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Full Length Research

Empirical Investigation on the Design and Fabrication of Cassava Grating Machine of 4.5kw

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Abstract: Cassava products has been diversified ranging from one product to another, such as the use of cassava in livestock feed, means that more maize and other feed materials used in the past can now be available for other uses. Diverse uses of cassava flour food products such as its glucose for pharmaceuticals products as well as food supplements, and to make alcohol and other beverages, would enhance farmers to cultivate more because of its financial benefits. There is a gap between industrial processors and producers of cassava products that must be strengthened. The Federal government of Nigeria's mandate to include 10% HQCF (High Quality Cassava Flour) flour in all products of wheat flour for bread-making has led to farmers and food processors demanding equipment and machinery to increase production. The aim of this research is to design and fabricate a cassava grating machine of 4.5kw and to carry out performance evaluation of the machine which met the objective of effective grating replacing the wooden grating machines. The materials were sourced locally which led to cost effectiveness of the machine. After, the machine was designed and fabricated, the performance evaluation of the machine was tested, the feed rate and grating rate were obtained as a function of time. The average feed rate of the machine was found to be 30kg/min which gave an input capacity of 1800kg/hr. Authors reported that it takes 1 hour to completely grate 740kg of cassava tubers.

Keywords: Power Transmission: Tacking: Stitching: Rotational Torgue: Speed Transmission: Design Calculations: Tabe Shear: Bending Machine: Welding machine.

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1.0 Background of the Research

Cassava originated from Latin America and thereafter was introduced to Asia in the 17th century and to Africa in about 1558 (Bamiro, 2007; Ajagba, 2018). In Nigeria, cassava is mostly grown on small farms, usually intercropped with vegetables, plantation crops, yam, sweet potatoes, melon, maize, cucumber, cocoa yam, Okra and even Yam. Cassava is planted 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 (Bamiro, 2007). Cassava products has been diversified ranging from one product to another, such as the use of cassava in livestock feed, means that more maize and other feed materials used in the past can now be available for other uses. Diverse uses of cassava flour food products such as its glucose for pharmaceuticals products as well as food supplements, and to make alcohol and other beverages, would enhance farmers to cultivate more because of its financial benefits (Kolawole, 2007; Olusesi & Joshua, 2022b). There is a gap between industrial processors and producers of cassava products that must be strengthened. The Federal government of Nigeria's mandate to include 10% HQCF (High Quality Cassava Flour) flour in all products of wheat flour for bread-making has led to farmers and food processors demanding equipment and machinery to increase production. The Raw Materials and Research Development Council (RMRDC) of the Federal Ministry of Science and Technology has organized stakeholders' workshop on cassava research and development with discussions centered on increasing technology for cassava production, processing and export. The need to develop adaptable machinery for cassava production and processing has become increasingly important (Fajemilehin & Jinadu, 1992).

Constraints to cassava processing include the absence of efficient equipment; appropriate processing technologies, machines, and tools. These are not easily affordable and sometimes unavailable at the farm level. The currently available ones were merely fabricated without thorough engineering research. Presently, the equipment available is the grater, dryer, and dewatering machines with the absence of frying machines. Some success was recorded with graters and some dewatering tools. The dewatering tools work in batches while factories need a continuously-working machine for better production. Almost all the processing of cassava requires the roots to be peeled at one stage or another, and no efficient peeler is on the market. One of the greatest constraints to cassava processing is drying, which takes up to four days to complete when using sunlight; the available dryers are expensive beyond the famers' means (Bamiro, 2007).

Significant market opportunities for cassava have opened up 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 (Olusesi & Joshua, 2022a). Cassava roots compete with other carbohydrate sources, especially maize and sorghum, on the basis of the price, nutritional value, quality and availability. Ajagba (2018) posited that 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 at35-40%, giving optimum rates of 25:1 (*Olumide, 2004*). The potential disadvantages of cassava roots are their bulk and rapid perish ability, their low protein content, and the presence of cyanide in all root tissues, having about 70% moisture content. Grating is the transformation of cassava tubers into pulp. Usually, peeled cassava is fed into the hopper then to the grating drum which rotates at a constant speed. The most common graters are made of the horizontal axis cylinder with serrated metal surface. The abrasion action of the cylinder surface grinds against the cassava roots and reduce them to a mash (Olumide, 2004).

