DEVELOPMENT OF A LOCAL SOLID FOOD PROCESSING MACHINE

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Abstract

As the world is tending toward automation systems, the need for the replacement of human energy in Africa kitchen with automatic machines to eliminate the tedious, laborious and time consuming indigenous process of preparing solid food cannot be overemphasized. This paper presents a locally designed and fabricated solid food processing machine capable of producing foods like amala, eba, semo etc. The inputs to the machine are water at room temperature and raw solid food ingredient (yam flour, garri, semo, etc) at aspecific time. The water is heated to its boiling point by a 1 kW heater with the temperature monitored by LM 35 temperature sensor when the ingredient is added. The mixture is handled by the electric motor which stir it for some time to desired texture. The stirrer runs at slow speed with the aid of gear reduction technique. The output which is succulent solid food is manually ejected by pushing the ejecting rod forward at the output. The machine was constructed and tested and the performance showed that the concept can work satisfactorily if improved upon.

Introduction

The need for the replacement of human energy with machines has been one of the driving forces behind technological development right from the onset. The process of making some of the solid foods are complex, tedious and time-consuming. The method employed in preparing food determines in the long run, its level of acceptance by the people. For instance, European countries are also concerned about food safety and food production policies to develop risk-based, farm-to-table approaches to control foodborne hazards (WHO, 2004).

Today, women liberation and involvement in the workforce has completely displaced the concept of full-time housewife thereby making it imperative for a mechanized and modernized method of solid food preparation. There are different varieties of staple foods in Nigeria. These are eaten routinely and in such quantities that it constitutes a dominant portion of a standard diet for Nigerian people, supplying a large fraction of energy needs and generally forming a significant proportion of the intake of other nutrients as well. The staple food of a specific society may be eaten as often as every day or every meal, and most people live on a diet based on just a small number of staples (UN FAO, 2017).

Many varieties of solid food in Nigeria and by extension, Africa, are cassava, cocoyam, potatoes or yam-based (UN FAO, 2010; UN FAO, 2012). The most common of these is pounded yam which is similar to mashed potatoes but all mashed and completely smooth with no yam chunks left. (Hudgens, 2004). Another variety is “amala” which is a thick paste made from peeled yam, cleaned, dried and then blended similar to pounded yam but normally darker (brown) in colour (Muncho, 2015). Cassava is another major staple food in the developing world, providing a basic diet for over half a billion people. (Food and Agriculture, 1995). Cassava, when dried to a powdery extract is also called tapioca, (or cassava flour, in Nigeria). (Groover, 2014).

At the Obafemi Awolowo University in the early 1980s, some undergraduates have taken up the challenge to research and develop a yam pounding machine. A design blueprint was developed and sold to a Japanese company who subsequently fabricated and imported into the country the first ever yam pounding machine (Uchenna, Chuka, Daniel, & Efosa, 2015). However, this machine was not affordable to the general masses due to its high cost. A few machines have also been developed for processing African solid foods such as the electric-powered yam pounder; (Uchenna et al., 2015; Ikechukwu & Muncho 2015) and fufu pounding machine (Puoza, Opoku, & Aboagye, 2015). The preparation time of pounded yam using this machine is also a problem factor in that the machine has to be stopped intermittently and allowed to cool in order to avoid overheating. Another one is the motorized yam pounder (Gbasouzor &, Mbunwe, 2015).

In literature, there have not been any attempt at developing a processing machine for other Nigerian solid foods such as yam flour, garri, semo, etc. Thus, the objective of this work is to construct a machine that will eliminate the tedious and laborious indigenous process of preparing such solid foods. This machine is designed to prepare about 2.5kgweight of solid food. After construction, it was specifically tested with garri and water to prepare eba. Though not yet tested with other solid food, the machine can work for other similar solid food as well. This is because the preparation of some of these solid foods are virtually the same which usually involves heating water to its boiling point and adding powdered raw food ingredients to it while stirring the combination to form a slurry paste.

Materials and Method

The materials selection for the solid food processing machine fabrication was carefully made in order to ensure the cost of the system unit is inexpensive and also without compromising the standard. The design involved the construction of a cylindrical cooking chamber with dimension as shown in Fig. 1. The structure also houses a stirrer powered by an electric motor. The cooling chamber of the system is made up of stainless steel to ensure high resistance to corrosion. The outer frame was made up of mild steel in other to minimize the cost.

