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DEVELOPMENT OF AN IMPROVED GARI FRYER

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ABSTRACT

Traditional frying of cassava mash into gari continues to be an onerous and complex unit operation for food processors. It is highly labor intensive, tedious, unhygienic and low productivity compared with the time and labor invested. The aim of this study was to design, develop a gari fryer, and evaluate its performance efficiency as affected by the *mash moisture content. Cassava mash of different moisture contents (44.12, 45, 46.99, 48.99, 50.31, and 54.94 %) were fried, and the performance characteristics including, roasting time, percentage material loss, throughput capacity, and functional efficiency were evaluated. Results obtained indicated that frying cassava mash at 44.12 % wb moisture content produced the best frying condition, as it had the least material loss and frying time of 25 % and 1.17 hr, best throughput capacity and functional efficiency of 6.6 kg/hr and 75 %. The fabricated gari frying does not require technical expertise and can effectively address the challenges associated with traditional gari frying.*

Keywords: frying time, functional efficiency, gari, material loss, throughput capacity

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1. INTRODUCTION

Cassava (*Manihot esculenta crantz*), has being the major source of carbohydrate which provides over 500 million people with calories in the third world countries [1]. Is a dicotyledonous perennial plant belonging to the family *Euphorbiaceae* which is predominantly cultivated in the low land tropics [2]. Cassava originated from the South America, where it is use as an important food crop before it was spread to other regions of the world [3]. Nigeria, Brazil, Thailand, and Indonesia has been referred to as countries with the largest production of cassava root due to the adaptability of this food crops to their climatic condition [4]. In the recent years, Africa has been the highest producer of cassava tubers with over 60 % of the global output, which is about 256 million tonne through the use of improved varieties [1]. Cassava contains nutrient elements like; potassium, iron, calcium, vitamin, folic acid, sodium, vitamin C, vitamin B-6, and protein [5]. Cassava tubers are usually processed immediately after harvest due to its high rate of deterioration after harvest [6]. It exhibits two types of deterioration after harvest; physiological deterioration (2 – 3 days after harvest) and microbial deterioration (3 – 5 days after harvest) giving rise to prompt processing after harvest [7, 8]. One of the major factor that limits the use of cassava as food is the toxicity of hydrogen cyanide which occurs as a result of the hydrolysis of cyanogenic glucosides [9]. In Nigeria, cassava are been processed to products like gari, abacha, flour, nodules, starch, and animal feed [5]. Gari is a creamy white or yellow granular product from cassava through unit operations including peeling, grating, fermenting, de-watering, and frying (simultaneous cooking and drying) [10, 11]. Gari in West Africa has been regarded as one of the most important cassava foods due to its convenience and multiplicity of use [11]. Gari production from cassava roots undergoes a sequential list of unit operation amongst which frying (garification) is the most critical and important operation since it determines the quality of the final product [12, 3]. During frying operation, heat is applied during stirring of the loose cassava mash against the roasting pan [12]. Heat supplied during frying reduces the hydrocyanide content and the moisture content to a safe level [13]. The moisture content of the fermented cassava mash after de-watering is usually between 50 to 65 % and reduces after frying [14]. Some variations observed on the quality of the gari produced are attributed to mash moisture content, cassava species, age at time of harvest, processing methods, types of machines, temperature of frying, fermentation period [15]. Some determinant factors of quality gari are high starch content (81.8 – 90.8 %), good flavor, low ash content (0.8 – 4 %), taste, attractive color, good texture and uniform size grains [16]. Traditional processing technique of gari is an onerous, complex and unvarying unit operation which requires a sound knowledge of combination factors which affects the quality and yield of gari produced [17]. The exposure of the operators to heat and fume has been the major attenuating factor reducing the efficiency of the traditional processing method and also the capacity of cassava handled by the operators [17, 18]. The quality of gari produced using the traditional method differs between operators and between batches [19]. Engineering improvement of the traditional processing of gari will help reduce drudgery and maximize the gari yield through semi-mechanization or full mechanization of the unit operations. Manually fried gari is still much acceptable to consumers because machine driven fried gari lack gelatinization before drying but looks more of roasted gari, it was also stated that cassava mash which are gelatinized, cooked, and dried are still manually effective because the energy profile which varies with time are carried out with experience [15]. Temperature control happens to be the most influencing factors which local processing depends largely [15]. Improvements which can be given to local or traditional processing of cassava into food are to develop the traditional equipment in other to produce low cost and less energy dependent equipment [6]. This gave rise to the development of the improved gari fryer. Effect of cassava mash moisture content on the functional efficiency of the fryer was also studied.

