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Design and Development of Power Driven Gari Fryer

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Authors' contributions

This work was carried out in collaboration between all authors. Author SAA is the principal investigator of the research, he coordinated the equipment testing, did statistical analysis and put up the research report for publication. Author WBA supervised the implementation of the research. Author MOS did engineering design analysis of the equipment. Author CFN did engineering drawing. Author KKE coordinated the implementation of the design. Author AAO supervised the implementation of design. All authors read and approved the final manuscript.

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ABSTRACT

A continuous process power driven gari fryer was designed, fabricated and tested at the Federal Institute of Industrial Research, Oshodi. (FIIRO), Lagos, to fry large quantity of cassava mash using locally available materials. The fryer which consists of major two sections; one to gelatinize cassava mash while the drying of the mash take place in the other section. The essential components of the fryer include feeder, frying troughs, rotating paddle arrangement, central shaft, coupling, top cover, gas burners, discharge sprout, main frame, insulation wall, sprocket and internal combustion engine. In operation, the rotating paddles convey the cassava mash during the gelatinization and drying process from the feeding point to the discharge sprout to obtain finished gari product. At constant speed of 8 rpm, the result showed that the time of frying ranged between 14 minutes to 17 minutes with an output of 83.2 kg/hr while the percentage yield of gari obtained ranged from 52.8% - 74.7%. Thus it is established that the capacity of the fryer is 500 kg per day

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as against the manual method of frying where 5 kg of gari is obtained within 30 minutes (80 kg/day) for 8 hours frying operation in local cassava processing industry in Nigeria. Hence, this makes the fryer to be suitable for gari production for small to medium scale enterprise.

Keywords: Gari frying; gelatinization; drying; cassava mash.

1. INTRODUCTION

Gari is a processed fermented product from cassava which is consumed in Nigeria as well as in most countries of the West African Coast and in Brazil. Its ability to store well and its acceptance as a convenience food are responsible for its increasing popularity in the urban areas of west and central Africa. Gari is creamy – white partially gelatinized roasted free flowing granular flour made from cassava roots [1]. Among many food products derived from cassava, gari is the most popular [2], The processing of gari involve the peeling, washing and grating of fresh cassava root; the resulting mash is put in a porous sack and allow to ferment for 3 – 5 days under heavy weight or screw press. After fermentation, the mash is dewatered with screw press, pulverized, sifted and roasted in iron pan to obtain gari [3]. The roasting process which usually dextrinizes the starch and dries the granules is called garification. Gari is commonly consumed either as gelatinized dough (EBA) served with sauces/soups or soak in cold water with sugar and roasted groundnut. It is a good sauce of energy and fiber. Its cheapness, ease of storage and preparation for consumption have combined to make it an important food item in Nigeria Gari grains are classified into five categories. These are: Extra fine grains Gari, Fine Grain Gari, Coarse Grain Gari, Extra Coarse Grain Gari and ungraded Gari: [4].

The most critical unit operation that determines the quality of the final product in gari production is the frying operation otherwise known as garification [5]. Gari frying though, a dehydration process, is not a straight forward drying process. It is not possible to produce gari from cassava pulp by just passing heated air through it. The product from such an operation would be dried cassava pulp or granules and not gari. The basic technology of gari making involves partial gelatinization of cassava mash and finally drying the gelatinized mash to obtain the end product. In simple term this means cooking and drying of cassava mash in a continuous operation, i.e. two in one unit operation. Hence, gari frying is an arduous and intricate operation that needs good understanding of the factors that affects the quality of the final product. Therefore, garification is a simultaneous process of cooking and dehydration operation. The processing of cassava into gari is largely done manually. However, some of the unit operations have been mechanized, but peeling and frying are yet to be fully mechanized [6].

There are various methods of frying gari which are traditional, improved village method and mechanized method [5]. Traditionally, this indigenous science has been defined when one observes a village woman doing the cooking (gelatinization) of cassava mash by supplying high heat and carrying out slow paddling. The drying is done at a lower heat and faster paddling intensity to facilitate the escape of moisture from the product. Gari is fried in shallow earthen-ware of cast- iron pans over a wood fire. A piece of calabash sections or spatula-like paddles of wood is used to press the sieved mash against the hot surface of the frying pan but it must be scrapped quickly and stirred constantly to keep the material moving to prevent it from burning until frying is completed when it reaches a temperature of 80°C to 85°C. The process takes 30 – 35 minutes, with the moisture content of the final product reduced to about 18% [7]. Since all these operations are manual the processor naturally inhales part of the hydrogen cyanide evolved and this is hazardous to human health. The discomfort due to heat and the sitting position of the operator have been of concern to researchers. The preparation of gari from cassava has basically been done according to traditional processing technique and through this method, the best quality gari is obtained but it is time consuming, tedious and lends itself to health hazard for the operator. Hence, efforts should be made to mechanize the garification operation for large scale processing.

Levi and Cruche [8] developed an improved village process which include special designed frying equipment among others. Thus, some innovations and improvements have been initiated and carried out in the equipment and the general set-up of the village method so as to alleviate the problem encountered in the operation. Improved village methods have some numbers of advantages over traditional method of frying. The nuisance of smoke was totally eliminated, the capacity and rate of frying were increased and fireplace is improved. The following equipment are improved village methods: (i) UNIBADAN (University of Ibadan) improved Gari Fryer is made of a rectangular fire place oven with a chimney and a frying pan. The fryer is operated by two people sitting on both ends of the fire place [9]. (ii) IITA (International Institute of Tropical Agriculture, Ibadan, Nigeria) model is a one-man operated Gari fryer with an elevated fire place oven. The frying pan is circular, made of cast iron and is smaller than the normal traditional pan in diameter but has more depth. The pan sits on the circular oven which has a chimney. (iii) RAIDS (Rural Agro- Industrial Development Scheme) developed by the Nigerian Federal Department of Agriculture and Rural Development is an improved fryer package for the Rural processor of gari. It is similar to the UNIBADAN model and it is rectangular in shape. Further development of gari production equipment took place in Brazil and West Africa. The planetary dryer was a Brazilian technology. The rotary louvre fryer-dryer was a design of 12T Cote D'Ivoire. The open type paddled dryer was a design credited to PRODA and FABRICO in Nigeria. All the surveys carried out have shown that the gari produced by various equipment has one deficiency or the other affecting its quality. The Brazilian planetary machine and 12 T dryer produce gari that is not properly gelatinized as evidenced by a lot of floury powder present in the finished product. The gari product from PRODA and FABRICO machines has low shelf life as the moisture content is about 15%. The moisture content of standard gari is 10% and below for a shelf life of over one year.

