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DESIGN, FABRICATION AND EVALUATION OF MOTORIZED CASSAVA MESH SIEVING MACHINE

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Abstract
The sieving operation occupies an important position in the effective transformation of cassava into fine 'garri' flakes however, the traditional sieving operation consumes time and energy which necessitated the design of an appropriate mechanical device. The method of operating any existing 'garri' sieving machine was realized to be inefficient and laborious like the traditional manual method. In order to solve this problem, the need thus arises to develop a better sieve that would not only remove the drudgery associated with it but also increase the output per hour to meet the high demand of 'garri'. The aim of this study is to design, fabricate carry out the performance evaluation of the machine. Some design criteria considered include durability, portability, and safety of operations. The components designed include; the sieve bed, screening material, shaft, pulley belt, hopper and power source. Cassava tubers were peeled, washed, grated, and fermented pulverized and frying. The machine was evaluated by varying the speed of operation (350, 400, 450rpm). The electric motor-powered sieve was tested at speeds of 350, 400 and 450 rpm. After sieving, sample of sieved 'garri' was used to determine its fines modulus using Tyler series analysis method. The throughput capacity and sieving efficiency were also calculated. At a speed of 350 rpm the sieve has the highest output capacity of 80.16 kg/hr with sieve efficiency of 92.01%. As the speed of the machine increases, the output capacity decreases.

Keywords
Sieve,
Cassava,
Throughput capacity,
Efficiency,
Speed.

1. INTRODUCTION

The need to design and develop efficient and cost-effective machines and equipment for cassava processing and handling operations cannot be overemphasized, given the present global status of the crop as a foreign exchange earner, a crop for food security and an important industrial raw material. Cassava (Manihot esculenta Crantz) is almost entirely produced and consumed in both developed and developing countries. It is highly productive, tolerant of poor soils, periods of drought and is relatively disease-free and pest-resistant. It provides a major source of energy for over 500 million people world-wide (Sulaiman and Adigun, 2008; FAO, 2002; Anywanu et al., 2021). Cassava is diversified into different food products and these products are available all year round thus making cassava an important staple food for many rural households in Nigeria (Adetunji and Osunlana, 2011; Hauser et al., 2025). Cassava is important, not only as a food crop but even more so as a major source of income for rural households. Nigeria is currently the largest producer of cassava in the world with an annual production of over 303 million tonnes of tuberous roots. (Eze et al., 2023) Cassava is largely consumed in many processed forms in Nigeria. Its use in the industry and livestock feed, is well known, but is gradually increasing, especially as import substitution becomes prominent in the industrial sector of the economy. As a cash crop, cassava generates cash income for the largest number of households in comparison with other staples. It is produced with relevant purchased inputs as frequently as and in some cases more frequently than other staples. A large proportion of total production, probably larger than that of most staples, is planted annually for sale (Olusegun and Ajiboye, 2009; Peter et al., 2010) 'Garri' is the most popular of the Cassava products in Africa (IITA, 2004. Forkum et al., 2025). It is a creamy-white, granular flour with a slightly fermented flavor and a slightly sour taste made from fermented, gelatinized fresh cassava tubers (ARS, 2012). After the processing operations such as peeling, washing, grating fermenting, dewatering, pulverization and frying. The next operation in the production chart is sieving in order to obtain fine 'gari' which pass through the sieve, it separates the coarse unwanted particles (oversize) which are discarded after each batch of sieving. Cassava tubers, after peeling, washing, grating, fermenting, dewatering, pulverization and frying, the next operation is sieving which is done in order to obtained fine 'garri'. Sieving is not only reducing the lump into fine particles (undersize) which pass through the sieve, it separates the coarse unwanted particles (oversize) which are discarded after each batch of sieving. Adetunji and Osunlana (2011) (Adetunji and Osunlana 2013) previous design, it was discovered that the speed of the reciprocating shaft of the sifter was too high, which led to spilling of the garri instead of sieving. It observed that sieving is one of the major problems of 'garri' processing over the years. From the previous design, it was discovered that the speed of the reciprocating shaft of the sifter was too high, which led to spilling of 'garri' instead of sieving it (Adetunji and Osunlana, 2011). In the traditional setting, this operation is accomplished using cane or raffia sieve. The craftsmen, who produce the sieves, set the aperture size by guess work or arbitrarily without consideration to the effect the size will have on sieving speed and the operator's comfort. The traditional sieving method is associated with waist pain resulting from the operators sitting position which involve bending and stretching, irritating sensation resulting from friction of rubbing. The process consumes time. For instance, to sieve a 30 kg worth of dewatered cassava mash may take about 60 to 90 min. This can translate to several hours in case of large-scale production. Therefore, this study aims at developing 'garri' sieving machine that will remove the bottleneck associated with sieving of fried 'garri'.

