

Performance Evaluation of an Automated Gari Fryer

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-----ABSTRACT-----

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. This paper reports a novel effort at developing a gari fryer and the performance of the machine at various conditions of cassava mash and operational parameters. The effects of operation speed, quantity of mash and trough temperature on the performance of the fryer were studied. The performance characteristics of the machine was evaluated at five different operating speeds (10, 20, 40, 60, 80 rpm), with respect to material feed rate (5, 7.5 and 10 kg) and corresponding change in temperature. The result shows that at an optimum speed of 20 rpm and initial mash moisture content of 41.2%, gari of 12.6% final moisture content was obtained at the twenty first minutes of frying using 5 kg charcoal as source of heat energy. The product obtained (gari) has a good texture and fit for consumption.

KEYWORDS : Gari fryer, functional efficiency, operational parameters, performance evaluation.

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I. INTRODUCTION

Gari is creamy-white granular flour with a slightly fermented flavour and a slightly sour taste made from fermented, gelatinized fresh cassava tubers. It is the most developed and storable commodity from cassava and is widely consumed in Nigeria, Brazil as well as in most countries of West African coast. The preparation of gari from cassava has basically been done according to local processing techniques. In the last three decades, a lot of research has been carried out to mechanize some aspects of the unit operations involved in gari production. These include peeling and washing of tubers, grating, dewatering, fermentation, sieving, frying and cooling. Some equipment has been designed to aid the large scale processing of cassava. They include graters [1]; peeling machines [2]; [3]; [4]; dewatering machines, sifters and pulverizers for dried cassava mash and gari fryers [5]. Earlier design on gari production plant did not produce the desired and acceptable cassava product for the consumers. The designers of those plants did not take into account the specifications of the existing local technology. The most critical unit operation that determines the quality of the final product in gari production is the frying operation. It has been quite difficult to mechanize this operation correctly and rightly because this operation was not well understood by many designers and manufacturers [6]. Some had erroneously assumed gari frying to be the same as dehydration while others had taken it to be roasting. Drying solid means the removal of some amount of water or other liquid from the solid material to reduce the content or residual liquid to an acceptable low values [7]. It is usually the final step in a series of processing and handling operations and the product from a dryer is often ready for final packaging. Drying is then a relative term and means a reduction in moisture content from an initial value to some acceptable final value. Cassava has about 60% water content while final gari is between 10-15% [8].

Gari frying (called garification), though a dehydrating process, is not a straightforward drying process. It is not possible to produce gari from cassava mash by just passing heated air through it. The product from such an operation would be dried cassava pulp or granules and not gari [9]. Gari frying is a simultaneous cooking and dehydrating operation; the product is first cooked with the moisture in it and then dehydrated [6]. The heat intensity during frying affects the quality of the product, in the village technique; the initial frying temperature is relatively low so as to avoid the formation of many lumps or caking. As the moisture content reduces and most of the small lumps developed, have been broken down by constant pressing and agitation, the temperature is increased in order to further cook and dehydrate the product.

The colour and paste of gari can then be enhanced by adding a few drop of palm oil. At the end of the frying operation, the product is still hot and a little bit damp. It is then left to cool and dry in a cool dry shade. The following points should be noted during frying: a]. Regulation of heat input with time during frying to avoid caking b]. Adequate agitation and pressing to break lumps formed c]. Ensure that the final product is cooked and dehydrated. Gari is consumed as processed or reconstituted with hot water to form a dough-like paste called "Eba", which is consumed with sauce. Gari is a very versatile commodity because its characteristics can be adjusted to conform to consumer specification. The main arguments against gari include its bulky starch content which can be augmented during processing or consumption. Gari should be consumed with animal or plant protein accomplishments [10] or protein enriched with soybeans to boost its protein content (from 1-2% to 9-12%) [11]. It is therefore the most developed, convenient and storable commodity from cassava. Several models of gari fryer were developed in previous research efforts, these include: the UNIBADAN model, UNN model, FABRICO model and PRODA model. However, this operation is still largely done by manual methods. Existing designs cannot cope with the emerging mechanized methods being utilized for other processing operations. There is need to produce a machine that will work at the same rate with other operation in gari processing and improved the quality of the product. The manual method of frying gari involved a lot of energy and time. Therefore a prototype machine for gari frying was developed in the Department of Agricultural Engineering, Federal University of Technology, Akure. The machine has low maintenance cost, reduced drudgery, save labour and eliminates smoke during operation.

