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Development of Cassava Frying Machine for Local Garri Processors

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Abstract

The fabricated garri frying machine was developed to obviate the problems and drudgery, high energy demand and low capacity associated with traditional method of frying cassava pulp into garri. The components parts of the machine include electric gear motor (prime mover), sets of gears speed reduction transmission system, frying component, mixing paddles system, delivery chute, delivery chute cover, stirrer shaft, machine frame support, heating chamber, bearings. The main frame is made of angle bars mild steel of 40mm by 20mm and 4mm thickness and serves as the main supporting structure upon which other component parts of the machine are mounted. The cylindrical frying chamber is made of stainless-steel metal sheet of 2 mm thickness, 283mm diameters which serves as inlet for sieved cassava mash into the frying chamber and exit for vapour during operation preventing formation of vapour condensation 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). The fried cassava mash (garri) discharge chute is located down side of the frying chamber. An electric gear motor (single phase 1.5kw/1Hp with 700rpm) fitted with sets of gears to reduce speed, this was used to propel the frying paddle shaft and paddle to allow for the slow and gradual movement of the garri within the frying chamber. The machine was evaluated to determine the efficiency. The machine efficiency is 93.3 % with a capacity of 6kg/hr. The fabricated garri frying does not require technical expertise and can effectively address the challenges associated with traditional garri frying which is ease to use and maintain.

Keywords: *Frying machine, Cassava pulp, Frying, Design and fabrication, efficiency*

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1. Introduction

Cassava (*Manihot esculenta crantz)* is a dicotyledonous root and the major root crop grown in Nigeria. Some other principal root crops grown in Nigeria are sweet potato, turmeric, onion and potato. Cassava which has been neglected by research workers is now receiving attention at both national and international research centers. The significance of the crop in tropical agriculture has been recognized in the area of its growth potentials uses; economic of production and genetic improvement (Okereke and Ojewola, 2017). Among the various food products processed from cassava tubers, garri remains the most processed (Ohimain *et al.*, 2013). Garri is creamy white colored grainy flour made from fermentation and gelatinization processes of cassava tubers which has faintly flavor and sour taste (Rufus and Odo, 2018). On the operations used in garri production, the cassava root is peeled and washed, grated into pulp and allow fermenting the dewatered. The dewatered mesh is partially gelatinized, dry fried (sometimes with palm oil) to some percentage dryness of about 12 % and cooled. The frying involves a simultaneous frying and dehydrating operation to get the final garri product. The intensity heat used for the frying often determines the quality of the garri. It is expected that the moisture content of cassava mash after pressing ranges between 45-60% which is reduced to about 12 % at the end of the garri frying operation (Manduabum, 2012; Olagoke *et al.*, 2014). The process of frying garri makes the product safe for human consumption. The heat supplied for this process helps in destroying the hydro cyanide acid, thus reducing its content in cassava mash to safe level and also reduces the moisture content in cassava to a safe level for storage.

Garri frying processes have been done using the traditional/manual technical and the mechanized method. In Garri processing using the traditional/manual technique, relatively low temperature is employed at the initial frying time. This is aimed at preventing the formation of lumps or caking of the gelatinized cassava mash. This is further achieved by constant pressing and agitation of the system. As the frying time progresses, the heat is increased to further cook and dehydrate the garri. Based on choice, the processor may decide to add few drops of palm oil to improve on the product colour and taste. During garri frying, it is necessary to regulate heat input with time during frying to avoid caking; adequate agitation and pressing to break lumps formed and ensuring that the final product is cooked and dehydrated. In Nigeria, many researchers have considered ways to improve garri frying such as designing a continuous processing Garri Frying Machine to simulate the traditional manual frying technique. In addition, the fabric model was produced by a manufacturing company in Nigeria and the UNN model (Gbasouzor and Maduabum, 2012). There are some improvements achieved in the machines produced, such as elimination of smoke, increased capacity and rate of frying and improved and improved working environment. Some basic principles in the traditional frying technique such as intermittent addition of the sifted cassava mash during the frying operation makes the operation a batch process operation. However, most of the designs adopted continuous flow process which presented significant limitation in the quality of the garri product. Meanwhile, the most critical aspect of the garri processing has remained the frying operation. In addition, it is worthy of note state that the manual operation of this process is very tedious, unhygienic with low output compared to the investment of time, money and human energy, though have till date produce the best quality of garri. Thus, a garri frying system that will produce garri which has the same quality attributes like the garri processed manually with relative high output is desired. In the traditional ways of frying garri it has been observed time and again that the method of frying garri has been strenuous on farmers, so with the help of this fabricated garri frying machine, problems such as drudgery during frying process, smoke caused by firewood and time of production has been reduced to minimal, also this fabricated frying machine has encouraged large production of garri within short period of time. Throughout garri frying processes, the moisture content concerted and most of the small lumps established are broken down by continuous pressing and agitation, heat is then increased in order to further cook and dehydrate the production. Formerly, design on garri production plants did not get the required and acceptable cassava production for the consumers. The researchers of those plants did not take into account the specifications of the existing local technology (Ogbuka and Odo, 2018).

