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Design and Implementation of a Low Cost Automated Garri Frying Machine

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Abstract:

The need to minimize human efforts in garri production (a widely consumed food in West Africa) has become a necessity due to numerous health hazards producers are exposed to during garri frying. This work is therefore focus on designing and implementing an automated garri frying machine. The machine consists of five basic components, these are: the frying compartment, heating coil, shaft connected with paddle, electric motor and a thermostat. The machine was tested to deliver 73% efficiency in garri frying compared to a 71.43% maximum efficiency from other known sources.

Keywords: Garri, hazard, frying chamber, electro-mechanical

I. Introduction

Cassava (*ManihotEsculentaCrantz*) is one of the most important energy sources in the human diet especially in tropical areas. It is a widely accepted food by Nigerians and other sub-Saharan countries in Africa [1,2,6].It is a basic staple food to more than 70% of Nigerian population and it is consumed at least once every day by about 500 million people in the world [4]. The cultivation of cassava crop is by the propagation of stem cuttings. Roots can be harvested between 6 months and 3 years after planting, depending on the cassava variety. The roots are dug up from the soil, removed from the plant and washed before being processed. It is rich in carbohydrates, calcium, essential minerals, vitamin B and C. About 70% - 80% of harvested cassava roots within tropical regions are processed into garri (eatable cassava mesh which can be consumed by soaking in cold water or processed using hot water) [4,8,10].

From time immemorial, garri has been fried locally through burning of woods and these have had adverse health effect on populace. The local methods of processing cassava roots into garri is a tedious and health challenging process that necessitate the need to replace human efforts in garri processing (especially garri frying) with electro-mechanical machines [3,8,11].

Earlier designs on garri production machines did not produce the desired and acceptable cassava product for the producers and consumers. The designs of these machines did not take into account the specifications of the existing local technology. It has been quite difficult to mechanize this operation correctly because this operation was not well understood by many designers and manufacturers. Some have assumed garification to be the same as dehydration while others had taken it to be roasting. Before the construction and development of ESUT (2015) model, a lot of research were carried out ranging from the village technique, improved traditional methods and mechanized methods designed by different research institutions, universities and companies [5,12,13,14]. It was discovered that local technique gives the best quality garri. The question is how this local technique can be simulated and mechanized using the same method to achieve the same or better quality of the product. In recent years a lot of research has been carried out to mechanize some aspects of the unit operations used in garri production. These include peeling and washing of the roots, grating/ grinding, dewatering, fermentation, sieving, frying and cooling.

II. Materials and Methods

The design concept for this machine consists of five basic components, these are: the frying compartment, shaft connected with paddle, electric heater, electric motor and reducing gear. The paddle is located on the upper edge of the shaft which is connected directly to the electric motor system. During the frying operation, the cassava mash is loaded into frying chamber and covered with the frying chamber cover. The electric motor transmits power to the shaft, as the shaft rotates it actuates the paddle, which starts frying the cassava mash in the frying chamber. The heating coil equidistantly wound around the frying chamber is used to heat the cassava mash, so that the cassava mash can be cooked and dehydrated. Each component is further discussed:

The Shaft: The shaft is a 0.914m x 0.04 m mild steal designed to transmit power to the paddle in the heating chamber.

Paddles: The paddles are made of stainless steel material (to minimize contamination) and are the main component that does the real garri frying. They paddles are firmly attached to the shaft which drives them through an angle of 360° during the frying the stage.

Frying chamber: The cylindrical frying chamber used in the setup is a good heat conductor capable of delivering sufficient heat acquired from the heating element to the cassava grit during the frying process. The chamber is carved from stainless steel material. Heat is allowed to heat up the cylinder from underneath it through heating coils which are situated equidistant around the sides of the cylinder. The top of the cylinder has rectangular openings through which ventilation and inspection is made possible during frying. There is an opening at the bottom end of the heating part of the cylinder where dry garri discharge into a basin. The bottom cylinder has bearing seating on both ends and strongly made of thick aluminum material such that applied heat could not affect its structure.

