Development and Performance Evaluation of a Motorized Garri Siever

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Abstract
A motorized garri siever was designed, constructed and evaluated for its performance. The design of this system was achieved by synthesizing the manual (traditional) sieving method using a combination of mechanisms to replace the manual actions. The machine eliminates the rigor and time wasting in the manual and local method of producing garri. The design was made as simple as possible for ease of operation and maintenance. Material selection was based on same design parameters such as strength, durability and rigidity. The machine is driven by an electric motor of 1HP. The efficiency of the machine was obtained to be 92.3%. The performance is quite reasonable compared to ones produced earlier with less than 50% efficiency.

Keywords: *design, siever, garri, cassava, machine.*

I. INTRODUCTION

Cassava, *Manihot Esculanta Crantz,* a dicotyledonous perennial plant belonging to the botanical family of *Euphorbiaceae* is almost entirely produced and consumed in most developing nations of the world. It provides a major source of carbohydrate for over 500 million people world-wide [1]. Cassava is diversified into different food products. Garri is the most popular of the cassava products in Africa [2]. It is a creamy-white granular flour with a slightly fermented flavour and a slightly sour taste made from fermented, gelatinized fresh cassava tuber [3]. Apart from human food, cassava is used for animal feed and alcohol production [4]. Cassava is a multipurpose crop for man and livestock. Cassava starch is an ingredient in the manufacture of dyes, drugs, chemicals, carpets and in coagulation of rubber latex [5].

Total production of cassava in Africa has increased from 35 – 80 million tons between 1965 and 1995 [6]. Africa now produces cassava than the rest of the world combined with biggest increase from 27% to 35% (of Africa total production) in Nigeria and 4% to 8% in Ghana [7].. Since 1990, Nigeria has surpassed Brazil as the world's leading producer of cassava with an estimated annual production of 26 million tonnes from an estimated area of 1.7 million hectares of land [8]. Other major producers of cassava are Zaire, Thailand, Indonesia, China, India, Malaysia, Malawi, Togo and Tanzania.

Cassava tubers once harvested begin to deteriorate and cannot be stored for more than a few days. Thus, there is a need for rapid processing of the tubers into a more shelf stable form. Cassava processing thus deserves serious attention in order to meet the local and international demand for cassava products. Cassava processing operations includes: peeling, washing, grating, fomentation, dewatering, sieving, garifying, cooling and storage. Labour intensiveness, long processing time, high production cost, poor product quality are among the major drawback of the existing traditional and even mechanized cassava processing methods. The general cost in the development of modern machines (mechanized) for cassava processing can be characterized by the quest for the highest possible productive capacity under the condition that the necessary and adequate machine efficiency is achieved. The aim of this work is to bring about an improvement on the existing traditional and mechanized sieve for garri processing.

II. MATERIAL AND METHOD

A. Design Analysis

The design analysis of the system was done based on conception and synthesis of existing manual sieving (traditional) process, by replacing it with a combination of mechanism. These mechanisms are conceived as follows:

The use of perforated sieve box to replace the manual sieve (bowl) and the use of belt drive system, shaft, motor, cam device and others to replace the entire human efforts and stress applied when shaking the bowling manually.

B. Design Consideration

In designing the motorized garri siever, the following factors were considered:

- **Kinematics:** The mechanism chosen to bring about the required reciprocating motion which is based on simple techniques.
- **Wear/Corrosion:** The material to be used should be resistant to corrosion and care should be taken to ensure suitable clearance in order to accommodate for wear especially when choosing the machine dimension.
- **Cost/Maintenance:** The fabricated parts and maintenance of the machine should be made with cost effectiveness in mind.
- **Strength/Stress:** The shaft of the machine is the component being subjected to stress; therefore, the strength of the material used for the shaft must be high enough to withstand such stresses (Bending and Torsion).

C. Description of the Machine

The machine is a mechanical system that uses the synthesis of existing manual sieving process by replacing it with a combination of mechanisms such as mechanical vibration which is achieved with the aid of mechanical shaker and motion transformation principle to sieve processed garri after dehydration.