2. MATERIALS AND METHODS

2.1. Materials

Cassava tubers were collected from Landmark University Teaching and Research Farm in Omu-Aran (Latitude: 8.14^{O}N, Longitude: 5.09^{O}E), Kwara State, Nigeria. It was used in evaluating the developed gari fryer for it functional efficiencies.

2.2. Methods

In the development of this machine, some design factors were considered which would promote the adaptability of this technology; (a) constant availability of the materials for construction (b) affordability by processors (c) safety (d) thermal compatibility (e) corrosion (f) corrosion resistance (g) clarity of construction and disassembling [12].

2.3. Design Analysis

The design analysis of the various component specifications are represented in the orthographic view shown in Fig. 1, while Fig. 2 shows the labeled isometric view of the developed improved gari fryer.

2.3.1. Frying pan design

The volume of the frying pan was calculated to know the quantity of cassava mash which it can conveniently accommodate [3].

$$V = l \times w \times h \tag{1}$$

$$\rho = \frac{M}{V} \tag{2}$$

Where l = length of the frying pan [m], w = width of the pan [m], h = height of the pan [m], V = volume of the frying pan [m^3], M = mass of gari [Kg], ρ = density of gari [Kg/m^3].

2.3.2. Heat required for the frying

The quantity of heat required for frying gari as stated by Ikechukwu and Maduabum and Sobowale et al. [18, 12].

$$Q = MC\Delta T \tag{3}$$

Where; M is the mass of the pressed cassava mash in the frying pan [Kg], C = specific heat capacity of the mash [J/kg^{0}c], T is the temperature [^{0}c], Q is the required quantity of heat [W].

2.3.3. Convective heat transfer rate

The equation 4 below was used in estimating the convective heat transfer rate [12]

$$Q_C = h_c A \Delta T \quad (4)$$

$$A = 2lw + 2lh + 2hw \quad (5)$$

Where; Q_C is the estimated convective heat transfer rate [W], h_c is the convective heat transfer coefficient [W/m^{0}c], A is the surface area of the frying pan [m^2], ΔT is the change in temperature [^{0}c].

2.3.4. Time required for frying (cooking and drying)

In relation of the heat transfer rate to the mass of mash been fried with time [18].

$$\frac{\Delta Q}{\Delta t} = \frac{\Delta_m}{\Delta_t} l_h \quad (6)$$

$\frac{\Delta Q}{\Delta t}$ = heat transfer rate, l_h = latent heat of transformation, $\Delta_t = \frac{Q}{m}$ = time required to fry gari

2.4. Machine description

As shown in Figure 2, the machine components include the following.

Frying pan: The pan was made using 2 mm stainless steel plate, having a cuboid shape of size$800 \times 500 \times 150\ mm$**.** The frying pan sits directly on top of the heating source unit.

Bellow: This is used to fan or blow the charcoal to maintain heat in the burning charcoal. The air also circulates heat generated by the charcoal in the heating compartment.

Chimney: This serves as the exhaust for smoke generated from the charcoal heating source, it also helps to reduce excess heat in the heating unit. It is made with 2 inch galvanized round pipe.

Castor wheel: This provides easy movement of the fryer. It has a diameter of 150 mm.