Heating Element: Heating element used is heating coil. The 3.0kw heating element placed around the frying chamber provides sufficient heat to heat up the cylindrical chamber up to about 69^{0}C [7,9]. The surroundings of the operable vicinity and the walls of the container are properly lagged using fiber glass wool. The heating coil has a control valve for regulating the temperature differences within the setup and the environmental temperature fluctuations via a thermostat input.

Fiber Glass: This is a material consisting of numerous extremely fine filaments of glass that are combined in yarn and woven into fabrics, used in masses as a thermal insulator.

Thermostat: this is a component/device used in the measurement and indirect control of temperature in a desired reference material with heating element. The thermostat is usually connected to a control nub (or digital control) and the control of the thermostat to one end of the heating element to turn ON or OFF the heating element based on temperature comparison between the thermostat read temperature and the preset temperature. The major function of the thermostat is to ensure temperature is maintained near a desired set point.

Machine frame: The machine frame forms the housing of the whole components, including the electric motor. It is rigid so as to withstand all the forces generated in the components during the frying operation. It was constructed using the square pipes.

Electric Motor: An induction type electric motor selected for its strength was used to drive the system (shaft and paddle). A two horsepower motor properly analyzed to carry the designed load was used in the setup. Three spur gears, two sprockets and chain mechanism were used for power transmission considerably from a short distance which causes the motor suspension from ground.

Flange bearing: Flange bearings are used when the axis of shaft is perpendicular to the bearing mounting surface. They incorporate a sealed bearing axis and four mounting holes. The bearing can be unbolted and removed which makes the bearing replacement easier and faster than traditionally rotary bearing that must be press into housing. Flange bearing protect the shaft from deflection which could cause vibration or other damage.

Material Selection

The main objective of material selection is to minimize cost as well as selecting the appropriate material to be used for each component considering engineering factors, environmental factors and/or service conditions of the components. Material selection/consideration is necessary for the optimization of the degree of reliability of selected materials. Table (1) below shows a summary of selected materials and reasons for their selection.

Table 1: Material for components production

S/n	Name	Material selection	Reason for selection
1	Machine frame	Mild steel	It is very cheap; it can withstand stress and bending force.
2	Heating chamber	Coil	Good thermal conductivity

3	Bolts and nuts	Mild steel	Good resistance to shear and bending forces.
4	Bearings	Flange bearings	Durable and effective
5	Shaft	Mild steel	Better resistance to shear and bending forces.
6	Frying chamber	Stainless steel	Good corrosion resistance and thermal conductivity
7	Paddles	Stainless steel	Good corrosion resistance and thermal conductivity

Standard Garri Parameters

$$moisture\ content\ of\ cassava\ mash\ (garri) = 42\%\ (Balami\ et\ al.\ 2012)$$

$$Fried\ moisture\ content = 12\%\ maximum (USAID, 2010)$$

$$Roasting\ temperature = 95℃\ (Ralman\ and\ Olatunde, 2014)$$

Calculations:

The percentage moisture content of the fried garri was calculated using equation (1) [9,13], equation (2-3) was used in calculating the face and side plate, equation (4-5) was used in determining the required motor power, equation (6) forms the basis for the shaft design, equation (7) was used in calculating parameters for the pulley design while equation (8) was used in calculating the diameter of the required belt while equation (9) was used in determining the sufficient heating element.

$$percentage\ moisture = \frac{(weight\ of\ wet\ sample + pan) - (weight\ of\ dried\ sample + pan)}{(weight\ of\ wet\ sample + pan) - (weight\ of\ pan)} \times 100 \qquad \text{(Eqn. 1)}$$

$$Area\ of\ face\ plate\ (2\ piece) = \pi dt = \pi \times 0.298 \times 0.003 - 2 = 0.0056172 m^2 \qquad \text{(Eqn. 2)}$$

$$Area\ of\ side\ of\ trough = \pi dl = \pi \times 0.301 \times 0.595 = 0.563 m^2 \qquad \text{(Eqn.3)}$$

$$centrifugal\ force = {mv^2}/{r} \qquad \text{(Eqn. 4)}$$

$$power = \frac{2\pi NT}{60} \qquad \text{(Eqn. 5)}$$

$$The\ equivalent\ turning\ moment (T_e) = \sqrt{(k_m m)^2 + (k_e . t)^2} \qquad \text{(Eqn.6a)}$$

$$Equivalent\ turning\ moment = \frac{\pi \times \tau \times d^2}{16} \qquad \text{(Eqn.6b)}$$

$$\frac{n_1}{n_{d1}} = \frac{n_{d2}}{n_s} \qquad \text{(Eqn. 7)}$$

$$length\ of\ belt = \frac{\pi}{2}(D_1 D_2) + x\frac{(D_1 - D_2)^2}{4C} \quad \text{(Eqn. 8)}$$