II. METHODOLOGY

2.1 Material

The main material used in the execution of the research work is fermented and sieved cassava mash which was obtained after a series of operations on the cassava root. These operations include peeling of the tubers, grating, dewatering, fermentation and sifting. The fermented sieved cassava mash was fried using the gari fryer developed at the Federal University, of Technology, Akure. The cassava mash was obtained at two local gari production factories; in Shagari village and along Ilesa expressway, Akure, Nigeria. The moisture content of the cassava mash was determined by gravimetric method. A known mass of the mash was placed in an oven at 110⁰ for 8 hours. The final weight was taken when the product has cooled down inside a desiccator, the moisture content was obtained in the wet basis as:

$$M_c = \frac{W_o - W_f}{W_o} \times 100\% \dots (1) \quad [7]$$

Where;

M_c = Moisture content (wet basis), %

W_o = Weight of wet mash, kg

W_f = Weight of dried mash, kg

A bag of charcoal used as source of heat energy for the frying operation was also purchased in Akure market in Nigeria.

2.2 Machine Description

The isometric and exploded view of the gari frying machine used for the experiment are shown in Fig. 2.1 and Fig. 2.2 respectively. It consist of a 500 mm diameter, 1500 mm long frying trough made of 2 mm stainless metal sheet, it carries a drum-auger conveyor fitted to a 1940 mm long drive shaft. The auger conveyor consists of the drum of 2 mm stainless metal sheet rolled to form a cylindrical shape; it has a diameter 280 mm and was 1480 mm long. The auger was welded to the drum with a flight of 105 mm and pitch of 210 mm. Stainless twisted wire brush (which has high resistance to wear) were attached to a rectangular metal plate of 80 mm X 60 mm which was also welded at an angle of 45⁰ round the drum to press the gari against the base of fryer as well as to break the clods that are formed during gelatinization. The upper chamber was made from stainless sheet and perforated to serve as exit for vapour during frying operation thus preventing formation of vapor condensation at the surface. The upper chamber is attached to the base fryer with hinge. The shaft of 25 mm diameter and 1940 mm long, made from mild steel, supported by pillow bearing and constantly lubricated for maintainability. There was a clearance of 5 mm between the auger flight and the base fryer. The frame was made from angular bar mild steel of 45 mm by 45 mm and 5 mm thick. The hopper is pyramidal in shape and situated at the right top hand side of the machine. It is the inlet in which the dewatered (pressed) and sifted cassava mash was admitted into the frying chamber. The discharge outlet which is the point where the fried cassava mash (gari) was collected was welded to the left side of the base fryer. An electric motor fitted with a reduction gear of variable speed (20 rpm to 100 rpm) was used to propel the fryer. It is a three phase motor of 1.5 kw (2 Hp). The machine also has a control box which is a special feature that allow for movement of the auger conveyor in the forward and the reverse direction. It contains two contactors (for forward and reverse movement), a three-way switch (forward, stop and reverse) and an overloaded relay.

2.3 Operation of the Fryer

The major objectives of frying gari are to cook and dry the cassava to a safe level where its consumption will not lead to any adverse effect. In achieving this, the heat was enough to cook the cassava mash. The heat supplied performed two functions:

- [1] It destroys the hydro cyanide acid by reducing the hydro cyanide content in cassava mash to safe level for human consumption.
- [2] It reduces the moisture content in cassava to a safe storage level.