These are owned by individual contractors who grate at a fee or by a group of processors and require 1-6Hp engines. The major intervention in cassava processing was the introduction of a medium-scale motorized cassava grater by the Agricultural Engineers Ltd in 1966 (Sanni, 2004; Ajagba, 2018) .The cassava grater presented a great innovation in cassava processing since grating is central to traditional processing of cassava in Ghana. Since then, several equipment manufacturers including engineering firms, research institutes, university departments, small-scale artisanal shops, blacksmiths and mechanics have developed and produced various types of cassava processing equipment (FAO, 2005). Mechanized graters have therefore shifted labor constraints from grating to the labor intensive tasks of harvesting, peeling and roasting, hence eliminating the fermentation process of cassava (FAO, 2008).

2.0 Design Consideration

The machine was designed to be efficient durable, portable and also cost effective during use in the household as well as safe and easily operated.

Table 1: Material Used In the Construction of the Cassava Grating Machine

S/N	Quantity	Component	Size/Model	Materials Used
1	1	Hopper	0.2mm	Mild Steel
2	1	Drum	0.2mm	Mild Steel
3.	1	Pulley	0.18m	Steel plate
4.	1	Internal Combustion Engine	6.5HP	
5.	1	Shaft	10-10mm	Mild Steel
6.	11	Bolts and nuts	M13 and M17	Mild Steel
7.	1	Discharge	0.2mm	Mild Steel
8.	4	Frame	0.5mm	Mild Steel
9.	1	Belt	42mm	Alloy Rubber
10.	1	Perforated Mesh	0.1mm	Steel Plate
11.	2	Handle	1mm	Mild steel
12.	2	Bearings	6204	Cast Iron
13	10	Rivet pins	Drive type	Stainless steel
14	1	Cover	0.2mm	Mild Steel

3.0 Description of Machine Parts

The machine was constructed with the following components:

3.1 The Hopper

This is the admission unit through which the cassava is admitted into the machine for grating. It has a rectangular plan which tappers gradually. Volume of the hopper is calculated using the following formula:

$$\text{Volume, } V = \left(\frac{1}{2}(a+b)H\right)L \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where,

$a =$ width of the hopper,
b = breadth of the hopper,
$H =$ height of the hopper and
$L =$ length of the hopper.

The cassava is fed into the machine through the hopper.

3.2 The Grating Unit

This unit consists of the shaft, perforated mesh, rolled sheet, circular disc and rivet pins. The drum was formed by the shaft passing through the rolled cylindrical sheet and it was welded in place by circular discs. This drum is then wrapped with the perforated mesh; they are attached by riveting which forms the grating drum.

3.3 The Main Frame

The main frame was constructed with angle iron. The angle irons are welded together to form the frame work. The welding provided very rigid joints. This is in line with the modern trend of providing rigid frame. This provides the strength and rigidity for the overall machine. $1^{1}/_{2}$ inch by 1½ inch angle iron was use

3.4 The Internal Combustion Engine

Internal Combustion engine was used to power the grating machine. A reduction pulley system is used to transmit power to the grater's drum at reduced speed and increased torque. This helps the drum to exhibit rotary motion, hence grating the cassava. This is the prime Mover of the cassava grating machine (See Table 2).

3.5The Discharge Unit

This directs the flow of grated cassava (Pulp) to a receptacle bowl. It is the continuation of the hopper. A shaft is a rotating machine element used to transmit power from one place to another. The power is transmitted by some tangential force and the resulting torque set up within the shafts permits the power to be transmitted from the Internal Combustion Engine of the machine or its elements linked up to the shaft. In other to transmit the power from the shaft to various parts of machine element, such as pulley, drums, and bearings, are mounted on the shaft. The members along with the force exerted cause the shaft to bending, hence exposing the shaft to bending moment and shearing forces.

Model	**182F(E)**
Type	OHV25
Bore$\times$ $Stroke\,(mm)$	82$\times$ 64
Displacement (ml)	337
Compression ratio	8:1
Rated Output kw/3000rpm	7
Max Torque N/m	23.5
Ignition System	Magneto
Starting System	Recoil
Cooling System	Air cooled
Fuel Tank Capacity (L)	6.5
Oil Capacity(L)	1.1
Fuel Consumed g/kw/h	1.1
Oil Consumed g/kw.h	1.1
Oil Trade Mark	SAE 40
Idle Speed (rpm)	1350
Size L$\times$ W $\times$ $H(mm)$	405$\times$ 450 $\times$ 445
Dry Weight (kg)	31(34)
Rated power (hp)	6.5

Table 2: Principal Technical Specification of the Internal Combustion Engine (Elegmax Manual) Force Exerted on the Shaft (Vertical force)

The machine element that exerts force on the shaft is belt, driven pulley, the internal Combustion engine and the grating drum.

