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Design and Fabrication of an Improved Garri Frying Machine

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ABSTRACT: The final stage of garification is frying and cooling. Throughout history, frying of garri has been done manually with minimal crude mechanization. Hence, the objective of this paper was to design and fabricate an improved version of garri frying machine for improve quality, enhance production rate and efficiency of the machine using various standard methods. the required temperature that could fry the garri containing 50-55% moisture content to a 12% garri can be taken to be 90°C With the design of this machine, we can infer that at a constant temperature of 90°C, about 50kg and more of cassava mash can be fried to get a high quality garri of about 10-12% moisture contained in 1 hour.

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Garri processing emanates from taking harvested cassava products through some extensive set of operations, such as peeling, washing, grating, dewatering, and fermentation, sieving, frying and cooling. This activity is well known in most parts of West African including Nigeria and has been done mostly by employing locally adopted processing techniques, whereby the cassava is peeled and allowed to ferment, and then grinded and sieved, and thereafter subjected to heating by frying in a dry heated pan. Traditionally, a shallow earthen-ware made of cast-iron pans is placed over heat obtained from wood fire, and with a wooden spatula-like paddles, the sieved mash is pressed against the surface of the frying pan as it is continuously stirred to avoid caking. Naturally, this operation which is known as garification, is repetitively performed for a specified period of time, to produce the finished product known as Garri. According to research, to obtain a quality product, factors such as the amount of heat per time during frying, uniform heat distribution by adequate agitation and pressing, and the confirmation that the product has been sufficiently cooked and dehydrated must be taken into consideration.

Sadly existing designs for Garri processing has been devoid of the above consideration, due to difficulties and failure to mechanize correctly, arising from erroneous assumptions made on the functionality, viability, and technicality employed. An improved garri fryer by the University of Ibadan as reported by Igbeka (1988) reveals a little advantages over the local fryer, reporting total elimination of pollution arising from the burning wood. The International Institute of Tropical Agriculture, Ibadan, Nigeria developed a modified design smaller in size compared to the normal traditional pan (Igbeka *et al.,* 1992). The model recorded elimination of smoke and heat hazards from the operator, with the elevated fireplace position. The Rural Agro-Industrial Development Scheme RAIDS developed a model similar to that designed by the University of Ibadan, having outlet gates or spouts for discharging finished products from the pan. Increased output per unit time was recorded, along with

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elimination of smoke. With the coming of the industrial revolution, some mechanized garri frying have also been recorded. The first jointly designed by the Newell Dunford Company in London and the Federal Institute of Industrial Research (FIIRO), Oshodi in Nigeria, employs heat from a gas fire controlled and regulated by thermostats. The product obtained was not acceptable as it didn't meet the basic characteristics of garri. The University of Nigeria, Nsukka (Odigboh and Ahmed 1982) achieved a well fried garri with 15% moisture content, at an average through-put of 66kg of garri per hour. The UNIBADAN model (Igbeka and Akinbolade, 1986) at 15 rpm, the capacity was 80kg/hr of finished product.

Most of the above mentioned designs have been made by adopting the specifications in terms of physical features and taste liken to those of locally existing process. Thereby leading to high human operation of the frying process, lengthy designed sizes of the machines, and poor product quality, attributable to poor design material selection consideration. However, with the wide acceptability of this product for food consumption, and the increasing demand arising from the growing population in Nigeria, an improved mechanized designs capable of addressing poor quality production often associated with the local design, and increasing production output is critical, and of benefit in addressing UN SDG goals on food security, as an improved production capacity will greatly ameliorate the current challenging food crisis bedeviling most parts of African, and increase job opportunities.

Therefore, the objective of this paper is to design and fabricate an improved and efficient version of Garri frying machine to obtain greater quality and enhanced production rate.

