

DEVELOPMENT OF AUTOMATED GARRI FRYING MACHINE FOR DOMESTIC USE

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ABSTRACT

The design and construction of a domestic automated garri frying machine, was carried out to reduce drudgery involve in garri production and enhance the quality of garri production for family consumption, this was achieved by designing the machine, selection of relevant materials base on design specifications, various parts of the machine such as the frame, control box, frying pan, heating chamber and stirrer were constructed and assembled. The machine was powered by electricity and operated by a control box that regulates the heating elements and stirrer to ensure perfect coordination of heating and turning of the mash for maximum performance. The frying efficiency and throughput capacity of the developed garri frying machine was 83.89% and 181.20kg/hr respectively.

Keywords: Cassava, Domestic, Design, Automated, Garri, Fryer and Machine

1 INTRODUCTION

Cassava (*Manihot esculenta* Cranz) is a woody shrub native to South America of the spurge family, Euphorbiaceae [1]. It is a very important crop that is extensively cultivated as an annual crop in tropical and subtropical regions for its edible starchy tuberous root, a major source of carbohydrates [2]. [3, 4] reported that Cassava is the third largest source of food carbohydrates in the tropics, after rice and maize which is a major staple food in the developing world, providing the basic diet for over half a billion people. In Nigeria, as in most African countries, cassava is one of the most important carbohydrate sources which is eaten daily in various forms such as garri, fufu, and tapioca [5, 6]. According to FAOStat, Africa accounts for approximately 64% (192 million MT) of the world's cassava production, with Nigeria taking the lead with a production of over 59 million MT in 2019 [7]. [3, 8] reported that in Nigeria About 95 percent of cassava is consumed as food in various forms and less than 5 percent of it is used for industrial purposes. Most of the Cassava produced in Nigeria is processed into products such as fufu, garri, flour, lafun, abacha, tapioca, chips, tidbits, pellets, chin-chin, bread, and other confectioneries for food, while animal feed, starch, glue, ethanol and biogas for industries are the minor use of the crop [9]. Irrespective of these options, [3, 10] reported that garri (roasted granules) and edible starch (which is a by-product from drying the grated tubers) have maintained an important position in the food timetable of many households in Nigeria and other countries of the world, although starch consumption is most notable in the south-south region of Nigeria. [11] stated that nearly 75% of cassava produced in Nigeria is processed into garri. Garri is a granular food product produced by grating cassava roots into mash, fermenting and de-watering the mash into a wet cake, and roasting the wet material into gelatinized particles [11]. Garri is a creamy white coloured