Weight of pulley, $w_p = m_p g$ ……………………………..(3)

Where, m_p = Mass of the pulley in Kg

g = acceleration due to gravity (9.81)

Weight of Drum $w_d = \rho v g$ ……………..………..………(4)

Where $_1$ = (Volume of the two circular plates + Volume of the of the rolled steel sheet + volume of the perforated Mesh).

Where ρ = density of the material.

For Mild Steel $\rho = 7680\,kg/m^3$

4.0 Methodology

The methodology involves the use of Machineries and Machining processes to achieve the desired design for the cassava grating machine.

4.1 Machineries

4.1.1 Milling Machine: This machine was used for cutting of the keyways on the grater shaft. The primary function of this machine during fabrication was to create a keyway for the passage of the grater shaft through the grating drum.

4.1.2 Drilling Machine: This involves hand drilling machine. The machinery was used for drilling purposes. The work is stationary, while the spindle carrying the drill chuck and bit move. The work must be held with a vice during drilling. This machine was used to drill holes for the passage of bolts used to hold the engine sittings and also to align the hopper.

4.1.3 Welding Machine: This was used in compliance with an electrode and tong for joining two or more metals together. It was used with mild steel electrode when welding the machine.

4.2 Welding Processes Used During the Grater Fabrication

4.2.1 Tacking: This involves the joining of the skeletal parts of the machine which can either be broken if it does not meet the requirement. It is the first step of the welding process which involves setting of the machine before adequate welding.

4.2.2 Stitching: This process is used to hold thin metals together firmly. It was used in fabrication of the grating hopper.

4.2.3 Running: This is used for holding thick metals firmly together. Welding shield or goggle was used for safety of the eyes. This process was used in the joining of angle iron with other metals during the fabrication of the machine.

4.2.4 Bending Machine: It is used to bend sheet metals up to5mm thick at different desired angles. This machine was employed in the bending of the roller drum and the lower base of the hopper.

4.2.5 Table Shear: This machine was employed to cutting the metal plates used in fabrication of the Cassava grating machine.

4.2.6 Pedestal Grinding Machine: This is used for sharpening the tool, and work piece used in the fabrication of the machine such as drill bit.

4.2.7 Hand Cutting and Grinding Disc Machine: This is used for cutting and grinding metals. After welding of the machine, the grinding disc was employed to produce more quality finishing of the machine.

4.3 Design Analysis and Calculation

4.3.1 Design Calculations: The design consideration for the fabrication of the cassava grating machine is producing a machine that can be easily assembled or dissembled and grate the cassava effectively. The grating drum is made up of metal to increase durability; the chute is inclined to allow force of gravity to act on the discharge of the cassava pulp.

4.3.2 Hopper Design: The hopper is designed on thel basis of a rectangular cross section of which the volume is obtained as follows:

$$V = l \times b \times h \quad \text{...} (5)$$

$$V = 0.78 \times 0.557 \times 0.37$$

$$V = 0.074 m^3$$

Where, V = volume of the hopper;

l = length of hopper;

b = breadth of the hopper and

h = height of the hopper.

The mass of the Hopper is given as follows:

$$m = \rho \times V \quad \text{..}(6)$$

Density of mild steel = 7860kg/m^{3} [llll]

$$m = 7860 \times 0.074$$

$$\text{m} = 583.65 kg$$

Where ρ = density and V = Volume.

4.3.3 Grating Drum Design: The primary design of the grating drum is a cylindrical shape and is given by:

$$V_g = \pi r^2 l \quad \text{..}(7)$$

Where,

V_g = volume of grating drum

r = radius of the cylinder, and

l = Length of the cylindrical drum.

Data given,

$\pi = 3.142$
$r = 0.05m$
$l = 0.34m$

Now,

$$V_g = 3.142 \times 0.05^2 \times 0.34$$
$$V_g = 0.0027m^3$$

The force acting on the cylindrical drum is given as follows;

$$F = V_g \times \rho \times g \quad \text{..(8)}$$

Where g = acceleration due to gravity

$$F = 0.0027 \times 7860 \times 9.81$$
$$F = 208.19N$$

4.3.4 Speed Transmission: From the internal Combustion Engine, (I.C.E), an Engine of $6.5hp$ was selected with a motor speed of $3000rpm$ which when converted to Kilowatts gives about $4.8kW$.

The pulley and the motor constitutes the transmission system. Both are reducing by a speed ratio of 1:3

d_1 = Diameter of the driver pulley

d_2 = Diameter of the driven pulley

Speed ratio $= \dfrac{d_1}{d_2}$,

where $d_1 = 0.06m$ and $d_2 = 0.18m$

Speed ratio 1:3

From the Internal Combustion Engine manual, an Engine of 6.5hp was selected with a motor speed of 3000 rotations per minute (rpm) which when converted to kW is equal to 4.85kW.