2. MATERIALS AND METHOD

2.1. Materials and Sample Preparation

Fresh cassava tubers were purchased from Sango Market, Saki, Oyo State, Nigeria. The criteria for the selection of the tubers were purely on visual observations in terms of being free from mechanical damage, rotten and free from foreign materials. The tubers were manually peeled, washed with clean water and grated to fine cassava mash. The grated cassava mash was bagged and placed on hydraulic press for dewatering process, thoroughly pulverized and then fried into 'garri' powder.

2.2 Design Analysis

2.2.1 Design consideration

The following design criteria were considered

i. The machine is constructed so that it can be easily dismantled.
ii. The sprocket and chain drive arrangement is used, coupled along with a flywheel to ensure high torque.
iii. Sieving Tray is used to ensure that all the materials pass through in order to pulverized and avoid minimum wastage.
iv. The stand of machine has a wide base to increase stability of the machine both at the peddling section and that of the main frame.
v. The chute is sloppy, so that the filtrate can slide downward and discharge by gravity. Above all, the design of the machine is considered to be cheap and of high economic viability when produced in mass production.

2.2.2 Shafts design

The power delivered by a shaft is calculated using the equation described by Olawale and Olaide (2013)
Where:

$$P = F \times V \quad (1)$$

P = Power (Nms^{-1})

F = Force of sifting (N) and

V = velocity (m/s)

2.2.3 Determination of the bending moment at each point of loading

This involves the preparation of the bending moment diagram on the two perpendicular planes: vertical and horizontal.

$$D_t = density\ of\ steel\ plate = 7930\ kg/m^2$$

$$V_t = l \times b \times h = 0.5 \times 0.5 \times 0.12 = 0.03m^3$$

$$W_t = 0.03 \times 7930 \times 9.81 = 2334N$$

$$M_p = mass\ of\ the\ pulley\ in\ kg$$

= Mass of the two small bearings + Mass of the two big bearing + Mass of the perforated mesh, and

Mass = Density of materials x volume of the materials = ρV

g = Acceleration due to gravity

Mp = (4 kg + 10 kg + 2.379 kg) = 16.379kg

Weight of pulley (Wt) = $M_p\ x\ g$

$= 16.379 \times 9.81 = 160.68N$

2.2.4 Design of hopper

The volume of rectangular hopper was calculated as:

$$V = L \times B \times H \tag{2}$$

Where:
L = Length (mm) *B* = Breadth (mm) *H* = Height (mm)

2.2.5 Pulley design

The ratio between the velocities of the electric motor/driver pulley and the driven pulley may be expressed mathematically as discussed below.

D_e = diameter of the driver pulley
D_d = diameter of the driven pulley
N_e = Speed of the driver, rpm
N_d = Speed of the driven, rpm

$$L_1 = \pi D_e N_e \tag{3}$$

$$L_2 = \pi D_d N_d \tag{4}$$

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 (Olawale and Olaide, 2013)

$$D_e N_e = D_d N_d \tag{5}$$

Therefore,

$$N_d = \frac{D_e N_e}{D_d}$$

L_1 = length of the belt that passes over the driver, in one minute
L_2 = length of the belt that passes over the follower in one minute

2.2.6 Belt design

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

$$L = \frac{(D_d + N_e)}{2} + 2x - \frac{(D_d + d_e)}{4x} \tag{6}$$

D_e = diameter of the driver pulley
D_d = diameter of the driven pulley
X = Centre Diameter
L= Length of the Belt Require
Where:

$$X = \frac{D_e + D_d}{2} + D_1 \tag{7}$$

2.2.7 Power design

The power p, in kw require to operate the machine was estimated using

$$P = Ww^3 r^2$$

$$P = \left(\frac{2\pi N^3}{60}\right) r^3 \tag{8}$$

Where:
W= mass of the pulley, kg w = angular velocity,
R= ratios of the pulley
N= number of revolutions per minute P= power

2.2.8 Pulley belt contact angle

The pulley belt contact angle θ was evaluated using the expression as in *(ASME, 1995)*
Using the expression

$$\theta = 180 + \frac{D_d - D_e}{2} \tag{9}$$

2.3 Fabrication Procedure

(i) Measurement and marking out of the required dimensions
(ii) Cutting of the marked-out component part
(iii) Bending and welding of the components
(iv) Drilling Grinding of the welded parts for a good finishing.

(v) Assembling of the components.
(vi) Painting to avoid rusting

2.4 Working Principles

The machine is basically powered by an electric motor, using belt and pulley system for transmission, which turns the worked camshaft. The motion is further transmitted to the tray thus providing the forward throw while the spring returns the load on the backward throw. The to and fro movement of the machine cause the sieving operation

