Design and Fabrication of an Improved Cassava Grater.

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ABSTRACT

There is need for the hygienic processing of cassava. Prevalent conditions in the commercial grating areas of this staple food show a susceptibility to food contamination. A home-scale cassava grater was improved on in design and fabrication. Machine efficiency, safety factors, and portability were considered in this research. The grating hopper and drum were modified with the drum having a stainless steel sheet wrapped around a galvanized mild steel core, The machine runs on a single phase one horse power electric motor at a speed of1440 rpm. The capacity of the grater fabricated was 158kg/hr and about 50 % reduction in price was achieved.

(Keywords: design fabrication, home-scale, improved, cassava, grater)

INTRODUCTION

Cassava originated from Latin America and was later introduced to Asia in the 17th century and to Africa in about 1558. In Nigeria, cassava is mostly grown on small farms, usually intercropped with vegetables, plantation crops, yam, sweet potatoes, melon, maize, etc. Cassava is propagated by 20 –30 cm long cutting of the wood stem, spacing between plants is usually 1-1.5 meters. Intercropping with bean, maize, and other annual crops is practiced in young cassava plantations.

There are two common varieties of cassava, namely, the bitter and sweet varieties. The cyanide content differs as well as suitability for different growing and consumption conditions. Usually, higher cyanide is correlated to high yields. Nigeria is the world largest producer of cassava tuber in the world, producing about 34 million tonnes of the world's 174.0 tonnes.

Over the past 25 years significant market opportunities for cassava have opened up in the animal feed industry, initially in the EEC (European Economic Community) countries but more recently for the rapidly expanding animal feed industries of tropical developing countries. Cassava roots compete with other carbohydrate sources, especially maize and sorghum, on the basis of price, nutritional value, quality and availability.

Cassava has several advantages compared with other carbohydrate sources, especially other root crops. It has a high productivity under marginal climatic conditions, which results in a low cost raw material. Root dry matter content is higher than other root crops at 35-40%, giving optimum rates of 25:1 or better. Over 85% consists of highly digestible starch.

Cassava starch has excellent agglutinant properties which make it especially suitable for shrimps and fish feeds, replacing expensive artificial agglutinants.

The potential disadvantages of cassava roots are their bulk and rapid perishability, their low protein content, and the presence of cyanide in all root tissues. Through simple processing the disadvantages of bulk and perishability can be overcome. A stable product is reached when moisture content falls below 14%. Natural drying is widely used to achieve this objective. Drying also permits the elimination of most of the cyanide from root tissues. The dried cassava product thus has only one disadvantage with respect to other carbohydrate feed sources: low protein content. This can be overcome through price competitiveness.

For export markets, where transportation over thousands of kilometers is necessary, further processing to produce high density pellets is carried out to minimize transport costs.

Presently in Nigeria, the products of cassava are usually locally consumed and exportation is limited because the products do not always meet the international standards for healthy foods. Thus, the need to encourage the small scale (home production) of cassava product to ensure quality of products and good hygienic values.

From the survey conducted, it was discovered that most of the cassava graters in the research area are usually corroding (reducing service life) due to the acidic nature of the cassava fluid and materials used for the fabrication. To ensure all cassava products is free from any taste, odor, or infected by iron content of parts (food poisoning) which may affect the quality of their contents (FAO/GIEWS, 2001) hence need to modify the design and use appropriate materials for fabrication.

The product tuber spoils after 2-3 days of harvesting, hence need for processing into safer stable products. In view of the above mentioned problems and the overall importance of the cassava products the following objectives are required to address the shortcomings of the grater. The following research objectives need to be accomplished.

1. To design and fabricate model cassava grater.

2. To modify the design of the existing cassava grater (dimensions) to the home use-small scale sizes.

3. To change the crude wooden drums used in cassava grating machines to lasting stainless steel and galvanized pipe.

4. Ensuring proper grinding performance thereby eliminating vibrating shifter/sieving since the cassava products can be re-grinded to finer particles after pressing and frying etcetera (ensuring no waste).

5. To save time and cost of processing cassava products by the average family.

6. To promote healthy consumption of cassava products.

MATERIALS AND METHOD

Design Considerations

- The machine should be efficient during use in the household as well as movable (portability) and safely or easily operated.

- Another problem is that cassava produces a large amount of cyanogenic glycosides so in selecting materials, for construction, adequate care must be taken not to use materials that cannot degrade/ corrode easily due to the acidic content in cassava.