In the past years, a lot of Research has been carried out to fully mechanize gari frying operation but most of these designs did not produce the desired and acceptable product for the consumers. Perhaps, the designer of those equipment did not take into consideration the critical specifications of the existing local technology. In developing any mechanized gari fryer the following features have to be considered as basic requirements: i. a continuous process operation leading to mass production of moderate capacity. ii. A regulated temperature mechanism which ensures simultaneous cooking and dehydration without roasting to desired moisture content after a specific period. iii. A mechanism that provides both stirring and lump breaking actions so that uniform cooking and dehydration in the entire mass is ensured and the desired texture produced. iv. An arrangement of paddles so as to produce a conveyor effect which will give the product a forward movement during the process [5]. There are few mechanized gari processing plants in the Nigerian Markets which are found to be performing well as regard the quality of gari.

Federal Institute of Industrial Research, Oshodi (FIIRO), Lagos, started the research and development in the area of mechanization of gari frying operation in Nigeria. The need to reduce drudgery associated with cassava frying and drying leads to evolution of various gari frying equipment by FIIRO. A pilot plant of capacity of one ton per day was designed in 1984 by FIIRO and the equipment built on license to Messers Newell Dunford Engineering Ltd. of Surrey, England. The set of equipment contained, among others, a rotary kiln for gari cooking by gelatinization and a louvre dryer for final drying of gelatinized gari. A technical feasibility test—running of the plant was carried out to determine the economics of the process. Although good quality gari was produced, cost analysis showed that the production scale was uneconomic. Also, Brazilian model gari fryer, this fryer consists of a Semi- circular steel plate and operates in a batch drying process. Atop the plate is a large ring geared mashed to an inner annulus which is connected to a vertical shaft with large steel paddles. A specific batch of sieved cassava is dropped into the circular plate and the eccentric paddles shift the mass circularly to produce a dry product. Lastly is the power driven gari fryer which was otherwise tagged "UNIDO sponsored FIIRO gari fryer". This model of gari fryer has been on the accurate simulation of the traditional technique being that it consists of two units for gelatinization of cassava mash and final drying of the product to obtain quality gari.

2. MATERIALS AND METHODS

2.1 The Power Driven Gari Fryer

The power driven gari fryer is a simple continuous process plant which consists of a semi-circular steel plate with rotating paddles fixed to a steel shaft slowly rotating on the axis of drum. The paddles are eccentrically located in such a manner that their motion compels the frying gari granules to move from one end of the plate to the other. The fryer which consists of major two sections; one to gelatinize cassava mash while the drying of the mash take place in the other section. The essential components of the fryer include feeder, frying troughs, rotating paddle arrangement, central shaft, coupling, top cover, gas burners, discharge sprout, main frame, insulation wall, sprocket and internal combustion engine.

2.2 Design Analysis

2.2.1 Design consideration

The design of the gari fryer-dryer which evolved by FIIRO/UNIDO is based on the principle of a two in one unit operation whereby the equipment has two compartments, one for the garifier and the other for the dryer. The type of gari fryer-dryer considered for the design is paddled type with continuous transfer mechanism. The garifier section has fewer paddles than the dryer side. Also the dryer side is open at the top while the garifier is partially closed. This would allow partial gelatinization at the garifier and drafting by escape of vapor at the dryer side.

The unit operations are therefore the feeder for input material, the garifier for the cooking of the material and the dryer for the roasting of the cooked product. It was considered to design for a capacity of 500 kg per 8 hour day finished product. This was used as a base for the analysis of input raw material and by products. The size of any dryer has been shown to be estimated according to a length to diameter ratio L/D which, for commercial practice, is a value between 4 and 10. Also in conventional design, the dryer is sloped at an angle between 0° and 10°.

2.2.2 Product retention time

The design equation of a dryer is empirically given as:

$$t = \frac{L/DR}{C_0(a-K_oV)} \tag{1}$$

Where t = product retention time; L the dryer length; Co. a constant between 0 and π; D the dryer diameter; R the r.p.m of shaft rotation; 'a' the slope of dryer; Ko a constant; V the linear velocity of the product being processed. The arrangement of paddles in the gari fryer-dryer and the radial arms have direct effect on the retention time of product.

2.2.2.1 Residence time during gelatinization

Using equation 2, the residence time

$$t = Ln/2\pi N tan\,\theta = 15.6 \text{ minutes} \tag{2}$$

Where, L is length of fryer (235 mm), r is width of paddling area (20 mm), N is rpm of shaft (16 rpm), n is no of starts of paddles (2) and θ is angle of inclination of the paddle (8.5°)

2.2.3 Design of the paddle system

Considering a particular paddle inclined at angle θ as shown in Figures 1 and 2, the arrangement is approximately similar to lead screw having a pitch and helix angle θ. The pitch of the paddle was determined according to Olanrewaju et al. [10].