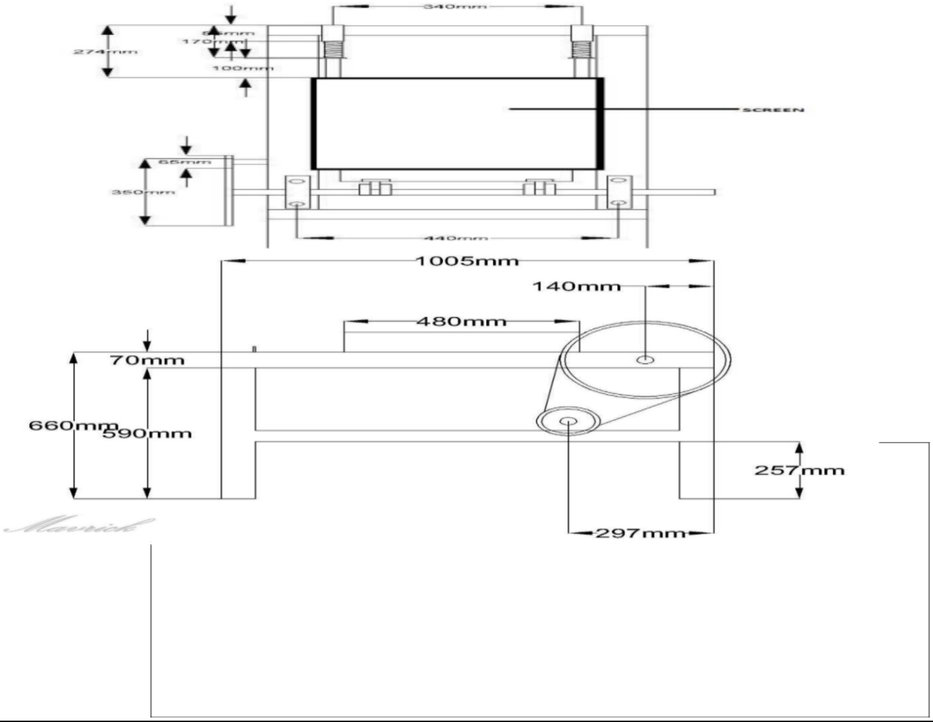

Plate 1: Pictorial view of the fabricated garri sieving machine

2.5 Test Procedure

Cassava tubers were bought from a local market in Saki. The tubers were peeled, washed, grated, fermented, dehydrated and frying into garri. The electric motor powered garri sieve was tested at speeds between 350, 400 and 450 rpm. 1, 2 and 3kg of garri were weighed in three replications. After sieving, sample of sieved garri and the gangue used to determine its fines modulus using Tyler sieves analysis method. The throughput capacity, output capacity and the sieving efficiency were also calculated.

2.5.1 Determination of sieving efficiency (%)

$$EF\ (\%) = \frac{w_1 - w_2}{w_1} \times 100\% \quad (10)$$

Where:

$EF = Sieving\ efficiency\ (\%)$

$Wg = Weight\ of\ the\ sieved\ garri\ (kg)$

$Wt = Initial\ weight\ of\ the\ garri\ before\ sieving\ (kg)$

2.5.2 Determination of output capacity (kg/hr)

$$Q_c = \frac{W_c}{T}$$

Where:

Q_c = Output capacity (kg/hr)

Wc = Weight of sieved garri (kg) and

T = Time of Sieving (hr)

3. RESULTS AND DISCUSSION

3.1 Performance Evaluation of Garri Sieving Machine

The Machine was tested at operating speeds of 350, 400 and 450rpm respectively using garri samples of 1, 2 and 3 kg respectively in three replicates. At speed 350 rpm and 26% M.C, the machine has the highest output capacity of 80.16 kg/s with sieving efficiency of 92.01%. As the speed of the machine increases the output capacity decreases. It implies that some of the garri that were supposed to be sieved has been conveyed along with the residue because the operating speed was too high for the sieving unit to adequately sieve the garri, thus, leading to decrease in quantity of the garri sieved.

3.2 Efficiency of the Sieve

A total of 60.98 kg of garri powder was used to evaluate the performance of the machine and the following results were obtained:

$w_t = Weight\ of\ total\ garri = 60.98\ kg$

$w_g = Weight\ of\ gangue = 4.87 kg$

$Time\ taken: 119s = 1.98 min$

$$Efficiency = \frac{w_t - w_g}{w_t} \times 100\% \quad (11)$$

$$Efficiency = \frac{60.98 - 4.87}{60.98} \times 100\% = 92.01\%$$

3.3 Output Capacity

$$Q_c = \frac{w_c}{T} \quad (12)$$

$$= \frac{5611.3}{70}$$

= 80.16 kg/s

4. CONCLUSION

The commercial based garri sieving machine was designed, fabricated and tested. It was found to be effective and efficient. This machine can be used for commercial purposes and it is affordable like the cassava milling machine with high scale production. This machine is an improvement on the traditional methods of sieving fried garri. The motorized garri sieve was observed to perform efficiently at all the sifting speed when compared with local sifter with high economic value.

The fabrication of garri sieving machine can be further improved and modify to increase its efficiency and output capacity by; making a rubber seal in-between the edge of the concave cover and the sieving chamber.

The receiving outlets should be folded to help gather the sieved materials effectively. It should also be produced in large quantity to make it cheaper and affordable to local farmers.

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