Development and Preliminary Testing of Gas Fired and Automated Garification Machine

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Abstract:- A gas fired and automated garification machine was developed and tested earliest to proffer solution to the challenge of effectively controlling frying temperature and agitators' speed during garification. The machine consistsof a control panel, 5.5Hp electric motor (prime mover), pulley, v-belt, shafts, differential gears, stainless steel metal pan, exit chute with cover, agitators (paddles), spark electrode, gas burner, heating chamber, electromagnetic gas shut off valve, temperature sensor, timer, block bearings and frame. The lower and upper frying temperatures and agitators' speed limits for the various stages in the process were achieved through the panel while heat distribution was achieved by using a radial gas burner and continuous agitation of the mash. Effective garifiication was achieved at 65˚C and 98˚C cooking and drying stages temperatures with a corresponding agitating speeds of 20rpm and 40rpm respectively. A 40kg mass of dehydrated cassava mash at 45%wb moisture level gave 30.40kg of fried gari at 12.17%wb after 15min of frying and consumed 1.87Kg (0.062kg/kg of gari) of the cooking gas. The machine accounted for throughput capacity and functional efficiency of 121.66kg/h and 76% respectively. The study indicates itsuser and gender friendliness and itis thus recommended for adoption by cassava processors.

Keywords:- *Automated, Development, Garification Machine, Gas Fired, Preliminary Testing.*

I. INTRODUCTION

Food crisis is a global menace [1]attracting the attention of solution givers. The quest to provide sustainable food through research and development in the area of crop planting, harvesting, processing and storage is consequently on the rise and cassava crop is not an exception. Cassava (*Manihot esculenta crantz*) is an important crop for food security in the tropics [2]. It is known as "the drought, war, and famine crop" because it can be grown in challenging conditions and can be harvested not only at the end of the season but when needed [2]. Cassava as food for man has long been available and thus making it possible for man to explore varying methods of its preparation and preservation as food for man and livestock[3]. Based on different customs, cassava tubers are processed into a variety of food products globally such as fufu, mingao, manicuer, dumby, farina, cassareep, ampesi, cassava rice, macaroni, cassava pudding, tiwul, wafers fried chips, garri and others [4].

Gari is a creamy-white granular flour with slight fermented flavour and sour taste made from fermented, gelatinized fresh cassava tubers mash [5]. Fermentation of cassava mash for three days usually reduces its hydrogen cyanide (HCN) to a level tolerable for human consumption[6].Sometimes, palm oil is added to the mash before frying to reduce HCN.Gari is the most developed or processed food product from cassava that exhibits higher shelf life and widely consumed in Nigeria, Brazil as well as in most countries of West African coast [5].

The roasting process during gari production which involves dextrinization and drying of cassava starch granules is called garification [7]. Garification is a simultaneous process of cooking and dehydrating dewatered and fermented cassava mash; that is, cooking itin the first instance and then later dehydrating it[8]. The heat intensity during frying affects the quality of the product, so the technique of using relatively low initial frying temperature to avoid denaturing and formation of many lumps is a common practice [5]. During frying, as the moisture content reduces and most of the small lumps get formed, constant pressing and agitation disintegrate them before the temperature is increased to further cook and dehydrate the product[5]. Gari is commonly consumed either as gelatinized dough (*eba*) served with sauces/soups or soak in cold water with sugar and roasted groundnut [9]. It is a good source of energy and fibre; its cheapness, ease of storage and preparation for consumption have strengthen its importance as a food item in Nigeria [7] and [9]. Garification processes can be done manually [9] or mechanically.

In Nigeria, many researchers have done several attempts to reduce the challenges associated with the garification process such as [10] [11] and [12] etc. An automated gari frying machine that uses charcoal as source of heat with a gari production capacity of 20kg/h at 20rpm optimum operating speed was designed and developed by [5]. The limitation associated with this model was the use of charcoal (non-renewable/ clean energy) that could adversely lead to environmental degradation.A model that uses cooking gas as a source of heat with a throughput capacity and functional efficiency of 6.6 kg/hr and 75 % respectively was developed by [13]. In terms of heat energy source, the model developed by [13] was an improvement over the model developed by [5] but the limitation here was the inability of the system to control frying temperature and speed automatically.Another model was successfully developed by [14] which was driven by the use of an electric motor; however, the heat source of the machine was also charcoal. An attempt to modulate gari frying temperature and agitators speed was designed and simulated by [15]. They successfully developed a system for controlling gari frying temperature where the gelatination (cooking) and drying temperatures were stabilized by using a PID Microcontroller-MATLABSIMULINK simulation schematic model. Similarly, [3] designed and simulated a gari frying machine which has a user-defined temperature regulation and motion control system. The design was

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developed by using Proteus simulation environment where temperatures and motion limits were set and maintained with the help of hardware programming (Arduino Integrated Development Environment). The outcome of the simulation test showed an effective regulation and control of temperature of the heating system and speed of the driving system to support further research and development of an automated gari frying machine. Hence, this study seeks to design, fabricate and test a gas fired and automated garification machine.