Table 1: Materials Used in the Construction of a Cassava Grater.

S/No	Name	Materials Used
1	Hopper	Mild Steel
2	Shaft	Mild Steel
3	Drum	Stainless Steel
4	Discharge	Stainless Steel
5	Pulley	Cast Iron
6	Electric Motor	Cast Iron with Windings
7	Bolts	Mild Steel
8	Belt	Alloy Rubber
9	Frame	Mild Steel
10	Rivet Pins	Stainless Steel
11	Bearings	Cast Iron
12	Perforated Mesh	Stainless Steel
13	Cover	Mild Steel
14	Handle	Mild Steel

Description of Machine Parts

The machine is expected to have the following components:

The Main Frame: The main frame will be constructed with angle iron. The angle iron are welded together to form the frame work. The welding provides very rigid joints. This is in line with the modern trend of providing rigid frames. This provides the strength and rigidity for the overall machine. 1 ½ ″ by 1½ ″ angle bars was used.

The Hopper: The hopper is the receptacle through which cassava is admitted into the machine for grating. It has a rectangular plan which the tapers gradually. Volume of the hopper = $[\frac{1}{2}(a + b)H]L = 23m^3$**.**

The Grating Unit: This unit consists of the shaft, perforated mesh, rolled sheet, circular discs and rivet pins. The drum will be formed by the shaft passing through the rolled cylindrical sheet and it will be welded in place by circular discs. This drum is then wrapped with the perforated mesh, they are attached by riveting.

Electric Motor and Pulley System: An electric motor is used to power the machine. A reduction pulley system is used to transmit power to the grater's drum at reduced speed and increased torque. This enables the drum to exhibit rotary motion thereby grating the cassava.

The Discharge Unit: This is a continuation of the grater's frame connected to the hopper. It directs the flow of the grated cassava to a storage pit or receptacle.

THEORETICAL ANALYSIS

Shafts Design

A shaft is a rotating machine element which is used to transmit power from one place to another. The power is transmitted by some tangential force and the resultant torque (or twisting moment) setup within the shafts permits the power to be transferred to various machine or its elements linked up to the shaft.

In order to transfer the power from the shaft, the various members such as pulleys, bearings, drum etcetera are mounted on it. These members along with the force exerted upon them causes the shaft to bending.

Therefore, we may say the shaft in this case is exposed to bending moment and torsional forces since it is utilized for torque transmission and bending moment (Figure 1).

Determination of the Bending Moment at each point of Loading

This involves the preparation of the bending moment diagram for the two perpendicular planes: vertically and horizontally (Figure 2).

Force Exerted on Shafts (Vertical Force)

The machine element that exerts force on the shaft is the belt pulley driven electric motor and grating drum:

Weight of Pulley, $W_p = M_p\, g$ **(i)**

Where M_p = Mass of the pulley in Kg = 1.5kg
g = Acceleration due to gravity = 9.81m/s
W_p = 9.81 x 1.5kg = 14.715N

Weight of Drum, $W_d = \rho\, V\, g$ **(ii)**

= ρ V g of [Volume of The two Circular plates + Volume of the Rolled Steel Sheet + Volume of Perforated Mesh]

Where ρ = Density of the Material
= For Stainless, 7930kg/m^3
= For Mild steel, 7860kg/m^3
V = Volume of the Material
Volume of pipe = $\pi \Delta r^2 h = \pi(0.25'' \times 0.245)^2 \times 0.35 = 4.1251 \times 10^{-3}\ m^3$
Volume of Circular Plate = $5.94 \times 10^{-5}\ m^3$
g= Acceleration due to gravity

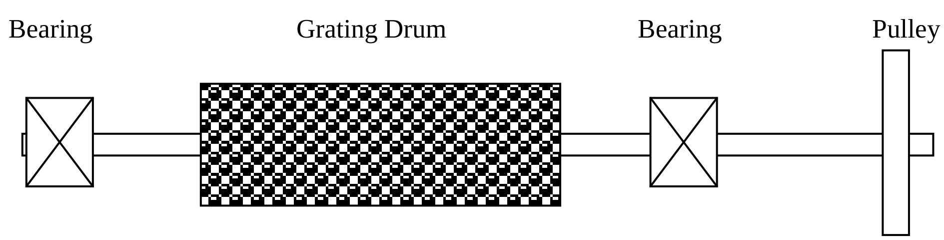


Figure1: Shaft Bending Moment Determination.

