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Design, Fabrication and Testing of a Horizontal Garri Fryer

Gbabo A.[1], Oyebamiji S[1], Gana I.M.[2*]

[1]*Department of Agricultural &Bioresources Engineering, Federal University of Technology Minna, Niger State, Nigeria*

[2]*Department of Agricultural & Bio-environmental Engineering, Federal Polytechnic Bida, Niger State, Nigeria*

***Corresponding Author:** Gana I.M., Department of Agricultural & Bio-environmental Engineering, Federal Polytechnic Bida, Niger State, Nigeria*

ABSTRACT

This research work was carried out to design, fabricate and test to ascertain the performance of a horizontal garri fryer. This concept was born out to reduce the excessive smoke, the drudgery encountered and time involved in frying garri manually by local processors. The machine consists of frying chamber, shaft, paddles, scooper, frame, heating chamber, chimney, discharge chute, gear box and an electric motor. The test result shows that at the machine speed of 45rpm, the highest machine efficiency of 90% was obtained. Also, a fine garri texture and best output were obtained at the same machine speed of 45rpm. The machine was designed with a capacity of 500kg per day. The development of this machine will exist in the production hygienic and quality garri, thereby increasing production.

Keywords: *Design, fabricate, testing, fryer, garri.*

INTRODUCTION

Garri is a fermented product that is processed from cassava tubers. For the majority of people this is the most popular meal. Its particle size ranges from less than 10µm (fine) to more than 2000µm (gross) (Agbetoye 1999). It is used both in Nigeria and in most West African coastal countries, and in Brazil. The frying of garri has become the most critical unit operation in the processing of cassava into garri. Garri frying is a concurrent process in the sense that the cooking and drying processes happens simultaneously. Garri can be regarded as a free fluent particulate product comprising of cassava particles that have been dried and gelatinized. The nutritional content of garri is carbohydrates which symbolizes that it is an energy giving food. Operations such as peeling and washing, grating, fermenting, dewatering, pulverization, sieving and frying are processes involved in garri production.

Garri according to the Standards Organization of Nigeria(SON), is classified into four major categories as extra fine grain garri(can pass through a sieve of less than 350µm aperture), fine grain garri(can pass through a sieve of less than 1000µm aperture),coarse grain garri(80% of grains passes through a sieve of 1400 micrometer) and extra coarse grain garri(not less than 20% of grain is retained on a sieve of 1400 micrometer aperture) (Sanni et al (2008). Also based on the fermentation length of days and whether palm/red oil is added or not, we have the red garri which is also called the “Bendel garri”. Frying is done traditionally by using a big thick pot placed above fire in which the operator agitates the grated cassava using spatula-like paddles of wood or calabash sections to press and mash against the hot surface of the frying pan (called “agbada”, by Nigerian Igbo) until it becomes crisp. It must be stirred continuously to avoid it getting burnt, which gives off a pleasant cooked aroma.

Firstly, the garri is cooked with the moisture and allowed to be dehydrated. The heat intensity during frying affects the quality of the product, and therefore should be a considering factor in garri frying. The moisture content of dewatered and sieved cassava mash is between 50 to 65 percent and should be reduced after the frying. In the traditional technique of frying, to avoid the formation of many lumps or caking, initial frying temperature needed is relatively low. As the temperature increases gradually, there is reduction in moisture content in which most of the small lumps developed would have been reduced by constant pressing and agitation by the paddles. Further increase in heat supplied to the drying surface causes it to be cooked and to dehydrate the product.

MATERIALS AND METHODS

Machine Description

Machine Frames

The frame gives support to the machine. It carries the frame support which makes the machine and its parts to stand without the operator holding it. It is fabricated using angle iron made from mild steel.

Frying Chamber

This is the part that houses the cassava mash, conducts heat and uses it for frying the sieved particles over a selected time. The frying chamber is fabricated with a stainless-steel material. The shape of the frying chamber is a combination of rectangle and hemisphere.

Machine Shaft

The material used for the shaft is mild steel. The rotating shaft carries the mixing paddles for the agitation and stirring of the garri while frying.