grainy flour made from fermentation and gelatinization processes of cassava tubers which has faintly flavor and sour taste [4]. Gari is the most popular cassava food in many West African countries owing to its cheapness, ease of storage and preparation for consumption [12]. Due to its convenience and multiplicity of use, [11] reported that gari is gradually gaining a foothold in the international food market. Gari is made by peeling fresh cassava roots, then washing and grating, fermenting, dewatering or pressing, breaking of the cake, sifting, roasting, sieving or grading, and packaging [11]. [12] stated that among all the operations involve in gari production, frying operation otherwise known as garification is the most critical unit operation that determines the quality of the final product. [11] reported that, gari quality can be defined on the basis of its safety and fitness for use by the target consumer. Thus; in order to satisfy the taste of the consumers a processor needs to integrate quality into the processing operations in order to build quality into the product. Gari frying is a simultaneous cooking and dehydrating operation; the product is first cooked with the moisture in it and then dehydrated (sometimes with palm oil) to get the final gari product [13]. The moisture content of dewatered and sieved cassava mash is between 50 to 65 percent that has to be reduced to about 12% after the frying [9]. The process goes with cooking the cassava mash with the moisture in it and then followed by dehydration. Gari frying (Garification) is mostly carried out following the traditional method which involves cooking (gelatinization) the grated cassava mesh over high heat in a shallow earthen-ware of cast- iron pans over a wood fire with slow manual paddling which takes about 30 – 35 minutes [13] which is followed by drying the fried gari under low heat with faster stirring as [14] reported that heat intensity during frying affects the quality of the product, and therefore should be a factor to be considered in gari frying. The traditional process of gelatinizing and drying gari is carried out over wood fire by women who on the process inhale part of the hydrogen cyanide, carbon dioxide and other harmful gasses released by the gari and the fire wood, as well the manual stirring exposes the women to high heat of the fire and body pains due to the stirring position. [15] reported that the traditional method of gari frying is associated with high labour intensity, tediousness, unhygienic and low productivity compared with the time and labour invested. These problems associated with the traditional gari frying has been of concern to researchers due to which improved village method and mechanized method of gari frying were developed. Among which are: an improved village process which include special designed frying equipment among others developed by Levi and Cruche in 1956 as reported by [13] which totally eliminated the nuisance of smoke, increases the capacity and rate of frying and improves the fireplace. Other improved village method of gari frying are improved gari fryer developed at University of Ibadan which is made of a rectangular fire place oven with a chimney and a frying pan which is operated by two people sitting on both ends of the fire place. And a one-man operated Gari fryer with an elevated fire place oven developed by International Institute of Tropical Agriculture (IITA) Ibadan, Nigeria among others. Recently, researchers have been trying to further improve the process of gari frying through developing an environmentally friendly gari fryer by eliminating or reducing the use of fire wood, making the equipment self-stirring such as a power driven gari fryer developed by [13], horizontal gari fryer developed by [14], gari frying machine with user-defined temperature regulation and motion control system developed by Onu et al. (2020) and an improved gari fryer developed by [15]. Despite the improvements achieved in the machines produced, such as reduction in the smoke, increased capacity and rate of frying and improved working environment, most of the machines are design to operate with a single fuel type (Fire wood, Charcoal or electric), some of these machines are still wood or charcoal fired which still poses the problem of smoke and contributing to global warming, while others are made of several components that are very expensive to acquire, operate and maintain. Some of the machines requires a complete deferent operating technique from the traditional method. This work is aimed at developing a system that will improve manual gari frying operation which is a batch process operation by retaining the operational principle with introduction of mechanization to enhance throughput and also obtain a good quality gari. This study will merge traditional technology and the mechanized systems, to produce a desirable, affordable, available and acceptable machine that will prevent caking of the cassava mash and ensure that the final product is cooked and dehydrated. The vertical paddle rotary gari frying machine will have the capability to produce good quality gari for human consumption in commercial quantity at a faster rate.

2 METHODOLOGY

This section considers the materials and method utilized in the execution of the work, design analysis of the vertical paddle rotary gari frying machine, principle of operation of the system and required system assembly.

2.1 Description of the vertical paddle rotary gari frying machine

The gari fraying machine consists of the main frame, frying chamber, stirring shaft, stirring pedals, heating unit and discharge chute as well as bearings, electric motor, gear box, speed control and power unit as shown on Figure .