Heating capacity of the fryer $= \pi\ (d_1^2 - \ d_s^2)\ \rho\ \times p\ \times\ n_1$ (Eqn.9a)

Power required = E/t (Eqn.9b)

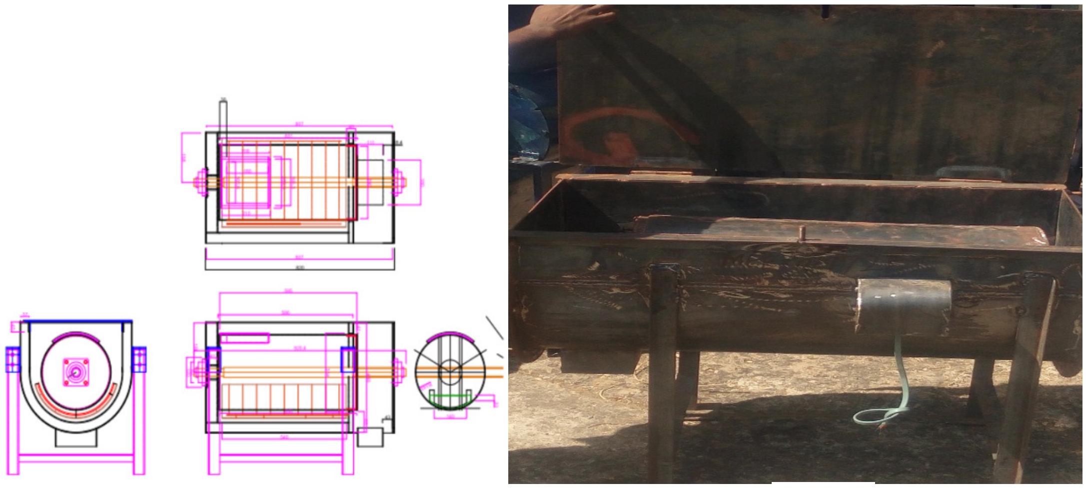
Bill of Engineering Materials and Evaluation (BEME)

Table 3.4: Bill of engineering materials and evaluation (BEME)

NAME OF MATERIAL	QUANTITY	COST (₦)
Metal sheet (3mm thickness)	2 pieces	2*20,000= 40,000
Angle iron	1 length	1*1,700=1,700
Flange bearing	2 pieces	2*2500=5,000
Square pipe	1 length	1*2000=2,000
Screw worm & paddle	-	1,500
Lagging material	-	3,000
Heating element	3HP	5,000
Shaft	1000mm	8,000
Electric motor	2HP	25,000
Thermostat	1 piece	3000
TOTAL		94,200

Design of Garri Frying Machine

Computer Aided Design (CAD) was used to create two and three dimensional drawings through AUTOCAD software. While it may be faster for an engineer to produce an initial hand drawing, it is more efficient to change and adjust drawing by computer.



(a) (b)

Figure 1(a): Engineering drawing for production (b) Fabricated garri frying machine

III. Result and Discussion

Performance evaluation

Garri mash with 42% moisture content was used to evaluate the performance of the machine.After frying, the moisture content was reduced to 11%.

% moisture content of cassava mash = 42%

% moisture content of fried garri using the garri frying machine = 11%

% moisture content of fried garri using the traditional method= 12%

Time taken to complete the frying process= 20 minute

Capacity of heating element = 3kw

Efficiency (traditional method) = $\frac{42-12}{42} \times 100 = 71.43\%$

Machine Efficiency = $\frac{42-11}{42} \times 100 = 73\%$

The intended design and implementation of an automated garri frying machine was achieved and was tested. The result obtained from the performance evaluation test showed 73% efficiency as against 71.43% in the traditional setup, indicatingan improvement in efficiency compared to the traditional and earlier known models like the UNN and UNIBADAN model. Our design is capable of producing 13kilogram of garri per hour.Based on the design, we recommend thatfuture design should make provision for alternate source of electricity other than public MAINS supply for the machine. This would further ensure the usability of the machine in areas without public MAINS supply. The design can however be replicated for larger garri production capacity.