Heating Chamber

The heating chamber particularly generates an amount of heat with the temperature range required for the frying of the garri. The source of heat is either firewood or charcoal.

Chimney

The chimney is attached to the machine for discharge of smoke. It is made with 16-gauge flat plate.

Bearing

It is a machine element, which supports another machinery. It permits relative motion between the contacting surfaces while carrying the loads.

Electric Motor

The electric motor generates the power that drives the gear box and in turn drives the machine.

Gear box

A gear box is a speed reduction machineused to reduce the speed of the electric motor.

Discharging Chute

This is an opening at the bottom end of one side of the frying chamber for the discharge of the garri after frying to the collector.

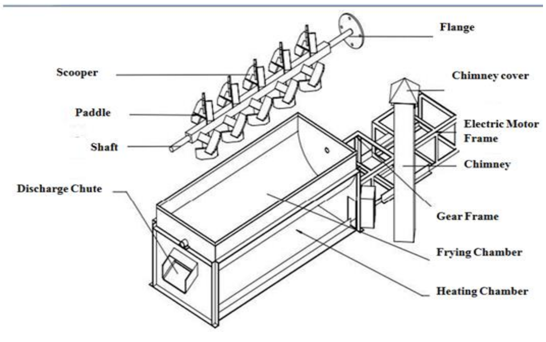

Figure1. *The exploided view of the machine*

Plate1. *The developed horizontal garri fryer*

Working Mode of the Machine

Power is transmitted from the electric motor when turned on to the gear box for reduction and then to the machine through the belt and pulley connection. The speed of the electric motor is reduced automatically by the gear box to allow for the slow and gradual agitation and turning of the garri in the frying chamber, thus creating room for retention period for effective frying. Before introducing the cassava mash into the frying chamber, the frying chamber is first heated to the expected temperature. The cassava mash is then introduced. As the shaft rotates, the paddles and scoopers mounted on it agitates and stirs the cassava mash until it turns to garri. After this the discharge chute is opened to discharge the garri to a collector.

Plate2. *Processing garri using the developed machine*

Design of the Major Parts of Machine

Determination of Volume of the Cassava Mash

The volume of the cassava mash was calculated in order to meet up with the assumed capacity. It is calculated using the following conventional formula as reported by Sobowale et al (2016)

$$v = \frac{m}{p} \quad (1)$$

Where, m is the mass of cassava mash (kg), p is the density of cassava mash (kg/m^3), V_{cm} is the volume of cassava mash (m^3).

Determination of Time Required for Frying

This was calculated to know the amount of time required to fry the expected capacity. According to Hong Kong, 2012 0.7kg of cassava mash containing 50 – 65% moisture can be reduced to 12% after frying for about 50seconds.

Determination of Volume of Cassava Mash Per Frying Batch

This was calculated to determine the adequate volume for the frying chamber.

$$V_b = \frac{V_m}{N_f} \quad (2)$$

Where, V_b = Volume of cassava mash per batch (m^3), V_m= $volume\ of\ cassava\ mash$ (m^3), N_f is $number\ of\ frying$

Determination of Machine Dimensions

The expected shape of the frying chamber was combination of a rectangle and hemisphere. The rectangular part and hemisphere part will be 4/5 and 1/5 of the total shape respectively.

Therefore;

$$V_f = \frac{4}{5} \times V_f = L \times W \times H \quad (3)$$

$$V_h = \frac{1}{5} \times V_f = \frac{2}{3}\pi r^3 \quad (4)$$

Where V_f is the volume of rectangle part of the frying chamber, V_h is the volume of hemisphere part of the frying chamber, L is the length of the machine, W is the width of the machine, H= height of the rectangular part of the machine, r is the radius.

Determination of Heat Required for Frying

The quantity of heat for frying garri was calculated to know the total heat required for frying the cassava mash. And also, to be able to recommend the quantity of heat required if heating element is to be used. This was calculated using the formula reported by (Sobowale et al 2016) , and is given as

$$Q = MC(T_f - T_i) \quad (5)$$

Where Q is the quantity of heat required (kg), M is the mass of cassava grit in the frying chamber (kg), C is the specific heat capacity of the mash, T_f is the recommended final temperature, T_i is the ambient temperature.