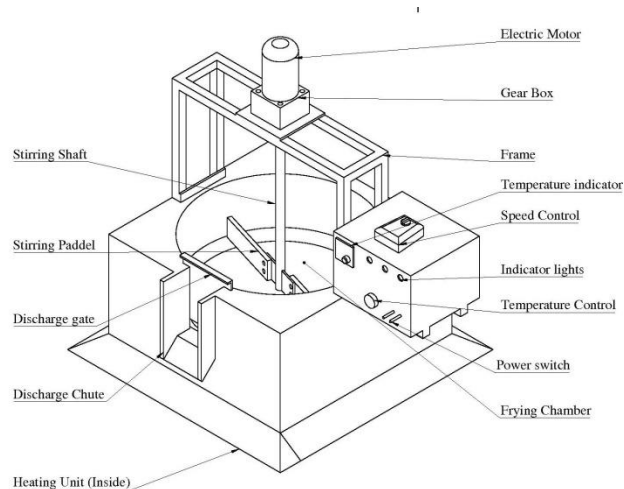


Figure 1. Developed Gari Fryer

The main frame is made of 40 mm by 40 mm by 5 mm thick mild steel square pipe serves as the main supporting structure upon which other component parts of the machine are mounted. The cylindrical frying chamber is made of 5 mm stainless steel sheet of 5mm, 800mm diameter and depth of 304.8mm. The top of the frying chamber was designed to be open which serves as inlet for sieved cassava mash into the frying chamber. In addition, it provides exit for vapour during frying operation aimed at preventing formation of vapour condensate within the chamber and also provides means for process inspection. The frying chamber is attached to the base where the heat source is located (cooking gas, electric heater and/or charcoal). The fried cassava mash (gari) discharge chute is located down side of the frying chamber. An electric motor (single phase/1.5 kW/2 Hp) fitted with a reduction gear of variable speed (20 rpm to 100 rpm) was used to propel the frying paddle shaft and paddle to allow for the slow and gradual movement of the gari within the frying chamber. The machine also has a control box for the control of the paddles. The frying chamber has its walls insulated to reduce heat loss. Heating chamber particularly generates an amount of temperature range that heats the cylinder up to 100 °C. The surroundings of the heating tray vicinity and the walls of the container are properly lagged to reduce heat loss. The burner has a control valve for regulating the temperature level while using electricity. A temperature sensor and temperature indicator is also fitted to the fryer indicating the temperature of the frying chamber.

2.2 Design of the Individual Components

The components of the fryer designed are as follows: frying compartment, delivery chute, delivery chute cover, stirrer shaft, bolt and nut, machine base/ frame and heating compartment.

2.2.1 Angle of friction of cassava mash

The friction force of the wet gari mash was determined by calculating the angle of friction of the mash on stainless sheet using Eq. 1

$$\tan \alpha = \frac{L_c}{D_t} \quad 1$$

Where, α = Angle of friction, Length of the pan, Diameter

2.2.2 Bulk Density of Cassava Mash

Mass of density of cassava in the pan was determined using Eq. 2

$$M = \frac{\rho}{V_m} \quad 2$$

Where, ρ = Bulk density of cassava of mash, V_m = Volume of the cassava of mash = 0.00587m³. M = mass of cassava mash in the pan = 3kg.

2.2.3 Heat required for the drying

The quantity of heat required to fry the cassava mash was determined using Eq. 3 with the consideration that the temperature of frying will be 100 °C and atmospheric temperature is 35 °C

$$Q = mc\Delta T \quad 3$$

Where, Q = Quantity of heat required, m = mass of the mash, kg, C = Specific heat capacity of the water in the mash = 4.2J/kg°C. ΔT = Change in Temperature range = 65°C.

2.2.4 Volume of frying pan

The volume of the pan was determined using Eq. 4

$$V_p = \pi r^2 h \quad 4$$

Where, V_p = Volume of pan, r = pan radius = 400mm, h = height of pan = 304.8.

2.2.5 Volume of cassava mash in the pan

The volume of the mash in the pan was determined using Eq. 5 considering that the pan takes only one third of its capacity.

$$V_m = \frac{1}{3} \times V_p \quad 5$$

Where, V_m = Volume of mash in the pan, V_p = Volume of the pan

2.2.6 Design of the stirrer Shaft

The stirrer shaft was designed based on strength using Eqs. 6 to 9 Length of shaft was calculated using Eq. 6 [15].

$$L_s = F_h + P_d - b_c \quad 6$$

Where, L_s = length of shaft, mm, F_h = frame Height, mm, P_d = depth of frame, b_c = bottom clearance. Torque acting on the shaft was determined using Eq. 7

$$T = \frac{60P}{2\pi N} \quad 7$$

Where, P = power of the motor, W, N = Maximum speed of shaft, rpm. To account for additional starting torque, a service factor is assumed to be 1.5. Then, $T_m = 1.5 \times 14.25 = 21.375 Nm$. The diameter of the shaft was determined using equation 8.

$$Z_p = \frac{\pi d^3}{32} \quad 8$$

Where, Z_p = Section Modulus of the shaft, d = diameter of the shaft, mm. According to maximum shear stress theory permissible shear stress can be determined using Eq. 9.

$$\sigma_s = \frac{T_m}{Z_p} \quad 9$$

Where, σ_s = permissible shear stress, $N/mm^2 = 96 \times 10^6$ for mild steel. Then Z_p in Eq. 8 = Z_p in Eq. 9, and From standard, a shaft with 20 mm diameter was selected.