The machine uses belt for the transmission of power from a prime mover to a line shaft pulley. A cam device is connected to the centre of the shaft and the other end of the cam device is attached to a rectangular shaped sieve box. Underneath the sieve box is the discharge channel which is trapezoidal in shape. The sieve can be changed to the desired unit. On the top of the cam device, there is the hopper. The machine has a standing that helps to hold an electric motor. Fig. 1 and 2 show the isometric and orthographic drawing of the motorized cassava siever respectively.

D. Operating Principle

The operation of the machine is not difficult. The machine is coupled to an electric motor (Prime Mover) via a v-belt drive to the pulley on the shaft. As the electric motor drives the cam shaft, the connecting rod transmits the rotary motion of the cam into a reciprocating motion which enables the shaker to move the sieve box to and fro. As the sieve box shakes and vibrates to and fro, garri is fed through the hopper to the sieve box where it is sieve and collected through the discharge unit.

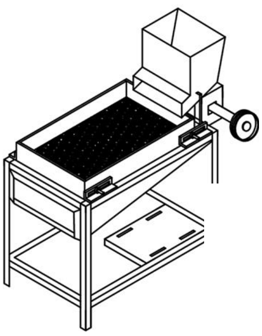

Fig 1: Isomentric view of the motorized cassava siever

E. Belt Drive Design

The relationship below is used to determine the transmitted speed:

$$\frac{N_2}{N_1} = \frac{D_1}{D_2} \qquad - \quad - \quad - \qquad (1)$$

Where N_1 (rpm) and N_2 (rpm) are the speeds of driver and driven pulley; D_2 (mm) and D_1 (mm) are the diameters of driver and driven pulley. The intended ratio of the speed of the driven pulley to that of the driver pulley used in the design is 4:5.

The centre distance, C (mm), between two adjacent pulleys is determined using the relation [9].

$$C = \frac{D_1+D_2}{2} + D_1 \qquad - \quad - \quad - \qquad (2)$$

The length of the open belt, L [mm], is given as:

$$L = \frac{\pi}{2}(D_1 + D_2) + 2C + \frac{(D_2-D_1)^2}{4C} \qquad -- \qquad (3)$$

In engineering, flexible drives such as ropes and belts can be used for power transmission over comparatively long distance instead of more expensive transmission drives such as gears.

Torsion on the shaft, T(N), exerted by the electric motor is computed using the equation below:

$$T = \frac{60P}{2\pi N_1} \qquad -- \quad - \qquad (4)$$

Where P(W) is the power rating of the electric motor = 1HP.