MATERIALS AND METHOD

The following design criterias take were taken into consideration to ensure the machine fit its purpose and is user friendly;

i. The type of material used for each component of the machine. This could either improve the quality of the garri or make it unfit for consumption.

ii. The speed of the shaft was put into consideration; therefore a 1.5hp electric motor was seen to be effective for this particular operation

iii. The source of heat that would be able to effectively fry the garri in the heating chamber was considered. Owing to the fact that this project could be used in the remote areas, charcoal was considered and chosen for effective frying.

iv. A good pulley system was considered with the use of V-belts such that motion can be transferred effectively from the motor to the 1st shaft and then to the 2nd shaft.

The Heating Chamber: The heating chamber comprising of a burner made of mild steel material as shown in Figure 2.

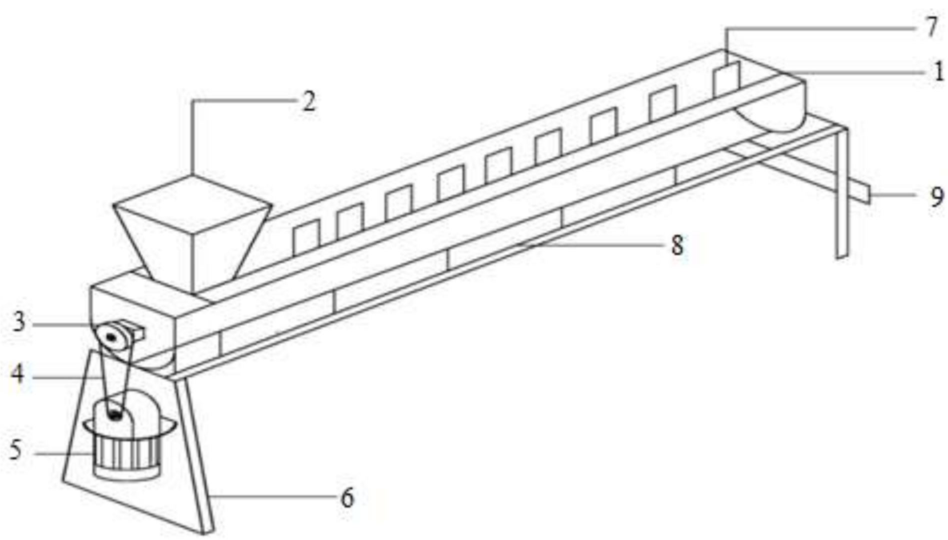

Fig 1: Orthographic Drawing of the Garri Frying Machine

The isometric drawing consist of the following components; 1. Frying Chamber, 2. Hopper, 3. Pulley, 4. Belt, 5. Motor, 6. Frame, 7. Paddle Blade, 8. Heat Chamber, and 9. Discharge Chute.

Design criteria: A mechanized machine requires an electric motor to transmit power, needed to drive the shaft, and a source of heat generation.

(i) To calculate the heat required for the cassava, the heat transfer could be applied thus:

$$Q = M_c(T_f - T_a) \quad (1)$$

Where Q = Heat required, M = Mass of moisture, C= specific heat capacity of water (moisture) = 4.2 kg/^{o}C, T_f = Drying temperature of garri, T = Ambient temperature

$$Mass = Volume\ (\mu) * Density\ (\rho) \quad (2)$$

(iii) Power required to drive the shaft

$$P = 2\pi NT \quad (3)$$

Where: P = Power, N = Expected revolutions/minute of the shaft, T = Torque required

(iv) Torsional moment (Mt) on shaft:

$$Mt = \frac{p * 60}{2\pi N} \quad (4)$$

Where Mt = Torsional moment, P = Power, N = Expected rev/min

(v) $$Mb = W\ x\ L \quad (5)$$

Where M_b=bending moment of shaft

(vi) to calculate for shaft diameter. Based on ASME Code equation for the circular shaft;

$$D^3 = \frac{16}{\pi Ss}\sqrt{(Kb * Mb)^2 + (Kt * Mt)^2} \quad (6)$$

Where D = Diameter of solid shaft, K_b = Bending moment factor, M_b = bending moment N_m, M_t = torsional moment Nm, K_t = torsional moment factor, S_s = allowable shear stress for steel shaft.