2.3 Construction of the vertical paddle rotary gari frying machine

The gari fryer was constructed from mild steel square pipe (frame), stainless metal sheet (frying pan), mild steel sheet (outside cover and paddle attachment), shaft steel, ply wood (for paddles), electric heating element, gas burner, temperature sensors, temperature control, insulation material and 2 hp electric motor. The gari frying machine was constructed by cutting the materials to the required sizes and welded using electric arc welding machine to form components of the fryer. The formed components were then assembled together and the other components such as the electric motor, gear box, power unit, temperature sensor, temperature indicator and motor speed controller were attach to the assemble components at their appropriate positions to complete the vertical paddle rotary gari frying machine as shown on Plate 1.



Plate 1. Constructed Vertical Paddle Rotary Gari Frying Machine

2.4 Operation of the vertical paddle rotary gari frying machine

During operation of the vertical paddle gari frying machine, heat is generated from the electric heating element or the gas burner or charcoal which heats the gari held in the frying chamber which cooks the gari at the initial stage of the operation and dries the gari at the latter stage of the drying during which the electric motor rotates the paddles through the paddle shaft for stirring purpose to prevent burning of the gari as well making the frying and/or cooking even throughout the whole mash contained in the pan. At the same time, the temperature indicates the temperature of the mash on the temperature indicator making the temperature control switch off and on the heating elements when the temperature of the mash goes above and below the required level respectively while using electric as the source of heat. While using gas or charcoal as the heating source, the temperature control is done manually by the operator when the temperature goes above or below the required level as indicated by the temperature indicator. At the end of the frying a batch of the gari indicated by uniform gelatinization at moisture content (10 – 12 %), it is offloaded by opening the discharge gate using a spatula.

2.5 Performance evaluation of the vertical paddle rotary gari frying machine

The performance of the constructed vertical paddle gari frying machine was carried out by frying 3 kg of gari mash 3 times with initial moisture content of 38.0% w.b. at paddle speed of 30rpm to assess its performance. The performance indices (frying efficiency and throughput capacity) were then calculated using equations. 10 and 11

$$F_E = \frac{M_o}{M_f} \times 100 \quad 10$$

And $Th_C = \frac{M_o}{t} \times 100$ 11

Where, F_E = frying Efficiency, %, M_o = mass of gari obtained, kg, M_f = mass of cassava mash fed into the frying pan during each operation, kg, t = Frying time, hr.

3 RESULTS AND DISCUSSIONS

Before the design of the vertical paddle rotary gari frying machine, some relevant physical and mechanical properties of cassava mash were determined. These properties are bulk density, moisture content and frictional angle. The results of those properties as presented Table 1 indicated that the average moisture content of cassava mash before frying was found to be 38.0% with a bulk density of 511kg/m³. The angle of friction of the mash on stainless steel sheet is 19.30 and the bulk density of gari after frying was found to be 429kg/m³.

Table 1. physico-mechanical properties of cassava mash and bulk density of gari

Replication	Moisture content of cassava mash (%)	Bulk Density of cassava mash Kg/m ³	Angle of friction of cassava mash on Stainless steel	Bulk density of fried gari Kg/m ³
1	38.0	500	19.4	427.0
2	39.0	520	19.2	429.8
3	37.4	513	19.3	429
Mean	38.0	511	19.3	429

The performance of the gari fryer as presented on Table 2 indicated that the average frying time 3 kg of gari mash takes about 50 sec with a frying efficiency of 83.89% with a throughput capacity of 181.2 kg/hr.

Table 2. Performance of the developed Gari fryer

Replication	Frying Temp. °C	Frying Time Sec	Weight of Gari Kg	Frying Efficiency %	Throughput capacity Kg/hr
1	60.00	50.00	2.38	79.33	171.36
2	60.00	50.00	2.56	85.33	184.32
3	60.00	50.00	2.61	87.00	187.92
Average	60.00	50.00	2.52	83.89	181.20

4 CONCLUSIONS

The developed vertical paddle rotary gari frying machine is cheap as it is constructed using low cost readily available materials which can be produced by local artisans and affordable by local gari processors to improve their production. The machine also will help eliminate the drudgery involve in stirring gari during frying as the machines stirs the gari automatically without the involvement of human, reduce in the cost of frying gari and eliminate the health risk of inhaling toxic gasses by the workers and reduce the negative effect of using firewood to the environment as it uses environmentally friendly fuels with a very high frying efficiency and throughput capacity of 83.89 % and 181.2 kg/hr respectively.

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