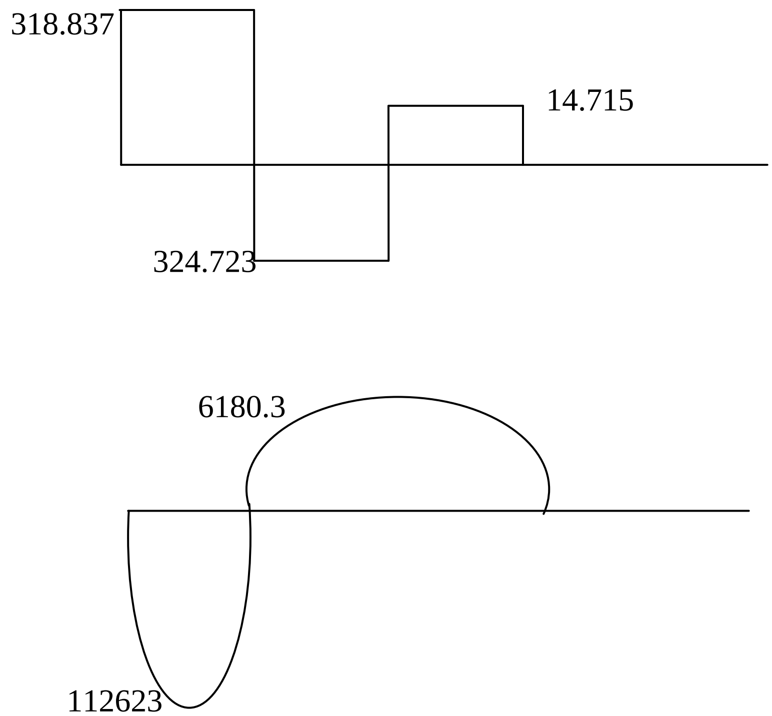


Figure 2: Shear Force and Bending Moment Diagram.

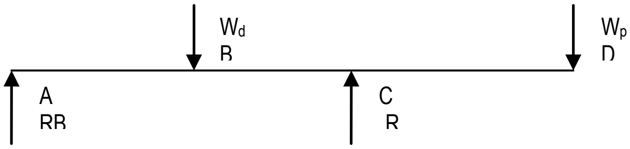
Point Loading of Shaft Due to Drum,

$W_d = 9.81[(\{4.125 + 0.0594\}10^{-3}x7860)$
$+ (7930 \text{ x } 4.125 \text{ x } 10^{-3})]$
$= 643.56N$

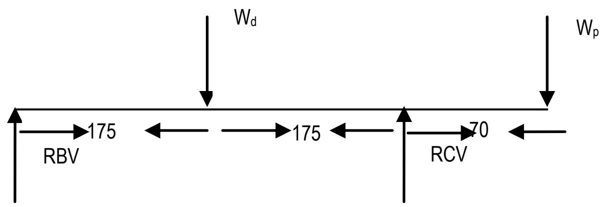
Distributed Loading Due to Drum = 643.56/350
= 1.839N/mm

<u>Reactions at the Bearings Due to Vertical Loading</u>

Below is represented the expected free body diagram of vertical forces acting on the shaft:



To obtain the reactions at each bearing, we will have to take moment about the two expected bearing points independently.



Taking moment about point A,
$-RCV(350) + W_p (420) + 643.56(175) = 0$

RCV = 339.438N

Taking moment about point B,

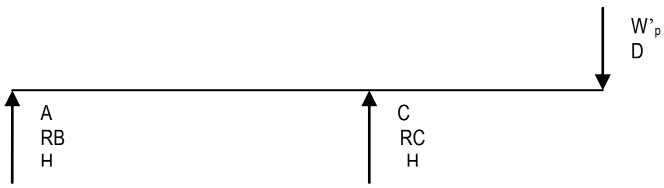
$-643.56(175) + RBV(350) + W_p (70) = 0$

RBV =318.837N

From the results of the calculations, we obtained the shear force and bending moment diagrams required.