2.2 Mechanized methods of frying Garri

Some of the works done on mechanized methods of frying gari in Nigeria were that of were Newell Dunford model. The equipment was a collaborative effort of Federal Institute of Industrial Research (FIIRO), Oshodi, Nigeria. and Newell Dunford Company, London. It is a garri processing plant of which the fryer has a unique component. In the frying units, heat generated in the gas fire is measured and regulated by thermostats at several points in the process (Ejiko, 2018). The Brazilian model was an equipment, designed and constructed in Brazil, appears to be better than the Newell Dunford models and the product obtained from it is comparable to Nigeria garri, even though it is not accurately the same. In the design, frying was not distributed within a given batch and the process looked more like dried cassava mash than cooked and fried garri (Ejiko, 2018). The Fabrico model design which was constructed and manufactured by a Company, FABRICO, in Nigeria, produces an end-product that is closer to one in the market (garri). The manufactured goods were not cooked but looked more like roasted garri. The University of Nigeria Nsukka, and the University of Ibadan improved on the design (Akingbala and Oyewole, 2019). Furthermore, The UNN model (University of Nigeria, Nsukka) design was constructed by Odigboh and Ahmed (2014) to faithfully simulate the village manual frying operations. The fryer drives automatically produce continuous flow of well fried garri at 16% moisture content. An average through-put of 67kg of garri per hour has been re -counted for this equipment. The UNIBADAN model was designed, constructed and manufactured in the University of Ibadan (Igbeka and Akinbolade, 2013). It is a continuous flow fryer which is an upgrading and modification of the UNN model, hence a modified version. Fabrico Model modified the earlier designs. The modification includes the paddles, the feeding device, and the heat source. The UNIBADAN model is constructed with a fryer plate, feeding hopper, power transmission devices, and shaft with paddles, pulverizes and an oven on which the fryer rests, The UNN model, is incorporate with a semi-circular trough open at the top, both ends and a fryer plate. It is positioned at an angle of between 5 and 18 with a length of 2.45 m and diameter 0.67 m. The metering device is one of the basic innovations in the model, hoper and the rate of metering is very crucial to the quality of the final product. Another innovation in this model is in the paddles. Like UNN model, paddles, the main shaft was design with 29 paddles and pulverizes fixed in such a way that they have a conveyor effect at the same time as they press (Ogbuka and Odo, 2018). The objectives of the study therefore are the development of Prototype Gas fuel Garri frying machine for local processors

2. Materials and Methods

Design Considerations

Since the design is to help local processors and to reduce the cost of frying and drudgeries, the materials used are sourced locally and at the cheapest price available. In materials selection, the availability, durability and low cost in the selection of the appropriate materials are taken into consideration for each component. The materials used in the construction were made of stainless steel to prevent corrosion which might lead to contamination of the cassava products. The machine was design to give a good efficiency, comfort and minimal stress on the operator and the maintenance of the machine can be carried out with ease.

Figure 1: Traditional Garri Frying Method

Description of fabricated garri frying Machine

The following are the descriptive structure of the main components of the garri frying machine as shown in figure 2.

Figure 2: Finished fabricated garri frying machine

The fabricated garri frying machine has some components or parts (Table 1); the electric gear motor (prime mover), sets of gears reduction transmission system, mixing paddles system, delivery chute, delivery chute cover, stirrer shaft, machine frame support, heating chamber and bearings. The main frame is made of angle bars mild steel of 40mm by 20mm and 4mm thickness and serves as the main supporting structure upon which other component parts of the machine are mounted.