Lead is pitch for a single start arrangement so that

$$\frac{Lead\ (Pitch)}{2\pi r} = \tan\theta \tag{3}$$

Where r is the width of the functional part of the paddle.

For a multi-start, lead = Pitch x number of start i.e. Lead = Pitch x n

$$\text{Pitch} = \frac{2\pi r \tan\theta}{n} \tag{4}$$

For every revolution of shaft, the material carried by a paddle moves through a length equal to the pitch, P.

2.2.4 Design of shaft

The main rotating shaft of the dryer carrying the paddles was determined using the standard procedures according to equation 5 [11]

$$d = \left[\frac{16}{\pi Sm}\sqrt{(Cm\ \ M)^2 + (C_0T)^2}\right]^{\frac{1}{3}} = 61.3\ mm \tag{5}$$

where d = shaft diameter; Sm the maximum shear stress of the shaft material; M the maximum bending moment; T the maximum torsional moment; Cm a constant called bending factor; C_o a constant called torsion factor.

Considering similar case for the dryer side, the loading is as shown in Figure 6.

2.2.4.1 Shaft diameter required

Let the ultimate tensile stress for the shaft material be 400 N/mm^2

Factor of safety = 12, Allowable stress, τ_{max} = $\frac{400}{12} = 33.3\ N/mm^2$ = 3.4 kg/mm^2