$1hp = 0.746kW$

Hence, $6.5HP = 4.85kW$

4.3.5 Power Transmission: The ratio between the velocities of the electric motor (driver pulley) and the grater pulley (driven pulley) is calculated mathematically as follows:

N_1 = Speed of the driver pulley in rpm = $3000rpm$

N_2 = Speed of the driven pulley in rpm = $1000rpm$

Length of belt that passes over the driver in one minute, L_1

$$= \pi N_1 d_1 \quad \text{... (10)}$$
$$= 3.142 \times 3000 \times 0.06$$
$$= 565.6m$$

Length of belt that passes over the driven pulley in one minute, L_2

$$= \pi N_2 d_2 \quad \text{... (11)}$$
$$= 3.142 \times 1000 \times 0.18$$
$$= 565.6m$$

Hence, length of the belt that passes through the driven pulley is equal to the length of the belt that passes through the driver pulley, therefore

$$N_1 d_1 = N_2 d_2 \quad \text{..(12)}$$

4.3.6 Determination of Centre of Distance: According to (R.M.A.I) Rubber Manufacturing Association International, the center of distance can be calculated by using the following considerations.

For Speed ratio less than 3,

$$C = \frac{d_1 + d_2}{2} + d_1 \quad \text{..(13)}$$

For Speed ratio greater than 3,

$C = D$

Hence,

$$C = \frac{0.06 + 0.18}{2} + 0.06 = 0.18m$$

4.3.7 Length of Belt: The length of belt can be calculated using the following formula:

$$L = \frac{\pi\left(d_1 + d_2\right)}{2} + 2C + \frac{2\left(d_1 - d_2\right)}{4C} \text{ ……………………. (14)}$$

Where,

$C =$ Distance between the center of the two pulleys

$L =$ Length of belt required.

$$L = \frac{3.142\left(0.16 + 0.18\right)}{2} + 2 \times 0.21 + \frac{2\left(0.16 - 0.18\right)}{4 \times 0.21}$$

$$L = 0.42\,\mathrm{m}$$

4.3.8 Angle of Contact on Driver Pulley: This is the lap angle of the belt over the Internal Combustion Engine. It was calculated as follows:

$$\theta = \left(180 - 2\alpha\right)\left(\frac{\pi}{180}\right) rads \text{ …………………………….(15)}$$

Where

$$\alpha = \sin^{-1}\frac{d_1 - d_2}{2C} \text{ ……………………….………….(16)}$$

$$= \sin^{-1}\frac{0.18 - 0.06}{2 \times 0.18} = 19.5^{\circ} \approx 20^{\circ}$$

$$\theta = \left(180 - 2 \times 20\right)\left(\frac{\pi}{180}\right) 0.0175$$

$$\theta = 2.45 rads$$

According to Hannah and Stephens, the Centripetal force acting on the pulley is given by:

$$F_a = \frac{MV^2}{R} \text{ ……………………………………….……… (17)}$$

Where,

$$V = \frac{2\pi d_1 N_1}{60} \text{ ………………………………….……..(18)}$$

$$V = \frac{2 \times 3.142 \times 3000}{60}$$

$$V = 18.8 m/s$$

$$F_a = \frac{1265 \times 18.8^2}{0.06 \times 1000}$$

$$F_a = 7451.0kN$$

4.3.9 Rotational Torque (T): The torque developed by a rotational body is given by calculating the product of the force causing motion multiplied by the radius of rotation.

Power rating; $1hp = 746watts$

$$T = \frac{746 \times 60}{2\pi N} \text{ ……………………………………….……. (19)}$$

$$= \frac{746 \times 60}{2 \times 3.142 \times 3000}$$

$$= \frac{44760}{18852}$$

$$= 2.374 kN/m$$

Power developed by a torque moving at angular velocity $\omega \; rads/sec$ (Output power) is given by:

$$P = \frac{2\pi NT}{1000 \times g} \quad \text{...(20)}$$

$$P = \frac{2\pi NT}{1000 \times 9.81}$$

$$P = \frac{2 \times \pi \times 3000 \times 2.374}{1000 \times 9.81}$$

$$P = 4.56kW$$

The power needed to grate cassava is dependent on the moisture content of the cassava, the size of the cassava and also the mass of the cassava. Hence, considering this factors, cassava of any size with any force can be overcome. The collection and grating efficiency were obtained as a function of percentage with the following formulae.

$$H = \frac{d}{a} \times 100\% \quad \text{...(20)}$$

$$I = \frac{e}{a} \times 100\% \quad \text{...(21)}$$

Where H = collection efficiency,
I = grating efficiency,
d = collected mass of sample (kg),
g = completely grated mass of sample,
a = mass feed of sample (kg).