Frying cassava mash from original moisture content to final moisture content was carried out by pouring the cassava mash of known moisture content and mass intermittently through the hopper into the fryer. The base fryer was heated using charcoal as a source of energy and the temperature was determined through the use of digital probe thermometer. The cassava mash gelatinizes while being moved over the heated surface of the metal trough and the gelatinization occurs at a temperature between 60°C and 65°C. The stainless wire mesh fixed to the auger drum rotating on the axis of the drum sweep the gelatinizing mash from the trough wall to prevent sticking and burning and also break the lumps that formed during gelatinization. The auger move the mash to and fro through the length of the base fryer with the help of the forward and backward contactor of the control box connected to the electric motor. As the moisture content reduces and most of the small lumps developed, have been broken down by constant pressing and agitation, the heat is then increased in order to further cook and dehydrate the product. The extent of drying depends on the increase in temperature and the length of time of the mash in the fryer. Also, the moisture content may increase due to condensation near the air (vapour) exit. The perforation at the upper chamber (cover) of the trough served as exit for vapour during frying operation thus preventing formation of vapour condensation at the surface. Virtually, all the starch granules have to be gelatinized during the cooking stage before drying commence at slow rate. The temperature of the frying trough and mash temperature were determined by using a digital probe thermometer.

2.4 Experimentation

2.4.1 Performance Criteria

Test parameters that were measured in evaluating the performance of the machine are throughput capacity and functional efficiency. Throughput capacity was defined as the ratio of the quantity of gari collected from the machine to the time taken.

$$T_c = \frac{W_s}{T} \dots\dots (2) \quad [1]$$

Where;

T_c = Throughput capacity, kg/hr

W_s = Mass of gari collected, kg

T = Time taken, hr

The functional efficiency was defined as a percentage of the product output to the material input.

$$E_f = \frac{M_f}{M_i} \times 100 \dots\dots\dots (3) \quad [1]$$

Where;

E_f = Functional efficiency, %

M_f = Mass of gari obtained, kg

M_i = Mass of mash introduced into the fryer, kg

2.4.2 Test Variables

Many factors which could affect the time required to reduce the moisture content of the cassava mash to the desired moisture content of the product (gari) and hence the performance of the machine include mash initial moisture content, quantity of mash introduced, the system dimension, thickness of the frying trough, thermal properties of the frying trough, frying temperature and machine speed. In the present work, three factors were investigated. These include; Speed of the rotating shaft, quantity of mash introduced and frying temperature.

[1] Determination of Optimum Speed

The experimentation began by pouring 10 kg cassava mash of 41.2% initial moisture content into the fryer and the speed of the rotating shaft was set to 80 rpm using 5 kg charcoal as a source of heat energy for frying. A very small quantity of mash (25g) was taken at the interval of three minutes up to the twenty first minute, the moisture content of the mash taken were determine by oven dried method and recorded. This

was repeated for speed of 60 rpm, 40 rpm, 20 rpm and 10 rpm respectively using the same quantity of cassava mash and charcoal. This first experiment was carried out to determine the suitable speed for the fryer.

[2] **Determination of Quantity of Charcoal Required**

The second experiment was conducted to determine the quantity of charcoal in kilogram needed to cook and dry a known mass of cassava mash. This was done by using the speed of 20 rpm which was discovered as the optimum speed for the gari frying process in the first experiment. Three different mass of charcoal in kg (3 kg, 5 kg and 7 kg) were used separately to fry the same mass of cassava mash of 41.2% initial moisture content. The moisture content was then determined at the twenty first minute of frying for each set.

[3] **Variation in Quantity of mash with time of frying**

The third set of experiments was done by varying the quantity of mash introduced into the trough (5 kg, 7.5 kg and 10 kg). The initial moisture content of the cassava mash used is 38.6%. The moisture content of the mash inside the fryer was also determined at three minutes interval up to twenty first minute for each set. The speed of the fryer shaft was set to 20 rpm while 5 kg charcoal was used as a source of heat energy.

[4] **Change in Trough and Mash Temperature with Time**

The fourth experiment was done to determine the temperature of the drying mash and the trough for a 10 kg mass of the cassava mash using the shaft speed of 20 rpm and 5 kg charcoal as a source of heat energy. The temperature was taken at three minutes interval up to twenty fourth minute.

