.4 Hopper design

The volume of the hopper (V_h) is given as:

$$V_h = \frac{1}{2}(a+b)xh\,x\,H \quad (17)$$

$$= \frac{1}{2}(32+40)x\,30\,x\,60 = 64800mm^3 = 64.8m^3$$

4. RESULTS AND DISCUSSION

4.1 Results

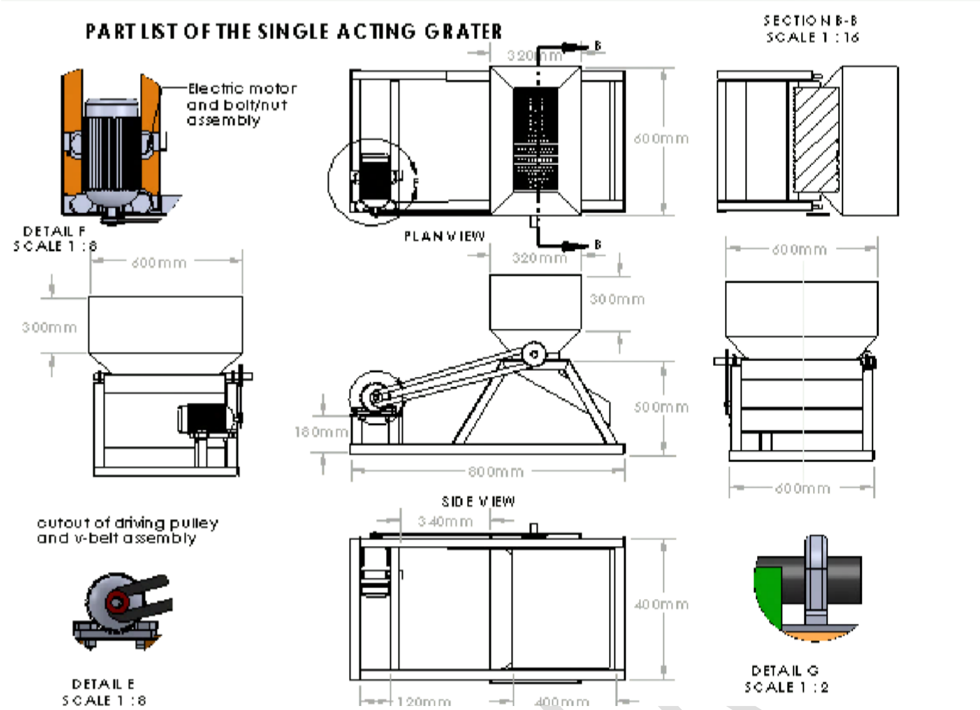

Figure 1: The isometric views, and orthogonal views of the machine

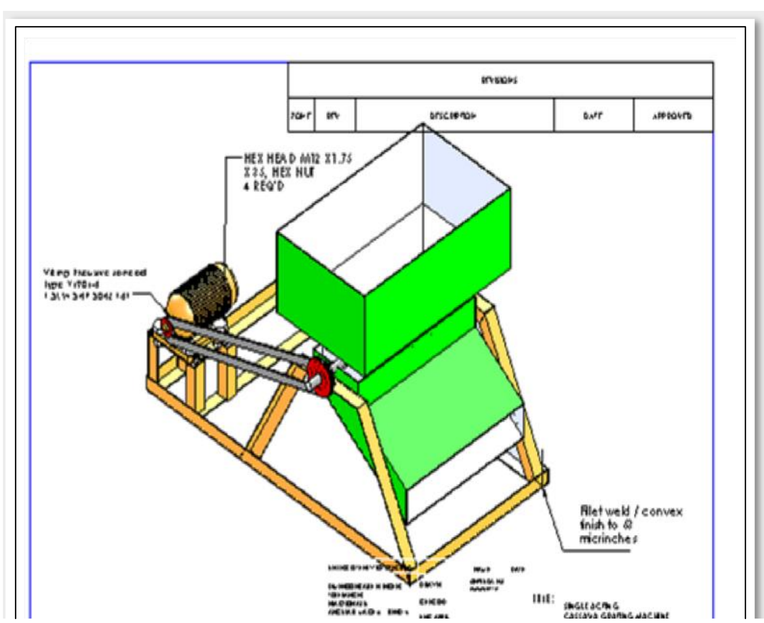

Figure 2: The 3D model drawing

Figure 1 showed the machine drawings of the constructed grater, drawn with the aid of Solidworks 2019 software. The views showed in figure 1 are isometric views, and orthogonal views, while figure 2 shows the 3D model drawing to aid in machine fabrication.

4.1.1. Performance evaluation

After fabrication of the grater, it was tested to ascertain its production rate in comparison with the existing grater. The evaluation was carried out using 100kg of cassava roots meshed on the existing grater with respect to time. The same quantity of cassava roots was also meshed on the improved grater with respect to time.

The grating was done in batches and the weight of each batch loaded was taken and recorded. The result of the outcome is shown in table 2.

Table 2: The results of the performance analysis

S/N	Weight of each batch (Kg)	Grating time (mins)	
		Existing Grater	Improved grater
1	18.20	2.90	2.36
2	20.00	3.20	2.60
3	20.50	3.28	2.67
4	20.6	3.30	2.68
5	20.7	3.31	2.69
Total	**100**	**15.99**	**13.00**

4.2. Discussion

From table 2, the total quantity of cassava roots loaded in existing grater is 100Kg and the total time required to mesh the quantity is 15.99mins. (0.27hrs).

The throughput capacity of the existing grater = $\frac{Input\ quantity\ (Kg)}{Required\ working\ time\ (hr)} = \frac{100}{0.27} = 370.37Kg/hr.$

The total quantity of cassava roots loaded into the new grater is 100 kg, and the total time taken to mesh the quantity is 15.99 mins. (0.22 hrs).

The through put capacity of the existing grater = $\frac{Input\ quantity\ (Kg)}{Required\ working\ time\ (hr)} = \frac{100}{0.22} = 454.55Kg/hr.$

From the analysis, the throughput capacity of the modernized grating machine was 454.55 kg/hr. against 370.37 kg/hr. obtained from the existing machine. The result showed that there was a great improvement in the production rate. This was as a result of the large meshed surface area adopted in the design.

5. CONCLUSION

Construction of the modernized grating machine was carried out with improved design specifications. A careful selection of the construction materials helps to achieve the stated objectives.
The constructed machine was tested, and it was found to perform its intended functions effectively and efficiently to enhance production of garri at a minimum time with less vibration while in use. Assembling and disassembling the machine is simple because of the design improvement. We recommend this machine to all homes for domestic use because it is durable, affordable, and can mesh a large quantity of cassava roots in a reduced time.

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