(vii) Length of key on shaft

$$L = \frac{\pi D}{2} \quad (7)$$

Where L= length of key in mm, D = shaft diameter.

Heat Required for the Cassava: From the related mathematical formula, as stated in equation (1),

$$Q = 16.29\ x\ 4.2\ (83 - 34.3) = 16.29x4.2(48.7) = 9491\ KJ/s$$

Shaft Design: Number of blades acting along the 3.2m length of shaft is 44 (that is 22 blades placed in 2 rows along the shaft), Width of blade = 59mm (59x10^{-3}m), Length of blade= 83mm (83x10^{-3}m), Thickness of blade= 2mm (2x10^{-3}m), Weight of each blade = mass x gravity;

Where Mass= Volume x Density

And volume= area x thickness = (59x10^{-3} x 83x10^{-3}) m = 4.9x10^{-3}m

Therefore Volume = (4.9x10^{-3}) x (2x10^{-3}) m = 9.8x10^{-6}m

(Were density of mild steel = 7.85kg/m^3)

Mass = 9.8x10^{-6} x 7.85 kg/m^3

Weight of each blade = 9.8x10^{-6} x 7.85 x 10^3 x 9.81 = 0.753 kg

Total weight of 44 blades= 33.12N

(Tension of the belt used as calculated in the belt and pulley design, T_1 and T_2 are 136N and 12.27N respectively.)

Power to Drive Shaft: From equation (5) in the related mathematical formulas

Power to drive shaft =2πNT

N=Expected rev/min of shaft = 45 rev/min, T= Torque required = F*r, F= Total load carried by shaft= weight of blades = 33.12N, r = radius of the shaft r = $\frac{50}{2}$ mm = 25mm

Therefore; $P = 2\pi NT = 2\ x 3.142 x\ 45\ x\ 33.12\ x\ 0.025 = 234.1 watts$

From the above calculation the power required to drive the shaft is 0.234kw and it is therefore suitable for the design to use 0.250kw or 250 watts electric motor.

Torsional Moment on Shaft (M_t)

$M_t = \frac{9550\ x\ P}{N} = \frac{9550\ x\ 0.250}{45} = 53.02Nm$

Diameter of the Shaft

$D^3 = \frac{16}{\pi\ x\ 55.8\ x\ 10^6}\sqrt{(1.5\ x\ 474)^2 + (1.0\ x\ 53.05)^2} = 9.127\ x\ 10^{-8}\sqrt{508335.3025} = 6.5\ x 10^{-5}$

$D = \sqrt[3]{6.5\ x\ 10^{-5}} = 0.040m = 40mm$

Design of Key: From equation (7) in the related mathematical formulas, L = $\frac{\pi D}{2} = \frac{\pi x 40}{2}$ = 62.83mm = 0.06283m

Material Selection: In selecting materials for the machine, it is very important to consider the properties of the materials. Table 1, presents the materials selected for the machine components and the reasons for their selection.

S/N	Machine Component	Criteria For Selection	Material Selected	Reason For Selection
1	Hopper		Stainless steel	Availability, low cost, stability and strength.
2	Frame		Iron	stability and strength
3	Shaft	Ability to carry the total load on shaft without bending	Bright Mild steel (BMS) (Φ25) mm	Availability, resistance to corrosion, high torsional strength high speed resistance to wear and low cost
4	Frying trough	Ability to withstand heat, corrosion and also retain heat a considerable time	Stainless steel	Ability to withstand thermal stresses, stability, strength and low cost.
5	Blades		Stainless steel	Availability, resistance to corrosion
6	Burner	Ability to withstand heat and corrosion	Mild steel	High torsional strength high resistance to wear and low cost.
7	Belt	Effective transmission of torque, and shock absorption	V-belt	Occupies less space exerts less tension or pulley
8	Pulley	It should be of light weight, high strength and durability	Mild steel	Comparatively lighter than cast iron, higher strength and durability.
9	Bearing	Minimize friction and have long service years	Single row radial ball bearing	Self-lubricating, withstands weight.
10	Prime mover	Ability to overcome shear strength and generate torque	Electric motor	Generates high torque rotate the shaft and paddles

Table 1: Selection of Components and their Justification

Testing of the Machine: In carrying out the test running of the machine, the following procedures were followed:

(1) Test running of the machine without load for about ten (10) minutes.