Due to Horizontal Loading

Below is represented the expected free body diagram of horizontal forces acting on the shaft



(iii)

Where

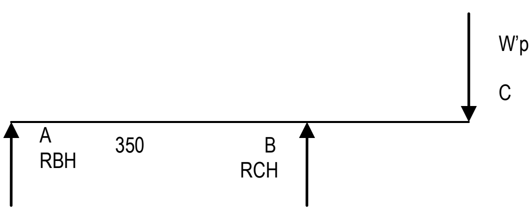
$$Angular\ Acceleration, \omega\ in \frac{rad}{s} = \frac{2\pi N}{60}$$ **(iv)**

Power Rating = 1hp =746W

$$Torque = \frac{746\ x\ 60}{2\pi\ x\ 1440}$$ = 4.95Nm

$$\text{Horizontal Weight on the Pulley, W'p} = \frac{4.95}{3''\ x\ 0.0245}$$ =67.35N

Using the W'$_p$ horizontal force, we then obtained the horizontal reactions at the bearings by taking the moments about the two bearing points independently.



RBH + RCH = W'p

Taking moment about Point A,

RCH (350) = 67.35(420)

RCH = 80.82N

RBH = -13.47N

From these results of the calculations, we obtained the shear force and bending moment diagrams required.

Considering the horizontal, vertical forces, and the bearing reactions, the maximum bending moment then obtained from the resultant bending moment,

(v) = 113958.08N

Then, the equivalent twist moment from the torque.

=113958.0895N

The diameter of the shaft can be determined by:

$$Equivalent\ Twist\ Moment, Te = \frac{\pi}{16} \times \tau \times Ds^3$$ **(vi)**

Where

τ = Permissible Shear Stress of the Shaft Material ,42MPa

D_s = Diameter of Shaft

$$113958.0895 = \frac{\pi}{16} \times 42\ X10^6 \times Ds^3$$

Ds = 23.996mm

D_s = 24mm

Speed Transmission

The transmission system consists of a pulley system reducing the motor speed by a ratio of 1:1
Note: D_e = Diameter of the driver pulley = 3″ x 0.0245 = 0.0735m

D_d = Diameter of the driven pulley

$$Speed\ Ratio = \frac{De}{Dd} \qquad \textbf{(vii)}$$

From horse power/motor speed, a motor speed of 1440rpm was selected.

Power Transmission

The ratio between the velocities of the electric motor pulley/driver pulley and the drum pulley/ driven pulley is calculated mathematically, as shown below:

Let N_e = Speed of the driver in r.p.m. = 1440rpm

N_d = Speed of the driven in r.p.m. = 1440rpm

Length of the belt that passes over the driver, in one minute = $\pi D_e N_e$ **(viii)**
= 332.5m

Similarly, length of the belt that passes over the follower, in one minute

= $\pi D_d N_d$ **(ix)**
= 332.5m

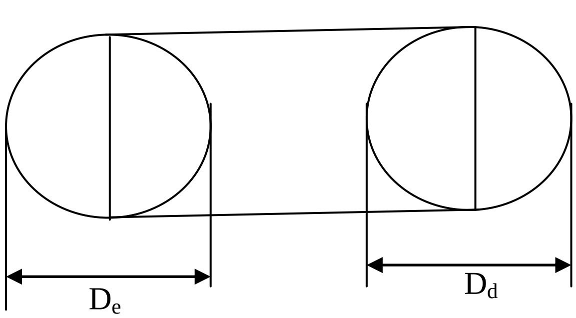
Since the length of belt that passes over the driver in one minute is equal to the length of belt that passes over the follower in one minute, therefore

$D_e N_e = \eta D_d N_d$ **(x)**

Therefore,

D_e = 0.0735m = 3″

Belt Design



Determination of Centre Distance (C)

Rubber Manufacturing Association(RMA) recommended that the centre distance is dictated by other consideration of the following values could be used:

For speed ratios less than three:

$$C = \frac{De + Dd}{2} + De \qquad \textbf{(xi)}$$

For speed ratios of 3 or more, C = D

Therefore,

$$C = \frac{0.0735 + 0.0735}{2} + 0.0735$$

C = 0.147 = 6″

Length of Belt

In order to compute the length of the belt required, we use the formula below

$$L = \frac{\pi(Dd + Dm)}{2} + 2C + \frac{(Dd - Dm)^2}{4C} \qquad \textbf{(xii)}$$

C = Distance between the center of the two pulleys

L = Length of Belt Required

$$L = \frac{\pi(0.0735 + 0.0735)}{2} + 2\,(0.147) + \frac{(0.0732 - 0.0735)^2}{4(0.147)}$$

L = 0.525m

Angle of Contact on Driver Belt Sheave

This is the lap angle of the belt over the electric motor's pulley:

$$\theta = (180^0 - 2\propto)\left(\frac{\pi}{180}\right) rad \qquad \textbf{(xlv)}$$

Where $\propto = \sin^{-1}\left[\frac{Ds - Dm}{2x}\right]$

$= \sin^{-1}\left[\frac{0}{2C}\right] = 0$

$\theta = \pi = 180^0$

METHODOLOGY

Machineries and Machining Processes Used in the Fabrication Processes are as follows:

1) Drilling Machine: This can be hand drilling or pillar drilling machine. This machinery was used for most drilling jobs. The work is stationery while the spindle carrying the drill chuck and bit moves the work must be held with a vice during drilling.