Conclusion

Garri frying is an arduous and intricate operation which requires technique to achieve quality product from its frying. The best quality garri till date are still those predominantly obtained from the village technique (local technique) but it is time-consuming and health challenging for producers.

The design of an efficient electric garri frying machine as our design is of a great economic value to the agricultural sector of a nation such as Nigeria where local garri production is in large quantity. In an effort to make life easier and better for the rural farmers, this concept will go a long way in improving their health status as they would no longer be exposed to smoke and heat nor have to sit continuously for very long hours. Based on the computations done, a frying efficiency of 71.43% was achieved.

References

1. L.O.Sanni, O.B. Oyewole, A.A. Adebowale&K. Adebayo,"Current trends in the utilization of roots and tubers for sustainable development," Brouwer, I.D, Traore, A.S. &Trèche, S. ,Eds: In: Food Based Approaches for Healthy Nutrition. Ouagadougou: PresseUniversitaire, Proceedings of the 2nd International workshop. Pp. 123–138, 2003.

2. M.O. Onitilo, L.O. Sanii, I. Daniel, B. Maziya□dixon&A. Dixon, "Physicochemical and functional properties of native starches from cassava verities in southwest Nigeria" Journal of Food, Agriculture and Environment.Pp 108–114. 2007.

3. A.B. Abass, N.T. Dziedzoave, B.E. Alenkhe&B.D. James,"Quality Management Manual for the Production of Gari" Ibadan, Nigeria: IITA, Pp. 48. 2012.

4. W. Awoyale, "Training Manual for the Production of Cassava Products in Liberia" Ibadan, Nigeria: International Institute of Tropical Agriculture (IITA), Pp. 44. 2018.

5. C. C. Egbeocha1 , S. N. Asoegwu1and N. A. A. Okereke, "A Review on Performance of Cassava Peeling Machines in Nigeria"Futo Journal Series (FUTOJNLS) e-ISSN :2476-8456 p-ISSN : 2467-8325 Volume-2, Issue-1, Pp- 140 – 168. 2016.

6. I. Oduro, W.O. Ellis, S.K. Aryeetey, K. Ahenkora&J.A. Otoo, "Pasting characteristics of starch from new sweet□potato" Tropical Science, 40,Pp 25–28. 2000.

7. T.N. Lengha, "The use of technology by women gari producers in Bamunkumbit village, Northwest Region of Cameroon" IJRDO□Journal of Agriculture and Research, 3, Pp37–52. 2017.

8. O.S. Ogundipe, O.A. Oyelade&A.J. Farounbi, "Cassava processing in Nigeria: a case study of gari processing" Continental Journal of Agricultural Sciences, 7, Pp10–16. 2013.

9. A. J. Egba, "Design and construction of garri fryers for local use" Unpublished B.Sc. project report. 1987.

10. E. U. Odigboh,"Prototype Machines for small- and medium-scale harvesting and processing of cassava" In: Mechanization of harvesting and subsequent processing of agricultural products in Tropical Africa and the manufacturing of relevant agricultural implements, Yaounde, Cameroun, CIGR III: 323 - 338. 1985.

11. E.U. Odigboh and S.F. Ahmed,“Design of a continuous process frying machine” Proceedings Nigerian Society of Agricultural Engineers, 6, Pp65 - 75. 1982.

12. D.G. Ibe,“A partially mechanized village-scale garri production system” Proceedings of Nigerian Society of Agricultural Engineers, 3, Pp. 223- 229. 1979.

13. A. J. Egba,“Design and construction of garri fryers for local use” Unpublished B.Sc. project report. 1987.

14. E. U. Odigboh,“Prototype Machines for small- and medium-scale harvesting and processing of cassava” In: Mechanization of harvesting and subsequent processing of agricultural products in Tropical Africa and the manufacturing of relevant agricultural implements, Yaounde, Cameroun, CIGR III: Pp 323 - 338. 1985.