(2) Testing of the machine with load to know if the blades were properly fixed and check if it has a good sweeping effect. Also to check if the drives are properly aligned.

(3) Testing of the machine with the load and when the cassava mash is being added to it. To see the accuracy of its operation by evaluating the quality of the garri.

After the test running of the machine, the following were observed:

(1) The Paddles - The blades were not properly loaded on the shaft and this resulted to a poor contact between the blades and the frying trough. Which led to some leftovers of the cassava mash in the frying trough after frying is completed. This leftovers have to be removed using a brush or any other useful equipment. Also longer lengths of paddles was used to replace the shorter ones that could remove all of the cassava mash.

(2) The Heating Chamber **-** It was difficult to ascertain the exact temperature while heating up the charcoal. But by the use of a thermometer which is not to be held too close to the burner because of its material. Also the temperature was ascertained by the varying the amount of coal put in the heating chamber and equally recording the range of amount of heat it could produce with such amount. After taking many if this temperatures and sizes, a particular one suitable for the frying is chosen.

(3) The Quality of Garri Produced **-** Before and after frying the temperature of the garri was taken and recorded. The garri was also weighed before and after frying. Therefore the amount of moisture in the garri was obtained and its percentage. The percentage of moisture lost could effectively show the efficiency of the machine after the garri has been cooled to room temperature.

RESULTS AND DISCUSSION

This newly designed Garri frying machine has a high productivity. It can continuously fry about 5kg per hour. It was also tested to see that garri of 10-12% moisture can be produced and fit for consumption. The Results of the Operation Parameters of the Machine are presented in Table 2. As seen from the table above, the required temperature that could fry the garri containing 50-55% moisture content to a 12% garri can be taken to be 90°C. Taking the ambient temperature of the cassava mash to be 34.3°C, we can obtain the values as presented in Table 3.

Table 2: Results of the Operation Parameters of the Machine

Quantity of coal (kg)	Temperature (°C)	Result (% moisture content in the garri)	Weight of cassava mash (kg)
2.0	77	22	25
3.0	83	18	25
3.5	90	12	25
4.0	95	6	25
5.0	103	2(burnt garri)	25

Table 3: Summary of the performance parameters of the machine

Weight of cassava mash (kg)	Weight of Garri (kg)	Frying temperature (°C)	Frying time (minutes)	% moisture lost	% moisture content of Garri
46	38	90	47	45	10
48	41	90	50	45	10
50	44	90	50	44	11
60	48	90	54	43.4	11.6
70	50	90	60	43	12

With the design of this machine, we can infer that at a constant temperature of 90°C, about 50kg and more of cassava mash can be fried to get a high quality garri of about 10-12% moisture contained in 1 hour, leading to an improved machine efficiency of 78%.

Conclusion: In developing any mechanized garri fryer, the following features have to be considered as basic requirements. A regulated temperature mechanism which ensure simultaneous cooking and dehydration, without roasting to a desired moisture content after a specific period. A mechanism that provides both stirring and lump breaking actions so that uniform cooking dehydration in the entire mass is ensured. From the design and fabrication of this newly mechanized machine, a reduction in the human effort involved in the frying process is achieved, along with an improvement in the quality of garri produced by using quality materials and components in the fabrication of the machine.

Declaration of Conflict of Interest: The authors declare no conflict of interest.

Data Availability Statement: Data are available upon request from the first author or corresponding author or any of the other authors

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