The net force, F_N(N), exerted by the belt on the shaft is determined as follows

$$F_N = F_1 - F_2 \qquad - \quad - \quad - \qquad (5)$$

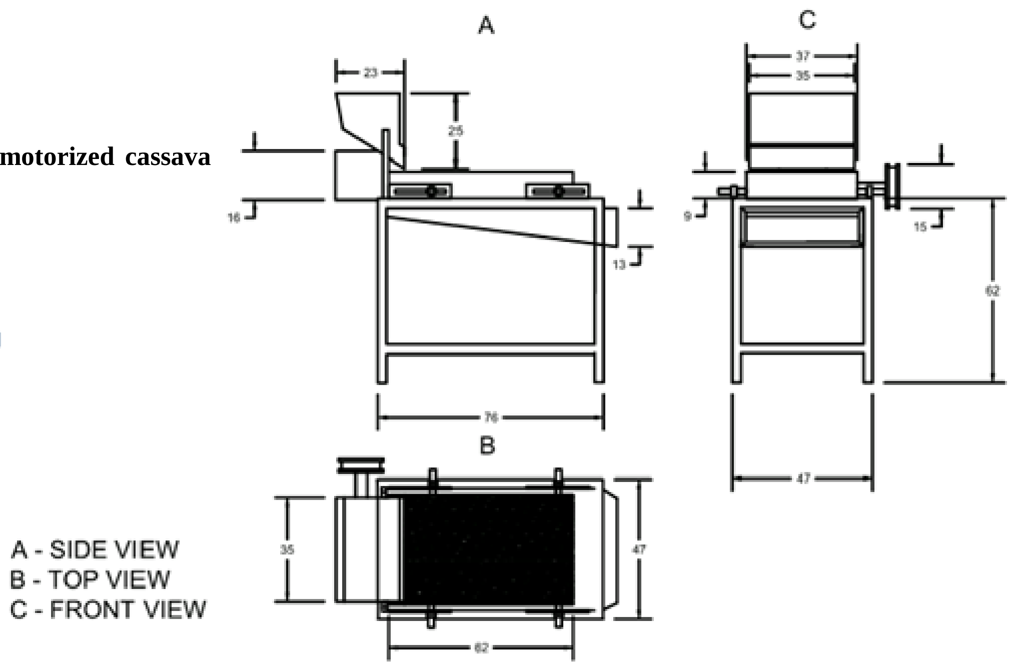

Fig 2: Orthographic view of the motorized cassava siever

Torque acting on the pulley, T is:

$$T = \frac{F_N \times D_2}{2} \quad - \quad - \quad - \quad (6)$$

$$T/R_2 = F_1 - F_2 \quad - \quad - \quad - \quad (7)$$

Where F_1 (N) and F_2 (N) are the tensions on the tight side and slack side; R_2 (mm) is radius of driven pulley.

$$\frac{F_1}{F_2} = e^{\mu\theta} \quad - \quad - \quad - \quad (8)$$

Where θ = angle of constant in [rad].
For open belt:

$$\theta = (180 - 2\propto)\frac{\pi}{180} \quad - \quad - \quad (9)$$

$$\propto = sin^{-1}\left(\frac{R_2 - R_1}{c}\right) \quad - \quad - \quad (10)$$

From standard table, the coefficient of friction for belt/pulley material that is tanned leather/iron steel is $\mu = 0.4$ [10].

F. Shaft Design

The line shaft was designed based on the strength not on rigidity because; twist and lateral deflection of the shaft are negligible. The shaft works like the propeller shaft of a ship; hence, it is subjected to axial load in addition to combined torsion and bending loads.

According to American Society of Mechanical Engineers (ASME) code equation for a solid shaft that experiences both bending and torsion load [9], the diameter of the shaft is given as;

$$D = \sqrt[3]{\frac{16F_N}{\pi \times \sigma_S}} \quad - \quad - \quad (11)$$

Also,

$$D = \sqrt[3]{\frac{16M_N}{\pi \times \sigma_b}} \quad - \quad - \quad (12)$$

Where F_N = Equivalent twisting moment
σ_s = Allowance shear stress of shaft material
M_N = Equivalent bending moment
σ_b = Bending stress of shaft material

But,

$$F_N = \sqrt{(K_M \times M)^2 + (K_t \times T)^2} \quad -- \quad (13)$$

$$M_N = \frac{1}{2}[(K_M \times M) + F_N] \quad -- \quad (14)$$

K_M and K_t are combined shock and fatique factor for bending and torsion respectively for the purpose of this design, K_M = 1.5 and K_t = 1, for rotational shaft, with gradually applied loads.
M = maximum bending moment at point where the shaft is centrally loaded, T = Torque.

G. Design of Sieve Box in Discharge Channel

The rectangular sieve box was designed and fabricated to a length of 0.50m, breath 0.37m and height 0.09m respectively.
Volume of sieve box (V_b)

$$V_b = L \times B \times H\ (m) \quad - \quad - \quad (15)$$

$$V_b = 0.50 \times 0.37 \times 0.09$$

$$V_b = 0.0166m^3$$

The trapezoidal discharge channel was designed and fabricated to a height (h) of 0.62m and opposite sides, X = 0.13m and Y = 0.37m respectively.

$$A_C = ½\,(X + Y)h \quad - \quad - \quad (16)$$

$$A_C = ½\,(0.13 + 0.37)\,0.62$$

$$A_C = ½\,(0.5)\,0.62$$

$$A_C = 0.155m^2$$

Volume of discharge channel (V_c)

$$V_C = A_C \times B \quad - \quad - \quad (17)$$

$$V_C = 155 \times 0.37$$

$$V_C = 0.0574m^3$$

H. Fabrication Procedures

1) ***Sieve Box:*** The rectangular shape sieve box was cut into 500mm X 90mm (2 pieces) and 370mm X 90mm (2 pieces).