Gas/ charcoal heating source: This provides the necessary heat needed for frying the cassava mash. Since is a dual heating source either of the two can be use.

Frame: This carries the frying pan during and after it operation. It is padded with fiber glass in other to minimize heat loss and to maintain the temperature within the heating environment. It is made of 2mm mild steel plate and has a dimension of $1000 \times 600 \times 700\ mm$**.**

2.5. Operation of the constructed gari fryer

The improved gari fryer uses a gas heating source. Charcoal was used as a source of heat. The heat generated from the charcoal was use to fry the cassava mash in the pan placed directly on the frame housing this unit. The sieved mash was introduced into the frying pan intermittently and stirred manually until a uniform gelatinization was achieved [18, 12]. Since there is formation of lumps as the moisture content of the mash reduces, "lump free gari" produced during frying is reduce by simultaneous pressing, scraping and stirring action during and when in operation. This frying process was continued until a uniform gelatinization was achieved at moisture content (10-12 %) [12]. At the completion of the process the frying pan was tilted to discharge the gari

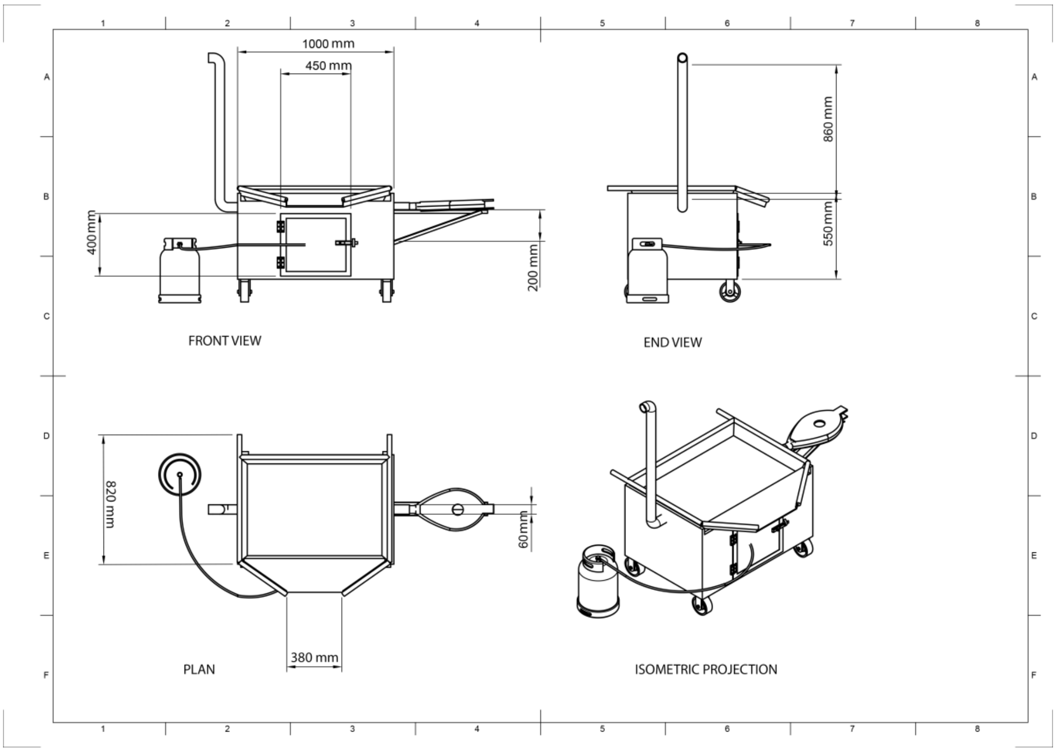

Figure 1 Orthographic view of the developed improved gari fryer

Figure 2 Isometric view of the developed improved gari fryer

2.5. Performance evaluation

The constructed gari fryer was tested for it performance efficiency. Some of the variables which can affect the quality of gari produced were analyzed. The following performance indicators were statistically studied [12, 17, 20].