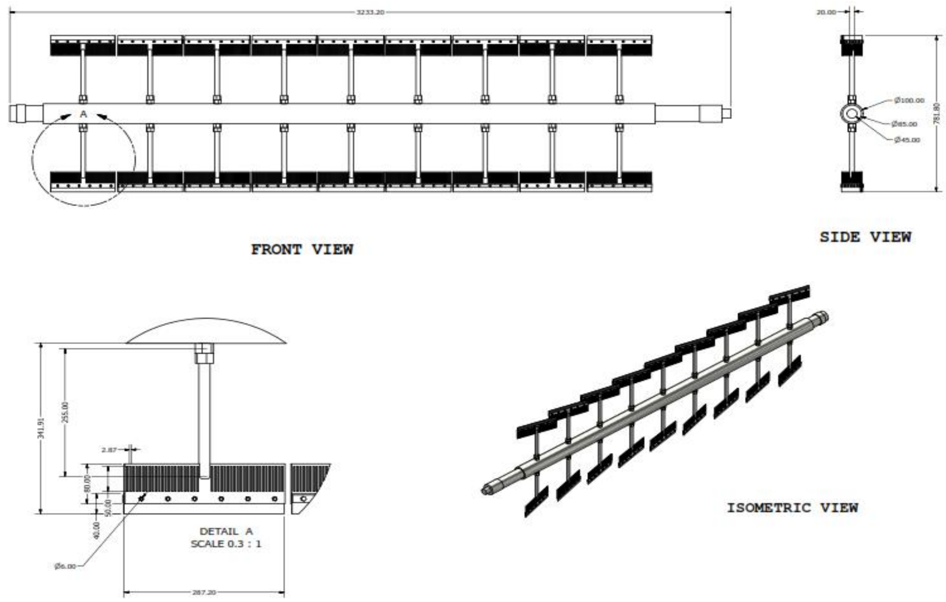

Figure 1. Shows the arrangement of two-start paddling system

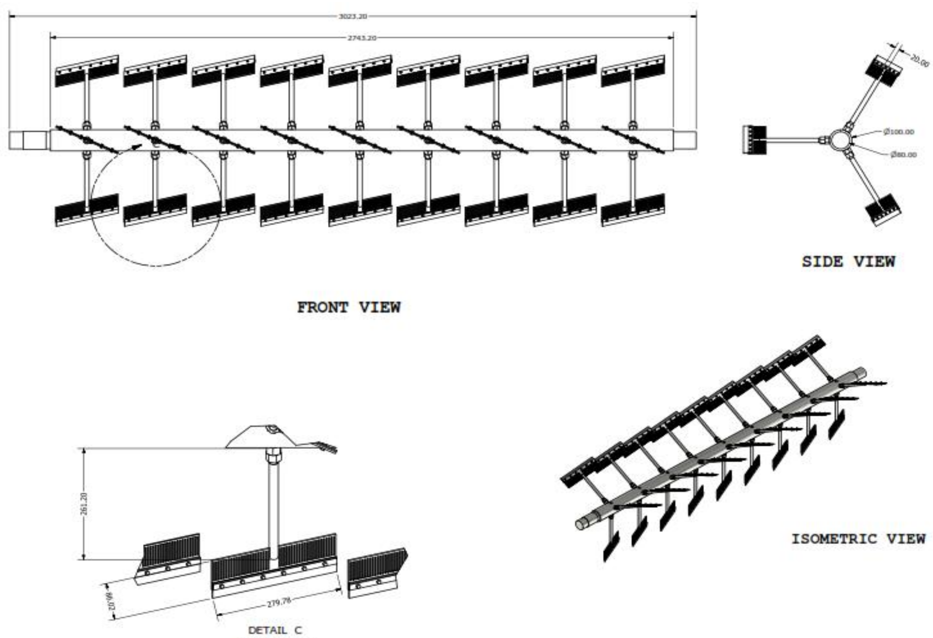

Figure 2. Shows the arrangement of three-start paddling system

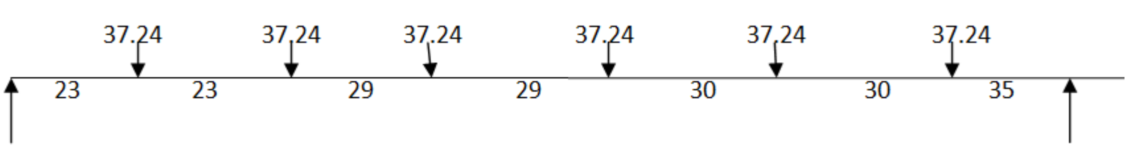

Figure 3. Fryer shaft loading

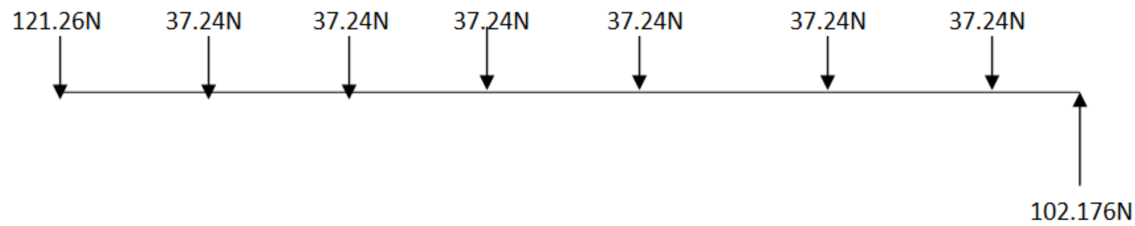

Figure 4. Dryer shaft loading

Shaft diameter is given by.

$$d_0^3 = \frac{16}{\pi\tau_{max}} \sqrt{(K_b M_b)^2 + (K_t M_t)^2}$$

Where bending factor, K_b and torsional factor, K_t are 3.0 and 2.5 respectively.

$$d_0^3 = \frac{16}{\pi \times 3.4} \sqrt{(46859 \times 3)^2 + (2.5 \times 25200)^2} \;,$$
$$d_0 = 61.3\ mm$$

A shaft of 65mm diameter is used for the design

2.2.5 Power required to drive the fryer – dryer

2.2.5.1 Rating of the screw conveyor feeder

Horse power required to drive a screw conveyor is given by equation 6 according to Bryon [12]

$$\text{h.p} = 1 + \frac{ALN + CWLF}{1{,}000{,}000} = 1 + \frac{(21\times2\times35)+(4.15\times58.53\times2\times1)}{1{,}000{,}000} \cong 1. \quad (6)$$

Where L is length of conveyor (ft), N is r.p.m of screw, C is ft^3 of material conveyed per hour, W is density of material transferred lb/ft^3

Where F range from 0.6 – 1.2 (F can be taken as I for convenience), N is 35 r.p.m, L is 3 ft, C is 4.15 ft^3/hr

W = 58.53 lb/ft^3

2.2.5.2 Rating of fryer – dryer drive

Maximum torque, M_t = 25200 kg-mm = 2517.4 N-mm = 2.571 KN-mm

$$\text{h.p} = \frac{2\pi N\, M_t}{60} = \frac{2\pi \times 16 \times 2.571}{60} = 4 \quad (7)$$

Where N = 16 r.p.m

2.2.5.3 Overall rating of main drive

Total power required: = power needed for feed screw + power for driving fryer-dryer i.e Overall power needed = 1 + 4 = 5 h.p or 4 kW

An electric motor, geared to speed 16 rpm, rated 5 h.p or 4 kW, 3 phase, 50 Hz, will be required for the design.

2.2.6 Material balance analysis

2.2.6.1 Mass Balance

It was considered to design for a capacity of 500 kg per 8 hour day finished product. This was used as a base for the analysis of input raw material and bye products.

2.2.6.2 Mass of 100% Dry Gari

For an output of 500 kg gari per day of 8 hours having 8% moisture content; Taking X kg to be the mass of 100% dry gari. From % moisture content formula:

Then $\frac{500 - X}{500} = 0.80, \quad X = 460\ kg$

2.2.6.3 Mass of Cassava to be processed

The mass of water to be removed from the cassava cake is calculated from the relationship given by Ichsani and Dyah [13] as:

$$m_w = m_i \frac{M_o - M_f}{100 - M_f} \quad (8)$$

Where; m_w and m_i are the mass of moisture to be removed and initial mass of cassava cake respectively in kg Mo and M_f are the initial and final moisture contents of cassava cake respectively in % (wet basis).

Taking y kg to be total mass of cassava needed to produce 500 kg of gari of moisture content 8% and taking Z kg to be mass of water associated.

$$y = (Z + 460)\ kg$$

% mass of water associated is given by;

$\frac{Z}{Z + 460} = 0.70$, $Z = 1075\ kg$ (Since moisture content of wet grated cassava = 70%)

Mass of cassava needed, y = 1075 + 460 = 1535 kg

2.2.6.4 Volume of cassava paste to be pressed

Bulk density was determined by the fraction of the weight of cassava mash over the volume of same in a graduated measuring cylinder as described by Onwuka [14]. For a paste of bulk density 979.15 kg/m^3 and grated cassava of 1535 kg.

$$Volume\ of\ paste = \frac{Mass}{Density} = 1.55\, m^3 \quad (9)$$

2.2.6.5 Mass of cassava mash after pressing

Moisture content can be reduced from 70% to 50% when grated cassava mash is pressed.

Taking the mass of water left in the pressed cake to be V kg. $\frac{V}{V+460} = 0.5$, $V = 460\, kg$

Mass of cassava mash after pressing= mass of 100% dry gari + mass of associated water left in the pressed cake = $460 + 460 = 920\, kg$

2.2.6.6 Amount of water pressed out

Amount of water pressed out = 1535 – 920 = 615 kg

2.2.6.7 Mass of moisture in the gelatinized mash

Volume of cake
$\frac{920}{979.15} = 0.94\, m^3 per\ 8\ hour\ day.$

Taking the moisture content after cooking to be 40% and w kg to be the mass of moisture in the cooked mash.

