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Design and Development of a Modernized Cassava Grating Machine

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Authors' contributions

This work was carried out in collaboration among all authors. Author IN did conceptualization, performed methodology, designed the analysis, wrote the protocol, reviewed and edited the manuscript, supervised the work. Author IUM wrote and prepared the original draft and Supervised the study. Author AUC managed the project administration. Author ONI helped in software and machine drawing of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aim: To improve the production rate of a grating machine through careful modifications to the design specifications of the existing one. The objective of the study was to develop a modernized cassava grating machine with a high-performance rate and high-quality output at a minimum time and economical cost.

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.

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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 with an efficiency of 95.12%.

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 Fig. 1.

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.

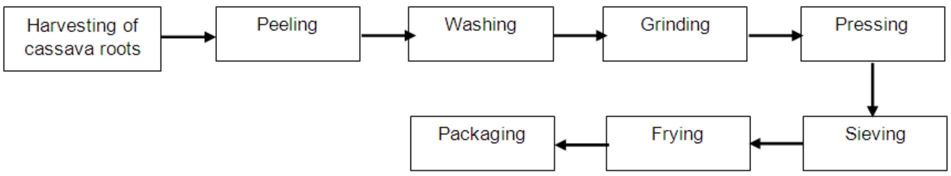

Fig. 1. The systematic garri processing flow diagram

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. Oyejide et al, Bello et al [10], [11] designed and fabricated cassava grating machine with 80% efficiency

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	Specification
1	Frame (structural base)	Angle iron	55mm x 55mm
2	Plummer block	Cast Iron	Ø40mm
3	Bolts & Nuts	Bolts & Nuts (stainless)	M16
4	Hopper and discharge chute	Sheet of stainless steel	2mm
5	Drum	stainless disc	Ø300mm x400
6	Electric motor	Cast Iron	1.HP, 1450rpm
7	V belt	Polyester fibre	530mm
8	Pulley	Mild steel	9" and 3" pulleys
9	bolts & nuts	Mild steel	M10
10	Shaft	Stainless shaft	Ø50mm x 600mm
11	Perforated sheet plate	Stainless sheet	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 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.

2.2.3 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.

2.2.4 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 Shaft Design

3.1.1 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 [3]

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/m^3, [3]

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)

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

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

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

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

3.1.2 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)

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

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

3.1.3 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)

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

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

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

3.2 Belt Design

The belt length (L_b) is given as:

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

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

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

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

= 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 $\frac{\pi}{180} x120 = \frac{3.142}{180} x120 = 2.09rad$

3.3 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

Fig. 2 showed the machine drawings of the constructed grater, drawn with the aid of Solidworks 2019 software. The views showed in Fig. 1 are isometric views, and orthogonal views, while Fig. 3 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.

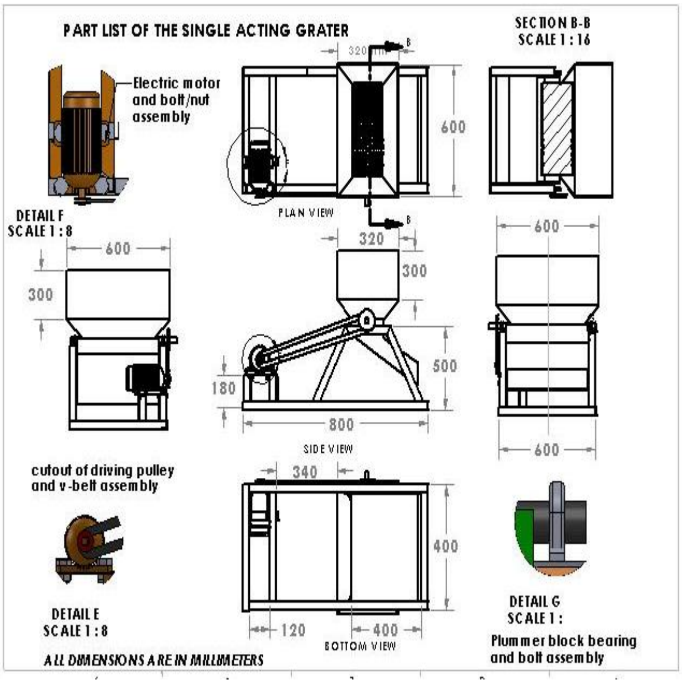

Fig. 2. The isometric views, and orthogonal views of the machine

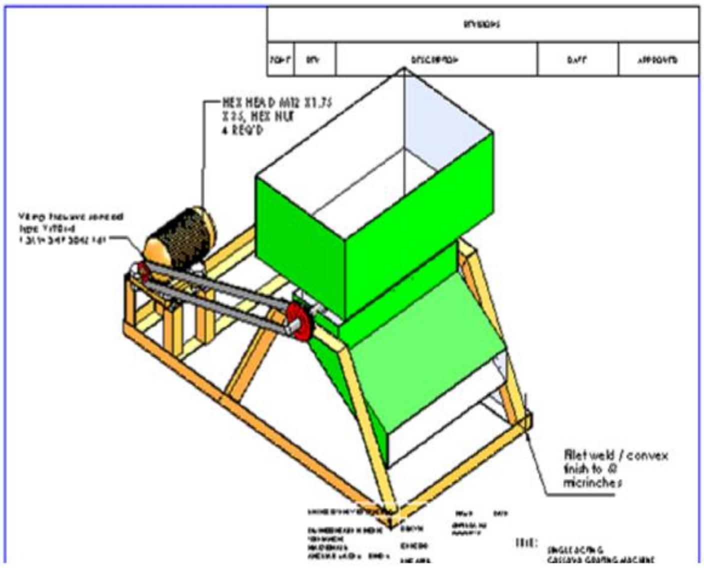

Fig. 3. The 3D model drawing

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	20.60	3.30	2.68
5	20.70	3.31	2.69
Total	**100**	**15.99**	**13.00**

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.

The efficiency of the machine was obtained through the following steps:

1. Weighing an empty container with a weighing balance
2. The mass of cassava sieved out was put in the container was weighed
3. The mass retained by the sieve was weighed as well

The weight of the empty container (We) = 0.20 kg
Weight of empty container + Weight of sieved out (We + Ws) = 6.50 kg
Weight of the retained cassava (Wr) = 0.52 kg
The output weight (Wo) = 6.30 kg
The input weight (Wi) = 6.62 kg

Then the efficiency of the machine = $\frac{\text{The output weight}}{\text{the input weight}}\ x\ 100\% = \frac{6.30}{6.62}\ x\ 100\%$

= 95.12%

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 13.00 mins. (0.22 hrs).

The through put capacity of the new 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. The efficiency of the machine was 95.12% and the capacity was 454.55 kg/h.

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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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