Feed rate, $F = \frac{a}{b}$ and Grating rate, $g = \frac{a}{c}$

Fig.. 1 Assembled Cassava Grater

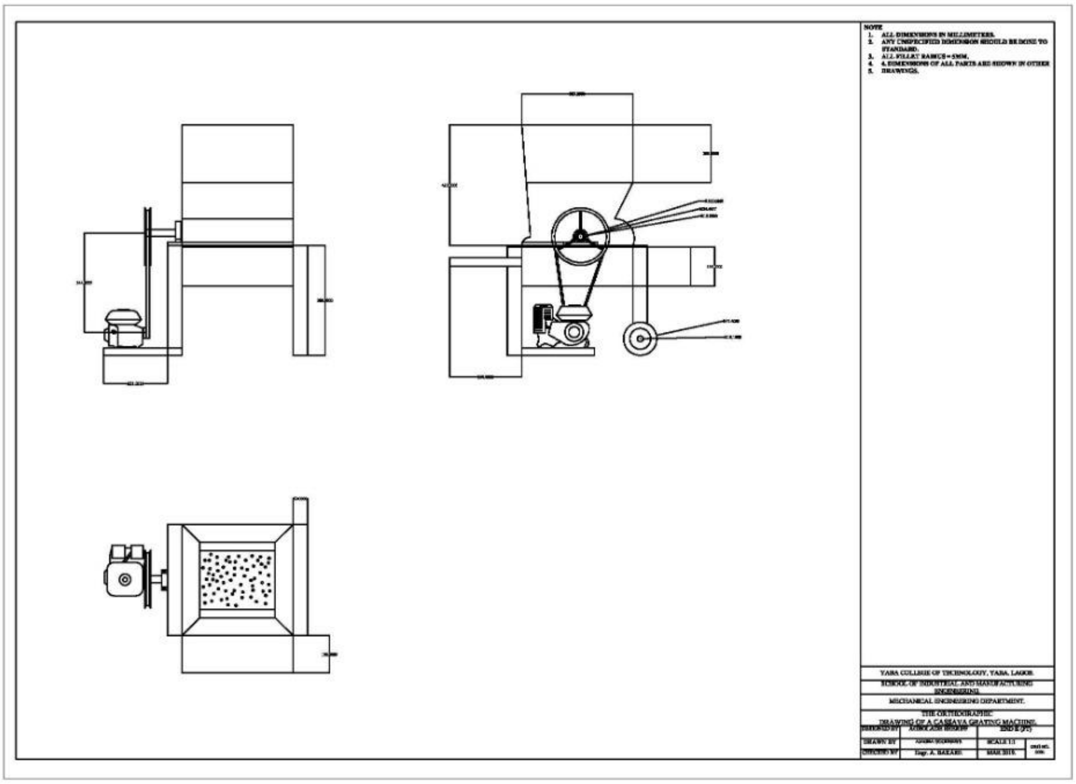

Fig. 2 Assembled Design of Cassava Grating Machine

5.0 Conclusion of the Research

The aim of this research was to design and fabricate a cassava grating machine of 4.5kw and to carry out performance evaluation of the machine which met the objective of effective grating replacing the wooden grating machines. The materials were sourced locally which led to cost effectiveness of the machine. After, the machine was designed and fabricated, the performance evaluation of the machine was tested, the feed rate and grating rate were obtained as a function of time. The average feed rate of the machine was found to be 30kg/min which gave an input capacity of 1800kg/hr. Authors reported that it takes 1 hour to completely grate 740kg of cassava tubers. The machine was designed, fabricated and tested. The result of the experiment showed that the weighed samples of 10kg, 20kg, 30kg, 40kg and 50kg cassava were used to carry out the performance evaluation of the machine. The average feed rate of the machine was found to be 30kg/min which gives an input capacity of 1800kg/hr. It takes 2.15 minutes to completely grate an average of 26.52kg of cassava that is about 740kg of cassava completely grated per hour. This indicates effective grating with average grating and collection efficiency of 86.1% and 93.25 respectively. With these results, it could therefore be concluded that aims and objectives of the project have been meet. The fabricated cassava grating machine was tested and found to be effective and efficient in performance. The authors in this study recommended that for mass production of the machine, stainless steel is preferable to mild steel to reduce corrosion of the machine and food poisoning.

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