[5] **Determination of Throughput Capacity and Functional Efficiency**

This experiment was done to determine the functional efficiency and throughput capacity of the machine putting into consideration the optimum result from the previous experiments. The machine speed was set to 20 rpm and 5 kg charcoal was used as the source of heat energy for the frying. Cassava mash of 10 kg with initial moisture content of 38.6% was poured into the frying trough preheated to temperature of 40⁰C. This was now done intermittently (using village technique); 2 kg of mash was poured into the base fryer and fried for two minutes, another 3 kg was added and fried for another two minutes before finally adding the remaining 5 kg. This helps in the prevention of burning and formation of cake or lumps. The cassava mash was then moved forward and backward intermittently with the aid of the control box connected to electric motor.

III. RESULTS AND DISCUSSION

3.1 The Effect of Variation in Operation Speed on the Time of Frying of Cassava Mash

The result of the performance test reveals the effect of the auger speed on the drying rate of cassava mash as shown in Fig. 3.1. At auger speeds of 60 rpm and 80 rpm and after a period of 21 minutes, the product obtained was not properly cooked and the final moisture content was between 16.5% and 17.8 % from the initial moisture content of 41.2%. This moisture was higher than the safe moisture for storage of gari. However, the speed of 10 rpm, 20 rpm and 40 rpm gave product (gari) of 9.2%, 12.6% and 13.9% respectively at the same period of frying. The Optimum operating speed was 20 rpm. The UNN model developed by [8] and that of UNIBADAN model designed by [12] operate at 40 reversals per minute and 15 revolution per minute respectively.

3.2 The Effect of Mash Quantity Feed into the Machine on the Time of Frying

The final moisture content obtained from the cassava mash of 5 kg, 7.5 kg and 10 kg fed into the machine were 11.5%, 11.8% and 12.4% respectively (Fig. 3.2). This shows that the higher the quantity of mash introduced into the fryer, the higher the final moisture content at the same period of frying. At the eighteenth minute of frying, the moisture content of 5 kg mash was 12.0 % which was even lower than that of 10 kg mash (12.4%) at the twenty first minute of frying.

3.3 Variation in Trough and Mash Temperature with Time

The result (Fig. 3.3 and 3.4) shows that the rate of change in mash temperature was directly proportional to time at the initial stage of moisture removal and cooking, but later constant with increase in time during the drying of cooked cassava mash. The same also applied to trough, as the trough is getting heated, its temperature increases with time and later constant with increase in time. The graph of moisture content against temperature is also shown in Fig. 3.5. It shows that the moisture content reduces with increase in temperature.

3.4 The Effect of Quantity of Charcoal used on the Time of Frying

In the second experiment, the final moisture content for charcoal of 3 kg, 5 kg and 7 kg are 16.2%, 12.4% and 10.2% respectively as shown in Fig. 3.6. This shows that the heat intensity was low during the drying of the cooked mash when 3 kg charcoal was used and too high for the drying of cooked mash when 7kg charcoal was used but that of 5 kg charcoal was adequate. It was also noticed that the gari obtained from 3 kg charcoal was not really gelatinised and that obtained from 7 kg has little lumps and also start burning at about nineteen minutes of frying.

3.5 Throughput Capacity and Functional Efficiency of the Machine

The mass of the product obtained (gari) and its final moisture content at twenty first minute of frying were 7.14 kg and 12.2% from 10 kg cassava mash and initial moisture content of 38.6% respectively using optimum operating speed of 20 rpm. Hence the throughput capacity of 20.4 kg/hr and functional efficiency of 71.4% was obtained