$$F_E = \frac{M_O}{M_F} \times 100 \quad (7)$$

$$C_T = \frac{M_O}{T} \times 100 \quad (8)$$

$$M_L = \frac{M_F - M_O}{M_F} \times 100 \quad (9)$$

Where; F_E is the functional efficiency, M_O is the mass of gari obtained [Kg], M_F is the mass of cassava mash fed into the frying pan during each operation [Kg], C_T is the throughput capacity of the fryer [Kg/s], M_L is the material loss during frying operation, M_L is the initial mass of cassava tubers [Kg]

2.6. Experimental design

The fresh cassava tubers were manually peeled, washed, grated and bagged. It was then allowed to ferment for 2 days on a tiled platform. The bagged cassava mash was mechanically pressed to remove water to desired moisture content wet basis (44.12-54.94 %) and sifted mechanically to remove lumps. A randomized design was used with three replicates.

3. RESULTS AND DISCUSSION

Table 1 Performance of gari under different mash moisture content

S/N	Mash moisture content, w.b (%)	M_F (kg)	M_O (kg)	Frying time (hr)	C_T (kg/hr)	F_E (%)	M_L (%)
1	54.94	10.00	5.00	2.17	2.4	50	50
2	50.31	10.00	5.50	1.92	3.0	55	45
3	48.99	10.00	6.00	1.77	3.6	60	40
4	46.99	10.00	6.50	1.55	4.2	65	35
5	45.00	10.00	7.00	1.33	5.4	70	30
6	44.12	10.00	7.50	1.17	6.6	75	25

3.1. Frying time

As indicated in Table 1, the frying time ranged from 1.17-2.17 hr. As the mash moisture content increased, frying time also increased as shown in Figure 3. Cassava mash at 54.94 % moisture content was fried at 2.17 hr, as compared with 1.17 hr of mash with 44.12 % moisture content. This might be as a result of the individual mash trying to get to the required moisture content range. The coefficient of determination shows that the values are highly correlated $R^2 = 0.959$. These findings is in agreement Sobowale et al. [12] who also reported that as the mash moisture content increased the frying time also increased in a power driven gari roaster.

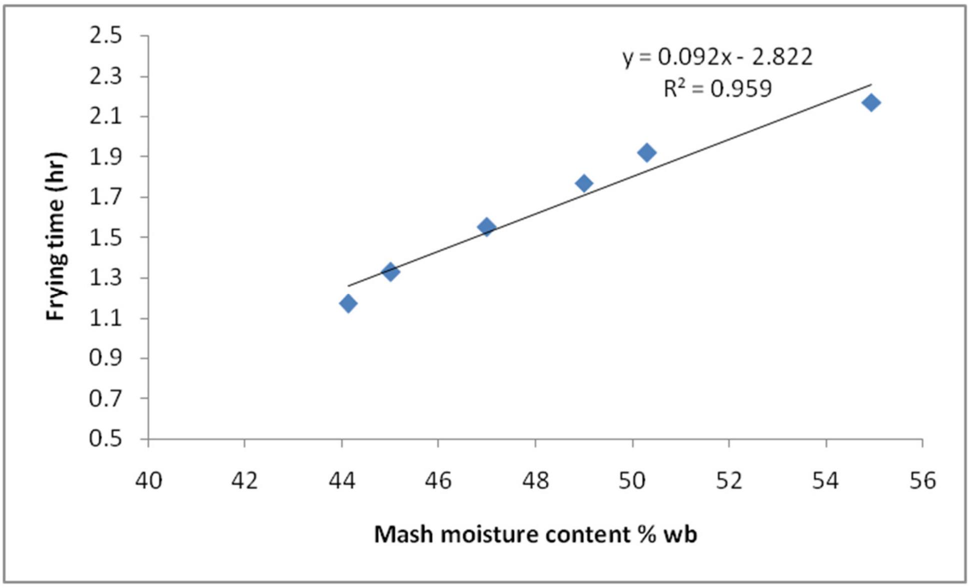

Figure 3 Effect of mash moisture content on frying time

3.2. Material loss

As shown in Table 1, percentage material losses ranged from 25 % to 50 %. Gari obtained at 54.94 % mash moisture content recorded the highest material loss of 50 % as compared with loss of 25 %. This result is in concomitance with the result reported by Sobowale et al. [12], but the material loss was as low as 7.8 %, this might be because they were able to regulate frying temperature which is one of the major contributing factors to material loss experienced during garification.