$\frac{w}{460+w} = 0.40$, w = 307.2 kg

2.2.6.8 Amount of vapor removable during cooking

Quantity of feed into the dryer = 460 + 307 = 767 kg per 8 hr. day

Mass of vapor removed at gelatinization = 920 – 767 = 153 kg

2.2.6.9 Amount of vapor to be ejected during drying

Taking M kg to be the vapor left after drying and the moisture content after drying to be 8%, Then $\frac{m}{m+460} = 0.08,$ So $m = 40\, kg$. Hence, gari produced = 460 + 40 = 500 kg

Amount of vapor removed during drying = 767 – 500 = 267 kg.

The mass balances were summarized in Table 1.

2.2.7 Design of screw conveyor feeder

For 500 kg of gari product per 8-hour day, the amount of material to be fed into the gari fryer from previous calculations is 920 kg of pressed mash. So the required conveying capacity $= \frac{920}{8} kg$ per hour = 115 kg/hr. Volume to be conveyed = $\frac{115}{979.15} = 0.1174\, m^3$ (i.e. v = 0.1174 x 10^6 cm^2)

Now Ift^3 = 28.3 x 10^3 cm^2, V =$\frac{0.1174\times10^6}{28.3\times10^3}\ ft^3$, $= \frac{117.4}{28.3} = \frac{4.15 ft^3}{hr}$. (10)

From hand-book, material to be conveyed is in the class of wet malt, starch, etc. denoted as class 3 with factor 'X' between 0.66 and 0.75. Taking 'X' as 0.7 and speed limit of 35 rpm.

$V = \frac{4.15}{0.7} = 5.93\, ft^3/hr;$ From capacity chart, screw diameter = 4'' = 100 mm; pitch $= 2'' = 50\ mm.$

The designed screw conveyor has the following details:

Diameter = screw conveyor which has the following details:

Screw diameter =100 mm, Pitch =50 mm, Speed =35 rpm, Length= 600 mm

Table 1. Summary of analysis of mass balance

Unit operation	Input (kg)	Output (kg)	Water Removed (kg)
Press (Dewatering)	1535	920	615
Fryer (Gelatinization)	920	767	153
Dryer (Final drying)	767	500	267

2.2.8 Equipment heat balance

The heat balance was determined according to standard procedures.

Heat delivered by burner = losses + heat transferred through fryer shell to the product.

Assuming 20% of this heat is lost to the surrounding and heat transferred through the fryer shell is Qs. Taking heat supplied by burner to be Qg

$$Q_g = 0.2Q_g + Q_s \tag{11}$$

Since heat Q_s is transferred by conduction, hence it was determined according to

$$Q_s = -KA\frac{dt}{dx} \tag{12}$$

Where A is surface area of material of shell, K is the thermal conductivity of shell material, $\frac{dt}{dx}$ is the temperature gradient.

$$Q_s \int_{x_1}^{x_2} dx = -KA \int_{T_1}^{T_2} dT.$$

Where boundary dimensions are x_1, x_2 for thickness of material and T_1, T_2 for surface temperatures.

$Q_s(X_2 - X_1) = -KA(T_2 - T_1)$, i.e.

$Q_s(X_2 - X_1) = KA(T_1 - T_2), (T_1 > T_2)$ Or $Q_s = \frac{KA(T_1-T_2)}{(X_2-X_1)}$

In this case, $T_1 - T_f$ = 300^0C from experiment.

$T_2 = T_m = 248\,^0C$

$X_2 - X_1$ = material thickness = 3 mm

Assuming that 25% of the shell surface is covered by the gas oven using standard equation;

$$\text{Area}, A = \frac{\pi \times r_g \times L_g}{4} = \frac{\pi \times 0.23 \times 2.345}{4} = 0.423\ m^2 \tag{13}$$

$Q_s = \frac{KAT}{X}$ = 48.5 x 0.423 x 17.3 x 10^3 = 354918.15 KJ/8 hour day = 12. 32 KJ/s

Using equation (9), $Q_g = 0.2Q_g + 12.32$ or $Q_g = \frac{12.32}{0.8} = 15.4\ KJ/s$

Heating value, (λ_g) of butane gas is 126400KJ/m^3 k

Gas consumed $= \frac{15.4}{126400} = 1.218 \times 1.218 \times 10^{-4}\ m^3/s$ = 3.5m^3/8 hour day.

Density, g of butane gas = 2.58 kg/m^3. Gas consumed = 2.58 x 3.5 = 9.05 kg/day

So a 50 kg butane gas bottle will be used up in 5 days, working 8 hours per day, i.e. one working week.

The design equation was used to build up Table 2.

2.3 Orthographic and Isometric Drawings

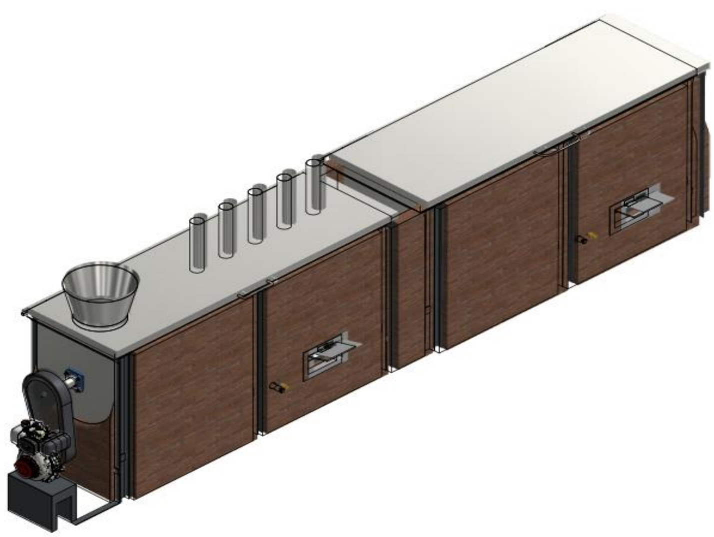

Figure 5. Isometric view of the fryer from the right

Figure 6. Isometric view of the fryer showing the paddles and inner part of the troughs