Figures

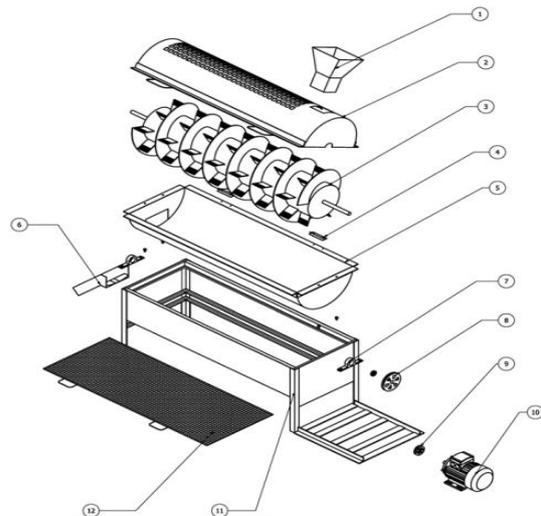
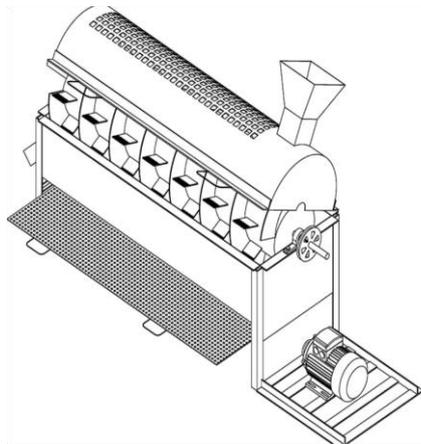


Figure 2.1: Isometric view of the machine

Figure 2.2: Exploded view of the gari fryer showing the component parts

Legend: 1 - Hopper; 2 - Upper chamber;
 3 - Drum-auger conveyor; 4 - Hinges;
 5 - Base fryer; 6 - Outlet; 7 - Bearing;
 8 - Shaft pulley; 9 - Motor pulley;
 10 - Electric motor; 11 - Frame;
 12 - Charcoal plate

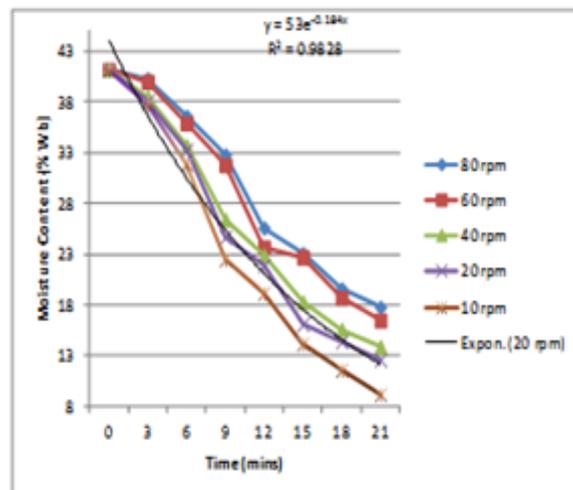


Figure 3.1: Effect of moisture content on the time of frying of cassava mash at different auger speed.

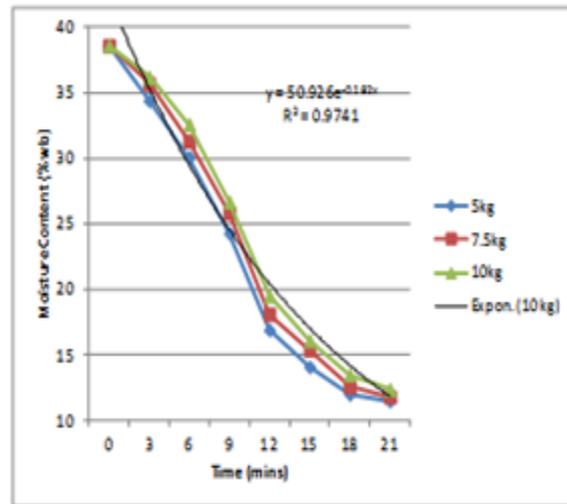


Figure 3.2: Effect of quantity of mash fed into the machine on the time of frying