II. MATERIALS AND METHODS

A. Materials

The materials for fabrication of the machine were selected, locally sourced and used based on strength, suitability and availability. High grade stainless steel metal was used for all the contact surfaces. The following electrical and electronic components were used for the design and construction of the automation system:

- Variable frequency speed controller
- PID based temperature controller
- Electromagnetic gas shut off valve
- Spark electrode
- Timer
- 220v-6kvolts transformer
- 4kw electric 5.5Hp etc.

Dewatered cassava mash was procured from Idofian market and used during the preliminary test of the developed machine.

B. Machine description and operation principle

The gas fired and automated garification machine (figure 1) consist of control panel, 5.5Hp electric motor (prime mover), pulley, v-belt, shafts, differential gears, stainless steel metal pan, exit chute with cover, agitators (paddles), spark electrode, gas burner, heating chamber, electromagnetic gas shut off valve, temperature sensor, timer, block bearings and frame. The cylindrical frying pan is made from high grade stainless steel metal sheet of 5mm thickness and its walls are lagged using fibre glass to prevent heat lost by conduction. The frying pan is a closed-end cylinder of 1200mm diameter and 300mm depth. The pan is situated on top of a cylindrical heat chamber of the same diameter and 450mm depth. The machine has a height of 1525mm. It has a radially designed and fabricated gas burner attached in the heat chamber under the pan for even heat distribution. A spark electrode placed inside the heat chamber automatically ignites the gas for the safety of the operator. The four (4) agitators/ paddles are made from stainless steel metal and attached to the transmission system of the machine.

Fig. 1: Gas fired and automated garification machine

The gas burner, gas cylinder and the control panel are connected with each other to automate the metering of gas and heat intensity.

During operation, the control panel is connected to electricity supply followed by switching ON the gas cylinder valve. A command from the panel ignites the radial gas burner and the rotation of the paddles is then initiated by another command before the introduction of the dewatered and pulverised cassava mash. Another command from the panel regulates and allows appropriate agitators speeds and temperatures for both the cooking and drying stages involved in the process. The agitators/ paddles rotate at the same time having contact with the surface of the frying pan to prevent sticking, burning and formation of lumps during gelatinization of the mash in the cooking stage of the process. After the drying stage, the exit chute is opened and the fried gari is discharged into a receptacle.

C. Determination of machine power requirement

The power required to overcome the loads and drive the system during operation was determined by using equation 1 [12].

$$P = \frac{2\pi N_2 T}{60} \quad (1)$$

Where, P = Power of the driven pulley, W; N_2 = Speed of the driven pulley, rpm; T = Minimum torque to drive maximum volume of the garri, Nm.

The required torque to effectively operate the machine wasdetermined by using equation 2 [12].

$$T = (W_\alpha + W_f)R_f \quad (2)$$

Where, W_α= weight of the connecting rod, N; W_f= weight of the driven pulley, N and R_f= radius of driven pulley, m.

D. Determination of the volume of frying pan of the machine

It was determined by using equation 3 [12].

$$V_p = \pi r^2 h \quad (3)$$

Where, V_p = cylindrical frying pan volume, m^3; r = radius of cylindrical frying pan, m; h = height of cylindrical frying pan, m.

E. Determination of the maximum mass of cassava mash per batch

This parameter was determined by using equation 4 [12].

$$m = \rho \times V_p \tag{4}$$

Where, ρ = Density of garri, kg/m^3 (1509 kg/m3 [16]); V_p = Volume of frying pan, m^3.

F. Determination of belt length

Equation 5 was used to determine the required length of v-belt[17].

$$L = \frac{\pi}{2}(D_1 + D_2) + 2C + \frac{(D_1 + D_2)}{4C} \tag{5}$$

Where, L = Length of belt, mm; D_1 = Smaller pulley diameter, mm; D_2 = Larger pulley diameter, mm; C = Centre distance of pulleys, mm.