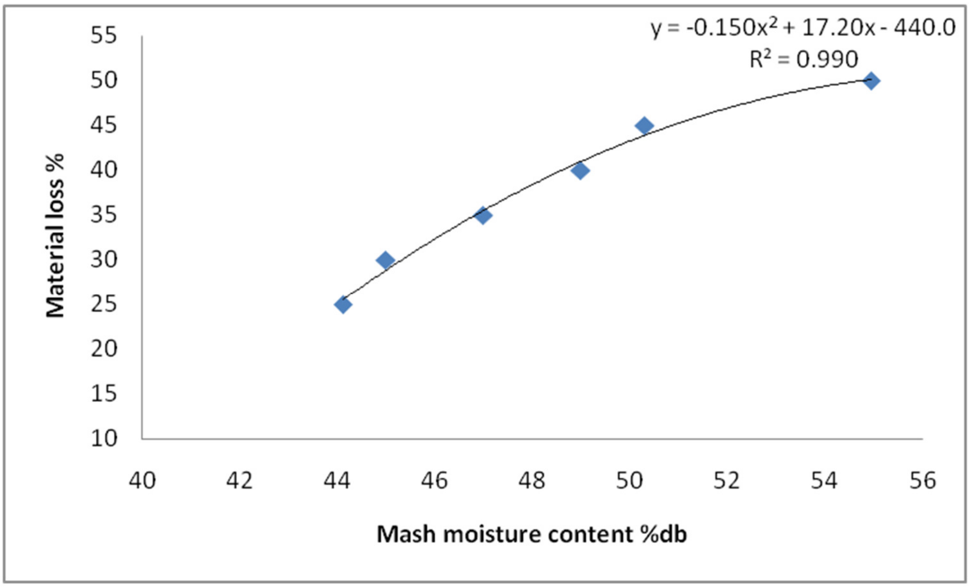

Figure 4 Effect of mash moisture content on percentage material loss

3.3. Throughput capacity

The throughput capacity of the machine under the different mash moisture content ranged from 2.4-6.6 kg/hr (Table 1). As the mash moisture content reduced, the throughput capacity increased as shown in Figure 5. The lowest throughput capacity of 2.4 kg/hr which was recorded at 54.94 % wb, corresponded to the highest material loss, while the best throughput capacity recorded at

44.12 %wb as 6.6 kg/hr corresponding to the least material loss. The designed gari fryer has a lower productivity when compared to the model of Ajayi et al. [13] of 20.4 kg/hr and model of Sobowale et al. [12] of 34.66 kg/hr which were motorized.