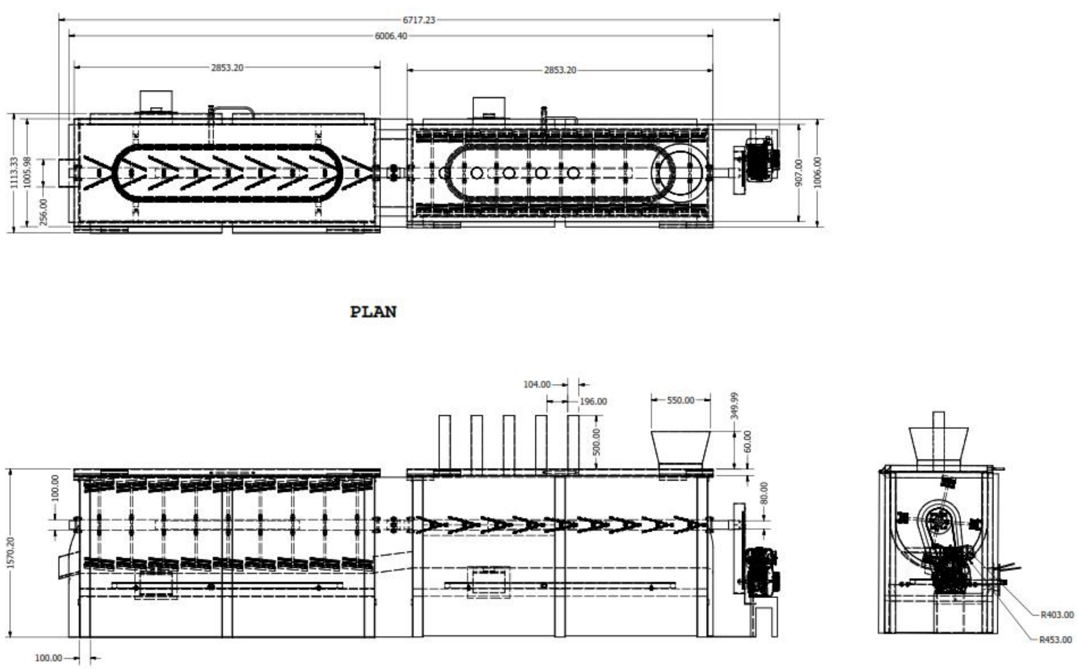

Figure 7. Orthographic view showing the garifier and dryer of the fryer

Table 2. Summary of the equipment design information

	Features	Fryer	Dryer
Fryer/dryer	Shell diameter	460 mm	700 mm
	Length	2345 mm	2440 mm
	No. of paddles	12	18
	Paddle arrangement	2-start	3-start
	Paddle inclination	8.5°	15°
Resident time	Gelatinization & Drying	8 minute	10 minute
Butane gas consumption per 8 hours day	16 kg		

2.4 Fabrication and Construction of the Gari Fryer

The fabrication of the power driven gari fryer was carried out at the Engineering Workshop, Federal Institute of Industrial Research, Oshodi, Lagos. Nigeria. Figures 5, 6 and 7 show the engineering drawings of the gari fryer. The frying, drying troughs and the end plates were fabricated from standard lengths of 2 and 3 mm thick of mild steel. Guillotine machine was used to cut the mild sheet of gauge 2 and 3 mm into sizes to form the frying trough, drying troughs and top cover. Mild steel was selected since the fryer is a prototype equipment for small to medium scale processors. The central shafts which carried the paddles were fabricated from mild steel rods of diameter 65 mm and lengths 3000 mm each which were machined to 61 and 63 mm diameter on the lathe machine. The two central shafts in the frying and drying chambers were connected together using coupling. The paddles were also fabricated using mild steel. Each of the paddle was spring loaded which was connected to the central shafts. The springs enable the paddles to adjust to the curvature of the troughs for proper scrapping. The paddles are inclined at angle to the axis of the central shafts which can be varied in order to vary the speed of product conveyance in the troughs. The main frame was fabricated from U - channel of dimension 100 × 100 mm. Following the design specifications, the U - channel was cut into appropriate sizes and welded together to serve as the support for the equipment and the internal combustion engine. Heat resistant Clay bricks were used to build an insulation wall around the fryer. The specification of construction materials is shown in Table 1.

2.5 Description of the Power Driven Gari Fryer

This fryer is a UNIDO (United Nation Industrial Development Organization) sponsored project designed and fabricated by Federal Institute of Industrial Research (FIIRO) Oshodi which is tagged "FIIRO Power Driven Gari Fryer" as shown in Plate 1. It is a simple continuous process plant which consists of a semi-circular steel plate with rotating paddles fixed to a steel shaft slowly rotating on the axis of drum. The paddles are eccentrically located in such a manner that their motion compels the frying gari granules to move from one end of the plate to the other. It consists of two trough chambers: gelatinization chamber and drying chamber. These two troughs are mounted on frame stand with insulation wall around the frame. The paddles are powered by diesel engine via chain drive. The source of heat is through gas burner which produces a wall temperature of about 250°C. The rotating paddles sweep the gelatinizing mash from the trough wall to prevent sticking and burning and at the same time convey the material through the length of the garifier towards the discharge sprout. Frying and Drying occurs during this process.