G. Determination of the quantity of heat required for garification

The quantity of heat required to cook and dry the dewatered cassava mash during garification was determined by using equation 6[12].

$$Q = MC\Delta T \tag{6}$$

Where, Q = Quantity of heat required, kJ; M = Mass of cassava mash in the frying pan, kg; C = specific heat capacity of cassava mash at moisture content of 45%wb, kJ/kgK (4.14kJ/kgK. [18]);ΔT= Temperature change, ˚C.

H. Determination of machine performance parameter

The procured dewatered cassava mash was pulverised by using a dried cassava grater to produce experimental samples. The moisture content level of the pulverised cassava mash was determined by using the gravimetric method [19] and equation 7 [5].

$$M_C = \frac{W_o - W_f}{W_o} \times 100\% \tag{7}$$

Where, M_C = Moisture content (wet basis), %; W_o= Weight of wet mash, kg and W_f= Weight of dried mash, kg.

The independent variables in table 1 were used during the preliminary test of the machine. The values of some of the independent variables were coined from [5] and [12] and others selected based on the previous preliminary studies. 40kg mass of pulverised dewatered cassava mass of 45%wb moisture was introduced into the machine which was already set to attain a maximum temperature of 65˚C and 98˚C, and agitating speed of 20rpm and 40rpm in the cooking and drying stages respectively. The same experiment was repeated twice to reduce experimental errors. Then, the performance parameters of the machine were computed.

Independent Variable	**Value**
Cooking stage maximum temperature, ˚C	65
Drying stage maximum temperature, ˚C	98
Cooking stage agitator/paddle speed, rpm	20
Cooking stage agitator/paddle speed, rpm	40
Moisture content of pulverised cassava mash, %wb	45
Mass of pulverised dewatered mash per batch, kg	40

Table 1: Independent variables used during preliminary test of the machine

I. Determination of throughput capacity

Equation 8 was used to compute throughput capacity of the machine [12].

$$TP_C = \frac{M_f}{t} \times 60 \tag{8}$$

Where, TP_C = Throughput capacity, kg/hr; M_f = Mass of gari obtained, kg; t = Time taken, min.

J. Determination of functional/drying efficiency

Equation 9 was used to compute functional/drying efficiency the machine [12].

$$n_f = \frac{M_f}{M_i} \times 100 \tag{9}$$

Where, η = Functional/drying efficiency, %; m_f = Mass of garri obtained, kg; m_i = Mass of mash introduced into the fryer, kg.

III. RESULTS AND DISCUSION

Table 1 shows the independent variables used during the preliminary test of the machine. In the study, the maximum temperature for cooking and drying stages, agitator/paddle speed for cooking and drying stages, moisture content of dewatered and pulverised cassava mash, and mass of pulverised dewatered mash per batch used in each experiment were 65˚C, 98˚C, 20rpm, 40rpm, 45%wb and 40kg respectively.

The mean values in Table 2 shows the performance parameters of the machine obtained in the preliminary test of the machine. The result shows that 40kg mass of dehydrated cassava mash at 45%wb moisture level gave 30.40kg of fried gari at 12.17%wb after 15min of frying and consumed 1.87Kg of cooking gas. The energy efficiency of the machine was 0.062kg of gas per Kg of gari produced. The machine accounted for throughput capacity and functional efficiency of 121.66kg/h and 76% respectively. The moisture content level of the fried gari was similar to the value in [5] and[12] but the throughput capacity and functional efficiency of the machine was higher than their results. This outcome can be attributed to the automation of the gari frying process and incorporation of a gas burner in the system.

Replications	Moisture Content of fried gari (%wb)	Mass of gari obtained, kg	Frying time, min	Cooking gas consumed, kg	Throughput capacity, kg/h	Functional efficiency, %
1.	12.20	30.50	15.00	1.94	122.00	76.25
2.	12.00	29.70	14.50	1.87	123.75	74.25
3.	12.30	31.00	15.50	1.80	119.23	77.50
Mean values	**12.17**	**30.40**	**15.00**	**1.87**	**121.66**	**76.00**

Table 2: Machine performance parameter

IV. CONCLUSION

A gas fired and automated garification machine was successfully developed and tested earliest. The outcome of this work has solved the problem of lack of gari frying machines with user-defined and automated frying temperature and agitator speed regulation and control. The machine has higher throughput capacity, functional efficiency and energy efficiency in comparative terms. The throughput capacity, functional efficiency and energy efficiency of the machine were 121.66kg/h, 76% and 0.062kg of gas per kg of gari produced respectively. Based on its efficiency and gender friendliness; less labour, energy, time and health hazard, the machine is therefore recommended for adoption by cassava processors.

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