2) Milling Machine: This machine was used for the cutting of the keyway on the grater shaft.

3) Lathe: This was used for an extensive array of precision works also such as boring, turning, facing of the assembly parts.

4) Hand Grinding\Cutting Disc Machine: This is hand held and it comes in two sizes. The disc comes in the sizes 9", 7", or 4" diameters. The 7" disc was used for cutting and grinding.

5) Welding Machine: It is used in conjunction with electrode and tong for joining two or more metals together. It was used with mild steel electrode when welding the mild steel. Welding can either be tacking (which can be easily broken) during setting, stitching, (which can be used to hold thin metals (1mm metal sheets together firmly) or running (which is used for thick metal plates, 3mm). The mild steel electrode of gauge twelve (2.5mm diameter) was used. Welding glasses (dark) was used when working.

6) Bending Machine: It is used for bending sheet metals up to 5mm thick at different desired angles. It was used for bending the 3mm grater sheets at 130^0.

7) Table Shear: It is big and heavy. It was used for cutting plate less than the 3mm and 4mm sheet, and it gives a straight cut edge unlike the hand cutting disc.

8) Pedestal Grinding Machine: It was used for sharpening the tools, work piece drill bits.

RESULTS AND DISCUSSION

<u>Cassava Grater Drawings</u>

Engineers use CAD to create two- and three-dimensional drawings, such as those for automobile and airplane parts, floor plans, and maps and machine assembly. While it may be faster for an engineer to create an initial drawing by hand, it is much more efficient to change and adjust drawings by computer.

In the design stage, drafting and computer graphics techniques are combined to produce models of different graters. We manipulate these models on video display screens until they incorporate the best balance of features, including ease of production and cost. Using a computer to perform the six-step 'art-to-part' process:

- The first two steps in this process are the use of sketching software to capture the initial design ideas and to produce accurate engineering drawings.
- The third step is rendering an accurate image of what the part will look like.
- Next, engineers use analysis software to ensure that the part is strong enough.
- Step five is the production of a prototype, or model.
- In the final step the CAM software controls the machine that produces the part.

During the design of the machine, the drafting software I used was AUTOCAD 2007 version. This was used to draw the orthogonal views, Isometric views and exploded drawings of the model cassava grater before the commencement of the fabrication processes.

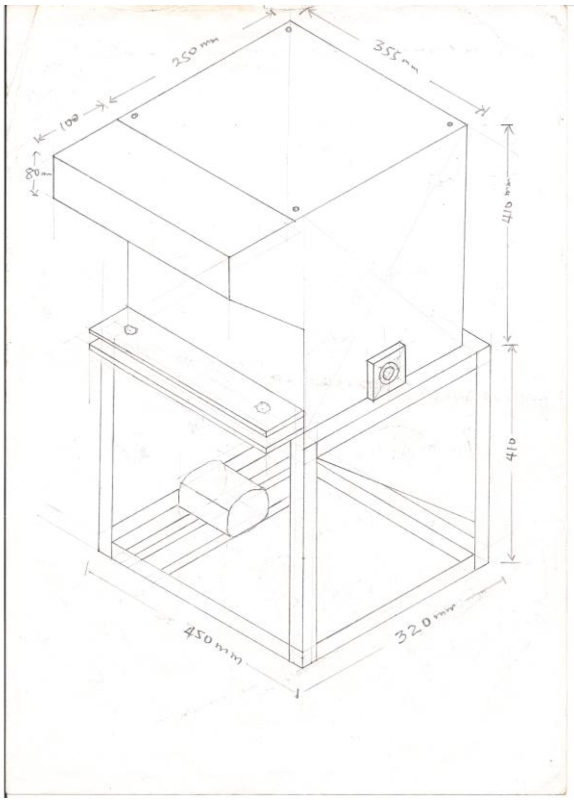


Figure 3: Isometric Drawing of Cassava Grater Fabricated.