Convective heat transfer rate

The convective heat transfer rate was calculated as reported by Sobowale et al (2016) and is given as

$$Q_a = h_a A(T_f - T_i) \quad (6)$$

Where Q_a is the convective heat transfer rate (w), h_a is the convective heat transfer coefficient (W/m°c), A is the surface area of the frting container (m^2), T_f is the recommended final temperature, T_i is the ambient temperature.

Time required for frying (cooking and drying)

In relation of the heat transfer rate to the mass of mash been fried with time is calculated as reported by Ikechukwu and Maduabum (2012)

$$\frac{\Delta Q}{\Delta t} = \frac{\Delta m}{\Delta t} l_h$$

Where $\frac{\Delta Q}{\Delta t}$ is the heat transfer rate, l_h is the heat of transfer, Δt is the time required to fry gari

Determination of Length of Belt Required to Transmit Power

The length of belt required to transmit power from the electric motor to the gear box was calculated to know the actual size of the belt that is needed to grip the pulleys very tight to avoid belt slip.

The length was obtained using the conventional formula as reported by Khurmi and Gupta (2005) and is given as

$$L = \frac{\pi}{2}(D_1 + D_2) + 2C + \frac{D_1 - D_2}{4x} \quad (6)$$

Where D_1 is the diameter of driving (motor) pulley, D_2 is the diameter of driven (machine) pulley, C is the center distance between pulleys

Determination of Angle of Contact between the Belt and Pulley

The angle which the belt formed with the smaller pulley was determined so that the tension built up between the belt and the pulley will be known. This was calculated with the following conventional expression reported by Khurmi and (Gupta 2005)

$$\theta = (180^0 - 2\propto) \times \frac{\pi}{180} \quad (7)$$

$$\propto = \sin^{-1}\frac{r_2 - r_1}{C} \quad (8)$$

Where $r_1$is the radius of the electric pulley, r_2 is the radius of the machinepulley, C is the center distance between pulleys, θ is the angle of wrap

Determination of Machine Shaft Diameter

The shaft diameter was determined to ensure a satisfactory strength and rigidity when the shaft is transmitting power under various operating and loading conditions. This was obtained using the conventional formula reported by Khurmi and (Gupta 2005)

Where M_b is the bending moment, M_t is the torsional moment, K_b is the combined shock and fatigue factor applied to bending moment, K_t is the combined shock and fatigue factor applied to torsional moment, S_a is the allowable stress.

Critical Speed of the Shaft

For obtain efficiency of the machine, the critical speed of the machine was determined as reported by Khurmi and (Gupta 2005)

$$D^3 = \frac{16}{\pi S_a}\sqrt{(K_b M_b)^2 + (K_t M_t)^2} \quad (9)$$

$$\omega_s = \sqrt{\frac{48\varepsilon l}{mL}} \quad (10)$$

where ω is the critical speed of the shaft, ε is the the modulus of elasticity of steel, m is the the mass of the shaft, L is the length of the shaft

Torsional Deflection of the Shaft

This was calculated to know the angle of deviation of the shaft in degrees and to make sure this angle of deviation is at its minimum as reported by Khurmi and (Gupta 2005)

$$\boldsymbol{\alpha} = \frac{584\tau L}{D^4 G} \quad (11)$$

α is the Angular shaft deflection in degrees, L is the Length of the shaft, G is the modulus of elasticity of steel, D is the 2.26×4√τ

Determination of the Power Required to Drive the Shaft

This was calculated to know the power required to drive the shaft and the scooper and paddles to be mounted on the shaft. It was calculated as reported by Khurmi and (Gupta 2005)

$$\mathrm{p} = \frac{2\pi NT}{60} \text{ and} \quad (12)$$

$$\mathrm{T} = \frac{\pi}{16} \times \tau \times d^3 \quad (13)$$

Where, P is the Power, T is the Torque, τ is the Shear stress of the shaft, D is the diameter of the shaft.