Hopper: The galvanized mild steel was cut into a rectangular shape with length and height of 350mm X 230mm (2 pieces) and also 250mm X 230mm (2 pieces).

2) ***Discharge Unit:*** The part of the trapezoidal shape discharge unit was cut in side X and Y with a length of 130mm x 370mm X 620mm (2 pieces) and a piece of 470mm X 130mm.

3) ***Standing Frame:*** An angular bar 30 X 30 was cut into 3 parts, 760mm (4 pieces) 620mm (4 pieces) and 470mm (4 pieces).

I. Tools and Equipment Used

The tools and equipment used for the cutting, measurement, fabrication, painting, etc. of the machine are as follows;

- Arc welding machine.
- Measuring tape
- Ruler
- Try square
- Drilling machined
- Disc cutter machine
- Angle grinder
- Painting brush.

III. RESULTS

A. Performance Evaluation

The performance of the machine was evaluated from its output capacity and sieving efficiency as follows:

$$Q = \frac{W_1}{T} \quad - \quad - \quad (18)$$

Where Q = Output capacity (kg/hr)
w_1 = Weight of the sieved garri
T = Time of sieving (hr)

Test I

$w_1 = 3\text{kg}$

$\text{T} = 30 \text{ sec} = \frac{30}{3600} = 0.0083hr$

$Q = \frac{3}{0.0083} = 361.5kg/hr$

Test II

$w_1 = 4\text{kg}$

$\text{T} = 38 \text{ sec} = \frac{38}{3600} = 0.011hr$

$Q = \frac{4}{0.011} = 363.6kg/hr$

Test III

$w_1 = 5\text{kg}$

$\text{T} = 51 \text{ sec} = \frac{51}{3600} = 0.014hr$

$Q = \frac{4}{0.014} = 357.6kg/hr$

Average output capacity (Q_{av})

$$Q_{av} = \frac{Test\ I + Test\ II + Test\ III}{3}$$

$$Q_{av} = \frac{361.5 + 363.6 + 357.1}{3}$$

$$Q_{av} = 360.7kg/hr$$

Determination of sieving efficiency

$$Ef = \frac{W_2}{W_1} \times \frac{100}{1} \quad - \quad - \quad - \quad (19)$$

Where Ef = Sieving efficiency (%)
W_2 = Weight of the sieved garri (kg)
W_1 = Initial weight of the garri (kg)

Test I

$W_2 = 2.8kg, W_1 = 3kg$

$$Ef = \frac{2.8}{3} \times \frac{100}{1} = 93\%$$

Test II

$W_2 = 3.6kg, \quad W_1 = 4kg$

$$Ef = \frac{23.6}{4} \times \frac{100}{1} = 90\%$$

Test III

$W_2 = 4.7kg, \ W_1 = 5kg$

$$Ef = \frac{4.7}{5} \times \frac{100}{1} = 94\%$$

Average Sieving Efficiency (Ef_{av})

$$Ef_{av} = \frac{Test\ I + Test\ II + Test\ III}{3}$$

$$Ef_{av} = \frac{93 + 90 + 94}{3}$$

$$Ef_{av} = 92.3kg/hr$$

IV. CONCLUSION

The motorized garri siever was designed, constructed and evaluated. The result obtained from the performance evaluation test showed a sieving efficiency of 92.3%. This is far better than what can be achieved by manual labour. The machine is safe to use and efficient. The machine was cost effective because the design and fabrication was done locally.

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