The cylindrical frying chamber is made of stainless-steel metal sheet of 2 mm thickness, 283mm diameters was designed to be open which serves as inlet for sieved cassava mash into the frying chamber. This is 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). The fried cassava mash (garri) discharge chute is located down side of the frying chamber. An electric gear motor (single phase 1.5kw/1Hp with 700rpm) fitted with sets of gears to reduce speed, this was used to propel the frying paddle shaft and paddle to allow for the slow and gradual movement of the garri within the frying chamber.

Machine Frames: The frame gives support to the machine. It carries all the parts which make the machine. It is fabricated using angle bar iron made from mild steel.

Frying Chamber: This is the parts that contains the cassava mash, conducts heat and fry the sieved particles over a selected time. The frying chamber is fabricated with a stainless-steel material. The frying chamber was attached to the base where the heat source is located (cooking gas). The fried cassava mash (Garri) discharge chute (20mm x 30mm) is located by the side of the frying chamber.

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. An electric gear motor (single phase 1hp, 700rpm) is used to propel the frying paddle shaft ass this allows the slow, uniform and gradual movement of the Garri within the frying chamber.

The burner: The burner is having a controlling valve for regulating the temperature difference while using gas burner. First the heating burner is engaged to bring the frying surface (frying chamber bottom) to the required temperature.

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

Design of garri frying machine

The components of the garri frying machine were designed using standard equations.

Frying chamber

The volume of the frying machine can be obtain using this equation below:

Volume of the frying chamber, V $=\frac{\pi}{4}D^2 \times h$ …… (1)

Table 1: Cost of Fabricated Garri Frying Machine

Materials	Unit	Unit cost(₦)	Amount(₦)
Bearings	500	4	2,000
Bolt and nuts (size 15)	150	20	3,000
Angle bars (4mm x 2mm)	5,800	1	5,800
Mild steel electrode	100	36	3,600
Stainless electrode	150	25	3,750
Gears	*15,000*	2	15,000
Stainless plate 2mm	36,500	Half plate	36,500
Mild steel plate 2mm	24,000	1	24,000
Shaft (344mm x35mm)	14,000	150mm	14,000
Bearing oval shape	1,700	1	1,700
Painting (paint and brush)	2,500	1	2,500
Cutting disc	1,000	1	1,000
Grinding disc	1,000	1	1,000
Burner	9,000	1	9,000
Electric gear motor	40,000	1	40,000
Auto card drawing	9,000		9,000
Workmanship	10,000		10,000
Transport	5,000		5,000
Total			**#187,850:00k**

Designed capacity of the machine

The designed capacity of the machine, Cd is a measure of the total volume of the cassava pulp the machine could fry in the frying chamber per unit time as shown in equation 2

$$\text{Machine capacity, } C_d = \frac{V_1}{T} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (2)$$

where V_1=volume of given cassava pulp

T=total time taken to require to fry garri pulp respectively

Shaft speed

To calculate the shaft speed, the following parameters are used:

$$\frac{D1}{D2} = \frac{N2}{N1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where, N_1= revolution of the smaller pulley, rpm; N_2= revolution of the larger pulley, rpm

Shaft diameter

The shaft diameter was calculated using the ASME code equation for a solid shaft having little or no axial loading with 10% factor of safety added and from the standard sizes, a shaft of 20 mm diameter was selected.

$$d^3 = 16/\pi s_s \sqrt{(K_b M_b)^2 + (K_t M_t)^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \ (4)$$

where, d=diameter of the shaft, mm

s_s =allowable combined shear stress for bending and torsion for steel shaft

K_b = combined shock and fatigue applied to bending moment (1.5-2.0 for minor shock)

K_t = combined shock and fatigue applied to torsional moment (1.0-1.5 for minor shock)

M_b and M_t = bending and torsional moments

Bearing

The bearing that will withstand the radial force of the shaft was selected and the radial force acting on the shaft was obtained from equation 4 (Krutz et al., 1984)

$$F = \frac{KW\ X 19.1\ X\ 106\ X\ k}{PD\ X\ RPM} \quad \ldots\ldots\ldots\ (5)$$

Where, F=radial force of shaft (N), KW = power transmission (kW); PD = pitch diameter of sheave (mm); RPM = shaft speed (rpm); k = drive tension factor.