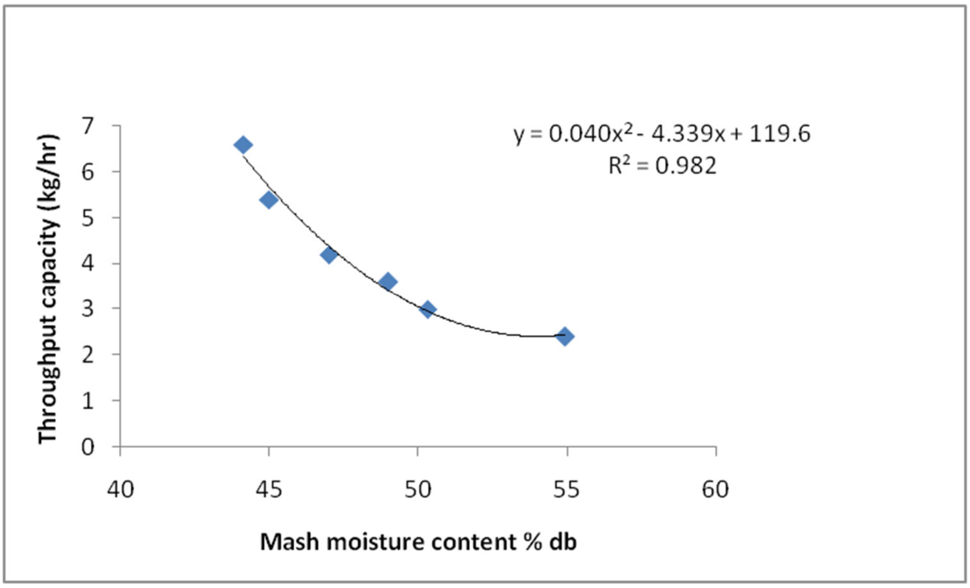

Figure 5 Effect mash moisture content on throughput capacity

3.4. Functional efficiency

The effect of mash moisture content on functional efficiency is presented Figure 6. Functional efficiency was observed to increase as the mash moisture content decreased. The best functional efficiency of 75 % was observed when the mash moisture content was 44.12 % wb. Similar result was also reported by Sobowale et al. [12], in which they recorded a maximum functional efficiency of 92.20 % in motorized model evaluated. This also validates initial observations made for the throughput capacity, frying time, and material loss.

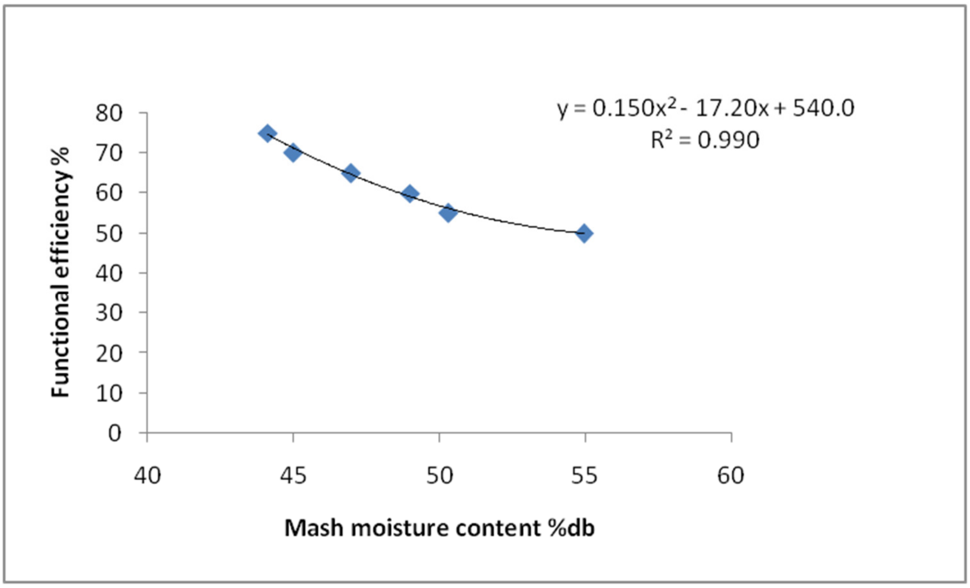

Figure 6 Effect of mash moisture content on functional efficiency

4. CONCLUSION

Frying of cassava mash into gari continues to be a tedious operation. To address this, a prototype gari frying machine was designed, constructed, and evaluated. The frying process took a range of 1.17-2.17 hr, while the optimum gari frying mash moisture content was at 44.12 % wb, with functional efficiency of 75 %, throughput capacity of 6.6 kg/hr, material loss of 25 %, and frying time of 1.17 hr. The smoke hazard attributed to the local gari frying was eliminated while heat loss was also controlled.

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