Table 3. Materials used for construction of the gari fryer

Materials	Specifications	Quantity
Mild Steel Sheet	3 mm thickness, standard size	6 pcs
Mild Steel Sheet	2 mm thickness, standard size	2 pcs
Hollow pipe	60 mm (Ø) (Central shaft for the 2 chambers)	6 m length
Hollow pipe	40 mm (Ø) (This is for the paddles attachment)	5 m length
Hollow pipe	70 mm (Ø) (for mounting of paddles on the central pipe)	1.5 m length
Sprocket	450 mm (Ø)	1 pc
Chain	3 m length	1 pc
I C engine	10 hp	1 pc
Spring	(2 mm thickness and 38-40 mm diameter)	30 pcs
Bolts & nuts	(Ø 10 mm)	24 pcs
Bolts & nuts	(Ø 8 mm)	60 pcs
Mild Steel Electrode	Gauge 10 & 12	4 packets
U – Channel	100 × 100 mm, standard length	4 pcs
Heat Resistant Clay Bricks	300 × 100 × 150 mm	350 pcs
Temperature Gauge	10°C – 500°C (graduated in 5°C)	2 pcs

Plate 1. FIIRO power driven gari fryer

3. PERFORMANCE EVALUATION

3.1 Materials and Processing

Cassava roots were brought from a local farm around FIIRO. The roots were processed in the food processing pilot plant of FIIRO in this order: Weighing: peeling, washing, grating, fermenting, pressing, granulating, frying and bagging. Gas was refill into the cylinder which was used as source of heat. The cassava used was hand peeled, washed, grated using electric motor power driven grater it was allowed to ferment before dewatering with a hydraulic press to form cake mash (granulation) which is introduced to the fryer (Figure 1) to be processed into gari. The equipment was used to fry the processed dewatered cassava mash into Gari. Three different tests were carried out using the equipment. The dewatered cassava mashes were fried in batches, with each of the samples weighed before and after frying using weighing scale. The initial and final temperature of each of the samples was also determined using thermometer.

The moisture content and the analytical characteristics of the Gari samples produced were determined at the food and analytical section of FIIRO. The moisture, fat, protein, carbohydrate, fiber and ash contents of the three gari samples were determined according to AOAC (2005). The results are as presented in Tables 1, 2 and 3. The yield was calculated on the basis of the weight of sieved fermented cassava mash before garification which was determined according to equation 14, [15]

$$Yield\ of\ gari = \frac{Weight\ of\ fried\ gari}{Weight\ of\ fermented\ cassava\ mash} \times 100\% \quad (14)$$

4. RESULTS AND DISCUSSION

Table 4 presents the time of frying and percentage yield of gari. The result revealed that the time of frying ranges between 14 minutes to 17 minutes for dried gari which range between 11.2 kg to 20.8 kg. Thus the average output of dried gari for the fryer is about 80 kg/hour which make the fryer to be suitable for small to medium scale enterprise. This is a great improvement over manual method of frying which is time consuming (about 30 minutes for just 5 kg of gari) uncomfortable and lend itself to health hazard for the operator. The percentage yield of gari obtained range from 52.8% - 74.7% which fall within the range 53.57% - 75.00% as reported by Olanrewaju [15]. Karim et al. [16], Akingbala et al. [17] and Oluwole et al. [2] had reported 31.20%, 29.9% and 24.9% respectively based on the weight of fresh cassava roots.

Table 5 presents the analytical characteristics of the samples of gari obtained from the fryer. It will be observed that the values of proximate composition obtained fall within the range of the standard values except for some samples with a slight deviation from the standard value when compared with standard values presented in Table 6. Furthermore, the result of proximate composition of the gari samples produced by the fryer is in agreement with report of other studies on nutritional composition of commercially available gari in Nigeria. For instance, Olanrewaju [15] reported that increase in garification duration resulted in reduction in the moisture and hydrogen cyanide contents, and cause an increase in sugar content and pH. He further reported that the proximate compositions of gari sample obtained in his study for moisture, protein, ash, fiber, sugar and hydrogen cyanide contents which were in the range 7.9% - 17.8%; 1.89% - 2.23%; 1.03% - 1.64%; 1.16% - 1.97%; 2.21% -5.05% and 14.08 mg/kg – 23.43 mg/kg respectively. Nwokoro et al. [18] also reported nutritional composition of gari samples collect from southern Nigeria for ash, crude fiber, crude protein, fat and carbohydrate which were in the range of 0.99% - 1.59%; 1.66% - 2.91%; 0.61% - 1.38%; 0.26% - 0.61% and 85.0% - 87.7%. The gari samples produced from the fryer had moisture content that was below the stipulated standard of revised gari regulation of 10% by Standard Organization of Nigeria/International Institute of Tropical Agriculture (SON/IITA) as reported by Sanni et al. [19]. This indicates that the gari samples produced have good storage potential and hence fit for export. This make the fryer to be suitable for production of gari.

4.1 Microbial Analysis of the Gari Samples

Table 7 presents the microbiological analysis of the gari samples produced. The result indicates that the samples produced from the fryer are safe for human consumption since the values of total plate count and yeast & mould count obtained for the samples fall within the acceptable values, while coli form count were Nil and *E. coli* were not detected.

Table 4. Time and yield of gari of the gari fryer

S/N	Initial Weight (kg)	Final Weight (kg)	Initial Temp. of Samples (°C)	Final Temp of Samples (°C)	Temp of Frying Trough (°C)	Time of frying (mins)	% Yield of Gari
1	15	11.2	27	90	80	15	74.7
2	15	10.4	27	87	77	14	69.3
3	25	16.1	27	85	92	16	64.4
4	25	16.4	27	85	85	15	65.6
5	35	18.4	27	87	85	17	52.8
6	35	20.8	27	87	90	15	59.4

Table 5. Proximate analysis of the gari samples

Test Performed			Results	
Proximate Analysis		**A**	**B**	**C**
Moisture	%(w/w)	7.38	5.89	6.78
Ash	‘’	2.51	1.37	1.11
Crude Fiber	‘’	2.69	2.89	2.54
Crude Protein	‘’	1.45	1.38	1.97
Fat (ether extract)	‘’	0.62	0.01	0.34
NFE (Carbohydrate)	‘’	85.35	88.46	91.26
Total Acidity as Lactic Acid	‘’	0.40	0.40	0.40