Gear system

The gear system was designed using equations 6, 7, 8, 9,10,11,12,13 and 14 for gear ratio, velocity ratio, speed of driven gear, pitch diameter, top and root diameter for the driven and drive gears respectively (Khurmi and Jupta, 2011).

$$\text{Gear ratio} = \frac{T_2}{T_1} \quad \ldots\ldots\ldots\ldots\ldots \ (6)$$

Where T_2 =driven gear, T_1= is the drive

Velocity ratio = $\frac{N_1}{N_2}$; ratio of rotation of speed of input to that of output gear ……………………………………….(7)

Speed of the driven gear = S_1 x T_1 = S_2 x T_2 ....(8)

where,

S_1, T_1 = Speed and teeth of drive gear

S_2, T_2 = Speed and teeth of driven gear

The pitch diameter for drive gear, dp = mT_1 …………...(9)

The pitch diameter for driven gear, dg=mT_2 ……. (10)

The top diameter for drive, dpt = $(T_1 + 2f_o)$m … (11)

The top diameter for the driven gear, dgr = $(T_2 + 2f_o)$m …(12)

The root diameter for the driven gear, dgr = $(T_2 - 2f_o)$m – 2c ……… (13)

Top and root clearance, c= 1.25m – 1.00m = 0.25m … (14)

Where, m= module = $\frac{2a}{T_1 - T_2}$

$$a = \frac{m(T_1 - T_2)}{2}$$

the height factor, f_o =1

Machine capacity
The capacity of the machine which is the amount of the cassava pulp to be fried within a specific given time was calculated using equation 15

$$\text{Machine capacity} = \frac{M}{T} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ (15)$$

Where M= mass of cassava pulp in kg; time taken in hours. The machine functional efficiency is the measure of the effectiveness with which the machine performs its intended function.
The functional efficiency of the machine was calculated using equation 16

$$Ef = \frac{u}{v} \text{ x } 100 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ (16)$$

where,
Ef= functional efficiency;
u= total mass of quantity output in kg and
v=total mass of quantity input in kg.

3. Results and Discussion

Performance Evaluation of the machine
After the design and construction of the machine, performance evaluation was done as it is the vital step in the process of machine development. A 3kg of cassava pulp was fed into the frying chamber with the burner lit on and the electric switched on. This was repeated four times and the mean was used for calculation;

Trial	**Mass of cassava pulp before frying**	**Mass of cassava after frying**	**Time taken (min)**
1	3	2.65	30
2	3	2.68	30
3	3	2.67	30
4	3	2.69	30
Mean	3	2.80	30

Mean mass of cassava pulp before frying = 3kg
Mean mass of cassava after frying (garri) = 2.80kg
Mean time taken in frying = 30 mins

Efficiency of the machine

$$Efficiency\ efficiency = \frac{mass\ of\ output}{mass\ of\ input\ material} \text{ x } 100$$

$$= \frac{2.80}{3} \text{ x } 100$$

4. Conclusion

The development and performance evaluation of the of the cassava frying machine has been successful done. The machine thereby increases then quality and reducing the drudgery involved in the traditional methods of frying garri. It is environment friendly and therefore, it can be interpolated that if 3kg is of cassava pulp is fried into garri in 30 mins, 100kg of mash garri will take 1000mins (16.6 hrs) to be fried. The 100kg of cassava mash is equivalent to 4 bags of cassava mash. The efficiency of the machine is 93.9 %. The fabrication of the garri frying machine was achieved by using local materials. 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.

Conflict of interest
The authors declare no conflict of interest.

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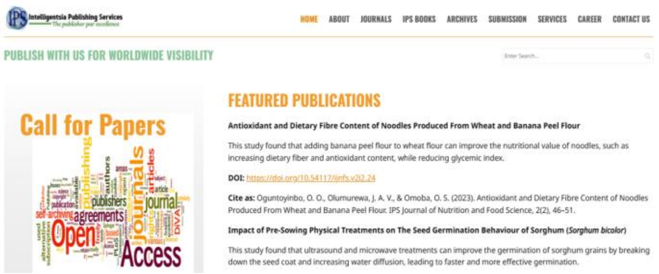

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