PERFORMANCE EVALUATION

There are several methods of testing for the efficiency of machines but with respect to this small-scale cassava grater, the following method for efficiency of the cassava grater was examined as follows:

(i) Employing existing wooden grating drum grater that is prevalent for grating taking the weight of the cassava being grated and the time taken to grate this size. 50g was considered for this method

(ii) Tests were also carried out on constructed machine using 50kg of cassava for five different batches. The time taken for each batch was accurately checked and recorded.

Each tuber of cassava was weighed and the weight of the whole batch of cassava obtained. The following measuring parameters were obtained and compared with the results of tests on the constructed machine.

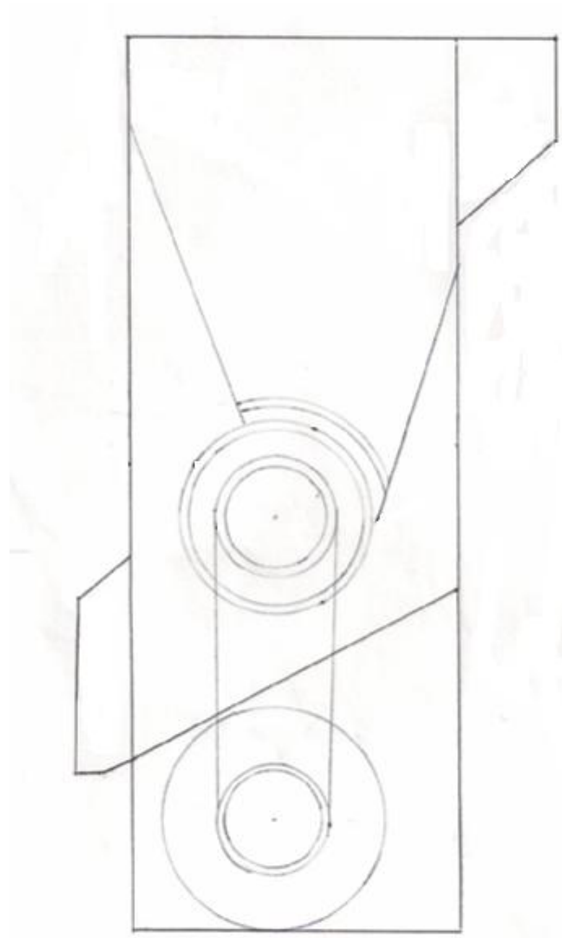


Figure 4: Front View of Cassava Grater.

Table 2: Indicating the Number of Loading and time taken for each loading in order to Evaluate Performance of Existing Machine.

Number of Loading	Mass of Cassava	Time Taken to Grate Loading
First Loading	1.95	
	1.55	
	1.98	
	2.02	
	1.75	
	1.75	
	1.58	
	1.90	
	1.42	
	1.88	
	1.78	
Total	19.56	2 min 58 secs

Rate of Cassava Grating (η_r)

This is quotient of the weight (Tonnes) of cassava extracted per hour.

For existing machinery,

$$\eta r = \frac{Weght\ of\ Cassava\ Grated\ (kg)}{Time\ Taken(Hrs)} \qquad \textbf{(xv)}$$

$$= \frac{[19.56 + 16.65 + 18.77]\ 3600(kg)}{[168 + 151 + 178](Hrs)}$$

= 390.4kg/hr

$$= \frac{[51.6]3600(kg)}{[1169](Hrs)}$$

=158.9kg/hr

Table 3: Cost Analysis of Cassava Grater.

S/N	Description	Size	Quantity	N
10	Electric Motor	1hp,1440rpm, single phase		11000
12	Bolts and Rivets	Drilling bit 5mm rivet and M6(13mm)-13pcs M10(17)-12pcs M12(19)-3" length—2pcs	2	100 250 1600
13	Electrode			1200
14	Cutting Disc Grinding	9" 7'	2 1	500 300
15	Painting(Red oxide, Cellulose)			2000
16	Flange bearing Carrier	4mm thick plate.8" dia	1	400
	Total			33,100

CONCLUSION

The home use/small scale cassava grating machine was designed, fabricated and tested. It was found to be effective and efficient and could grate about 158.9kg/hr.

This machine can be used at home-scale for domestic applications and it is affordable since the cost of production is low which will reduce during large scale production.

Based on the construction materials selection and quality of fabrication work, the machine is durable and expected to last for about 10years.

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