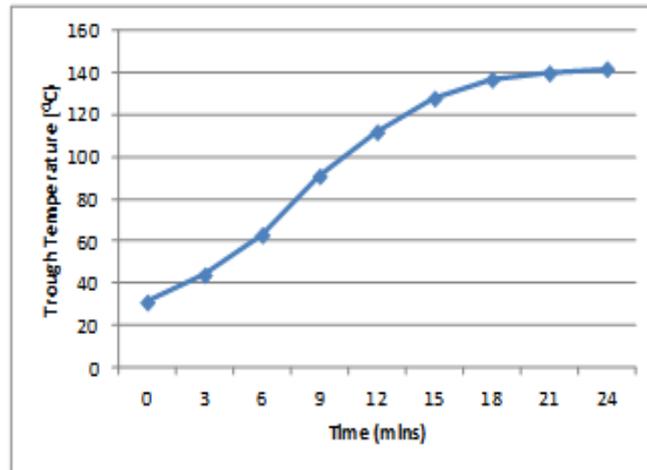


Figure 3.3: Change in trough temperature with time

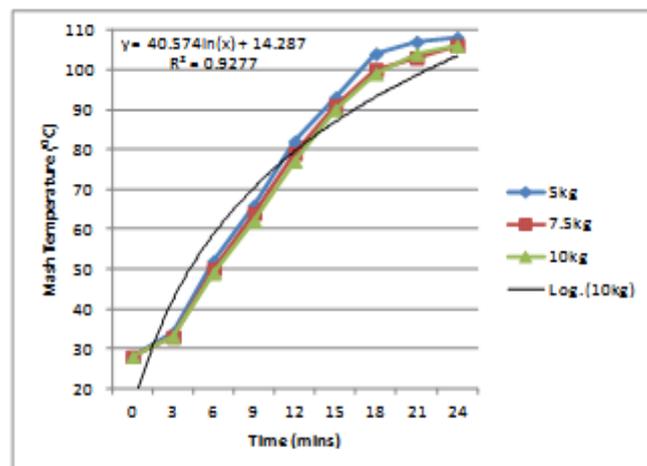


Figure 3.4: Change in mash temperature with time

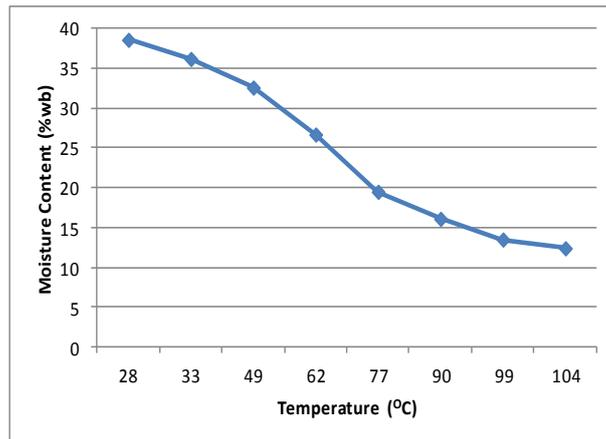


Figure 3.5: Graph of mash moisture content against mash drying temperature

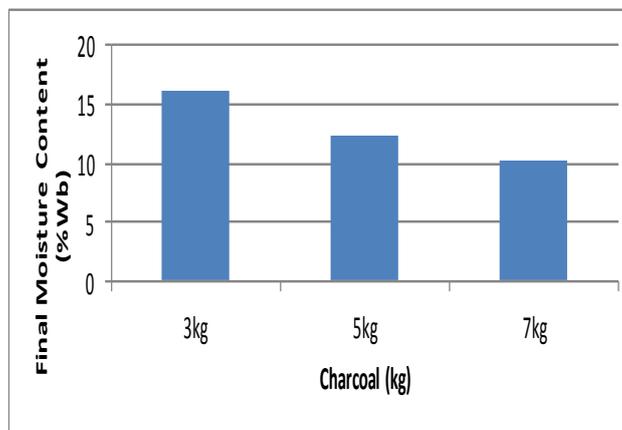


Figure 3.6: Effect of quantity of charcoal used on moisture content

III. CONCLUSION

The performance of gari fryer designed and fabricated at the department of Agricultural Engineering, Federal University of Technology, Akure was evaluated. The optimum speed of the machine was 20 rpm and the average of 5 kg mass of charcoal was used as a source of heat energy. The throughput capacity and functional efficiency were 20.4kg/hr and 71.4% respectively. The machine performed satisfactorily during the period of operation with minimum breakdown. It reduced drudgery, labour, and time of operation and also eliminates smoke during operation. The machine is recommended for adoption and commercialization to meet the need of gari processors.

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