Table 6. Analytical standard of gari in Nigeria

S/N	Analytical Characteristics	Range of values
1	The total acidity of Gari	≤ 1% m/m measured as lactic acid
2	Total Cyanide content of Gari	≤ 20.0 mg/kg.
3	The moisture content of Gari	≤ 7.0%m/m.
4	The crude fiber content of Gari	≤ 2% m/m.
5	The Ash Content of Gari	≤ 1.5% m/m

(NIS 181: 2004 – Standard for Gari) IITA and SON

Table 7. Microbiological analysis of gari samples

Samples		A	B	C
Total Plate Count	Cfu/g	9.2 x10^4	5.0 10^4	9.3 x 10^4
Yeast & Mould Count	‘’	1.5 x 10^2	5.0 x 10^4	3.8 x 10^4
Coli form Count	‘’	Nil	Nil	Nil
E. coli	‘’	ND	ND	ND

ND = Not Detected

5. CONCLUSION

On the basis of the physical characteristics of cassava mash, power driven gari fryer was designed, constructed and tested. At constant speed of 8 rpm, an initial weight of 140 kg and a temperature reading of 120°C of frying trough, an output of 83.2 kg/hr was established with a yield of 59.4% within the resident time of 15 minutes. The proximate composition of the gari samples produced from the fryer, fall within the stipulated standard of revised gari regulation by Standard Organization of Nigeria/International Institute of Tropical Agriculture (SON/IITA). The capacity of the fryer was 500 kg per day as against the manual method of frying of 5 kg for 30 minutes which is equivalent to 80 kg per day for 8 hours frying operations in local cassava processing industry in Nigeria. Hence, this makes the fryer to be suitable for gari production for small to medium scale enterprise. However, it is recommended that the fryer is constructed with food grade material such as stainless steel of quality grade.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Sanni LO, Adebowale AA, Awoyale W, Fetuga GO. Quality of gari (roasted cassava mash) in Lagos State, Nigeria. Nigeria Food Journal. 2008;26(2):125–134.
2. Oluwole OB, Olatunji OO, Odunfa SA. A process technology for conversion of dried cassava chips into gari. Nigeria Food Journal. 2004;22:65–77.
3. Agunbiade SO, Adanlawo IG. Effect of varying fermentation periods on the sensory and physicochemical properties of gari. Journal of Applied and Environmental Sciences. 2007;3(1):1-6.
4. NIS 181. Nigerian Industrial Standards for gari. Standards for cassava products and guidelines for export. ISBN 978 131 248 3. Printed in Nigeria by IITA; 2004.
5. Igbeka JC. Recent development in gari. Frying Process and Equipment; 1995.
6. Ajayi OO, Olukunle OJ, Dauda M. Performance evaluation of an automated gari fryer. The International Journal of Engineering and Science (IJES). 2014;3(2):39–46. ISSN (e): 2319 – 1813. ISSN (p): 2319 – 1805.
7. Bencini MC. Post harvest and processing technologies of African staple foods: A technical compendium. Agricultural Services Bulletin No. 89; FAO, Rome; 1991.
8. Levi SS, Cruche CB. FIIRO Research Report No. 2; 1956.
9. Egba AJ. Design and construction of gari fryers for local use. (B.Sc.) Project Report, Agricultural Engineering Department, University of Ibadan, Ibadan, Nigeria (Unpublished); 1987.
10. Olanrewaju TO, Jeremiah IM, Onyeanula PE. Design and fabrication of a screw conveyor. CIGR Journal. 2017;19(3). Available:http://www.cigrjournal.org
11. Khurmi RS, Gupta JK. A textbook of machine design (14th Ed.). New Delhi: Eurasia Publishing House. (PVT) Ltd. (Chapters 7 & 14); 2008.
12. Bryon VH. How material properties and other factors affect a screw feeder’s power requirements. Powder and Bulk Engineering Articles Index. CSC Publishing; 2013. Available:www.Powderbulk.com

13. Ichsani D, Dyah WA. Design and experimental testing of a solar dryer combined with kerosene stoves to dry fish. American Society of Agricultural and Biological Engineers. 2002;1–3.
14. Onwuka GI. Food analysis and instrumentation; Theory and practice. Naphthali Prints, Lagos. 2005;133.
15. Olanrewaju AS. Effect of garification (Roasting) duration on the quality characteristics of cassava gari. Annals. Food Science and Technology (AFST). 2016;17(2).
16. Karim OR, Fasasi OS, Oyeyinka SA. A gari yield and chemical composition of cassava roots stored using traditional methods. Pakistan Journal of Nutrition. 2009;8(12):1830–1833.
17. Akingbala JO, Oyewole OB, Uzo–Peters PI, Karim RO, Bacchus–Taylor GSH. Evaluating store cassava quality in gari production. Journal of Food, Agriculture and Environment. 2005;3(1): 75– 80.
18. Nwokoro SO. Nutritional composition of gari sievates collected from some location in Southern Nigeria. Pakistan Journal of Nutrition. 2005;4(4):257–261.
19. Sanni LO, Maziya–Dixon B, Akanya JN, Okoro CI, Alaya Egwuonwu CV, Okechuku RU, Ezedinma C, Akoroda M, Lemchi J, Ogbe F, Okoro E, Tarawali G, Kumbira M, Patino J, Ssemakula MG, Dixon A. Standards for cassava products (Gari) and guidelines for export. IITA, Ibadan, Nigeria. 2005;39-42.

APPENDICES

Plate 2a and b. The testing of the power driven gari fryer

Plate 3a and b. Showing the discharge sprout and the side view of the power driven gari fryer

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