Determination of Maximum working Stress of the Shaft

This was calculated to know the allowable stress of the shaft and its behaviour under working condition. It is obtained with the following expression,

$$\sigma = \frac{16T_s}{\pi d^3} \quad (14)$$

Where,σ is the *maximum permissible work in-gstress*, d is the diameter of shaft, T_s is the Torque of the shaft

Testing of the Machine

After the fabrication, the machine was tested on no load. This was done in order to determine the functionality of all parts of the machine, to ensure that all the parts are moving freely and the sound level okay before the purchased cassava mash was brought and fed into the frying chamber, with this the cassava was allowed to be fried as the paddles mounted on the shaft agitates the garri for even distribution. After the frying, the time taken for frying was taken and recorded and the discharge chute opened for discharge of the garri.

The parameters that were measured and tested for in determining the performance of the machine are texture, output and machine efficiency

- Texture (granulation) of the garri: the texture was determined by feeling the fried garri with hand.
- Output: The output of the machine is determined in order to know the capacity of the machine, which is the quantity of garri the machine produced in a day with respect to the expected frying time and assumed capacity, it was calculated as reported by Sobowale et al. (2016)

$$\text{Machine efficiency } M_{out} = \frac{M_f}{T} \times 100 \quad (15)$$

Where, M_{out} is the machine output (kg/s), M_f is the mass of garri obtained (kg), T is the time required to fry the gari (s)

- Machine efficiency: the machine efficiency is defined as the capability of a machine to convert inputs to outputs efficiently without waste. This is done in order to ascertain the performance of the machine. it was calculated as reported by Sobowale et al. (2016)

$$\text{Machine efficiency} = \frac{M_f}{M_m} \times 100 \quad (16)$$

Where, M_f is the mass of garri obtained (kg), M_m is the Mass of cassava mash introduced into the fryer (kg)

Results and Discussion

- Texture of the Garri: It was observed that the texture of the garri is a function of variation in operational speed. The result of performance test of the machine obtained reveals that at machine speed of 73rpm, the texture of the fried garri was very coarse. This is as a result of the paddles and scooper not breaking the cassava mash well due to the machine high speed. Reversely, at low machine speed, the texture was observed to be fine. Therefore, the optimum operating speed is 45rpm.

- Machine Efficiency: the output was observed to be optimum as the speed of the machine decreases, while as the speed of the machine increases the output reduces. Hence, the best output for the fryer was observed when the speed of the machine was 45rpm. This also validates observations made for the garri texture. Similar result was also reported by Sobowale et al. (2016), in which they recorded a maximum functional efficiency of 92.20 % in motorized model evaluated. This also validates initial observations made for the throughput capacity, frying time, and material loss.
- Output: the output obtained per frying period is 50kg/hr which when multiplied by ten (number of frying per day) will give the assumed capacity of the machine per day. And this was obtained the machine speed of 45rpm. Therefore, the optimum speed of the machine that will produce the expected capacity with fine garri texture is 45rpm. The designed garifryer has a higher productivity when compared to the model of Ajayi et al. (2014) of 20.4 kg/hr and model of Sobowale et al. (2016) of 34.66 kg/hr.

Table1. *Shows the result of the performance of the machine under different speed*

S/N	Speed of machine(rpm)	Mass of cassava delivered (kg/hr)	Machine output (mass of cassava obtained) (kg/hr)	Machine efficiency (%)	Texture
1	73	55.50	40	72	Very coarse
2	58	55.50	43	77	Coarse
3	45	55.50	50	90	Fine
4	39	55.50	52	94	Very fine

CONCLUSIONS

After the successive design, fabrication and testing of the equipment, it was concluded thatthe fryer provided a good mechanism for both stirring and lump breaking actions so that uniform cooking and dehydration in the entire mass is ensured and the desired texture produced. From the performance test, it was discovered that the optimum speed of the machine is 45rpm which gives the required texture and machine efficiency. The machine reduced drudgery, labor and time of operation and also eliminates smoke hazard during operation attributed to the local means of frying garri.

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