The capacity of the cooking chamber is determined thus:

$$V = \pi r^2 h \qquad (1).$$

Given r = 7 cm, h = 15 cm,

$$V = \pi \times 7^2 \text{x } 15$$

$$= 2309 \text{ cm}^3.$$

That is, equivalent to approximately 2.31 *l*.

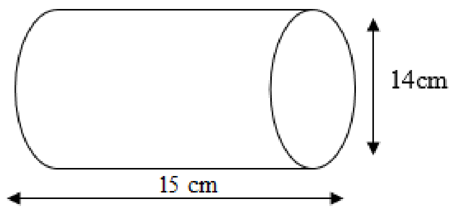

Fig 1: The Dimension of the Cooking Chamber

A 220V, 373 W, electric motor was employed to convert the electrical to mechanical energy through the shaft and the stirrer at a very low speed. Two flat bars of stainless steel material were designed for the stirrer and they are the main components that do the stirring. Stainless steel is used to avoid possible contamination of food that due to rusting of metallic parts (Ikechukwu & Muncho, 2015). The two bars were designed and welded together at an angle of 90° to each other at the centre and they rotate together through angle 360° while stirring. The stirrer is coupled to the shaft which is made of stainless steel designed to transmit power to the stirring rods for stirring operation. The shaft is coupled to the rotor of the electric motor.

A 1 kW electric heater is employed to heat the water in the cooking chamber. The heating operation is controlled by a microcontroller PIC16F using LM35 as a sensor to monitor when the water boils and switching off of the heater to allow the user to add the powdery foodstuff and then kick start the stirring operation. A scrapper made up of stainless steel material, formed in a circular shape which permits the two stirring rods to rotate effectively is included to scrape the food/water mixture. It is attached to a straight rod perpendicularly, which can freely move linearly within the shaft.

To determine the heater rating, it is assumed the water heating operation commences at room temperature of 20°C. Since the required temperature is the boiling point of water at 100°C, hence the change in temperature ΔT is determined thus:

$$\Delta T = 100 - 20 = 80 \text{ °C} \qquad (2).$$

$$\text{Using } Q = MC\Delta T \qquad (3)$$

where: Q is the work done (J)

M is the mass (kg) and

C is the specific heat capacity (J/kg).

Given that 1 *l* water of is approximately 1 *kg*, therefore, the mass of the volume available for the process is 2.31 kg.

$$\therefore Q = 2.31 \, x \, 4185.6 \, x \, 80$$

$$Q = 773.5 \text{ kJ}.$$

Since 1 joule = $2.78x10^{-7}$ kWh, therefore 773.5 kJ is equivalent to 0.215kWh. Thus, using a time of 12 minutes (0.2 h) to boil the water,

$$P = \frac{E(kWh)}{T(h)}$$

$$P = \frac{0.215}{0.2}$$

$$P = 1.1 \text{ kW}.$$

1kwh heater was chosen.

To determine the size of the electric motor required, the weight of the content of the cooking chamber and the frictional force were determined. The weight of 1 *l* of each food powder was determined as shown in Table 1. *Garri* power has the highest weight of 0.8 kg and this was used for the calculation.

Table 1: Weight of each solid food type

Solid food type	**Weight of 1 *l* volume (kg)**
Cassava flour	0.70
Semovita	0.75
Garri	0.80

The force required to drive the stirrer was determined as follow:

$$F = ma \qquad (3)$$

where: *F* is the force (N);

m is the mass (kg) and

a is the acceleration (m/s^2)

Total mass required is the mixture of the water and that of the powder.

Total mass = mass of water + mass of powder

= 2.31 + 0.8 = 3.11 kg.

If the motor accelerates at 8 m/s^2, then the required force to drive the shaft is

F = 3.11 x 8

= 24.88 N.

The frictional force between the two stainless steel parts (the chamber and the scrapper) is determined as:

$$F_{ss} = \mu ma; \qquad (4)$$

where F_{ss} is the frictional force between the two stainless steel;

μ is the coefficient of static friction, given as μ = 0.8;

m is the total mass and

a is the acceleration in m/s^2.

If the shaft rotates at 8 m/s^2 total mass is 3.8 kg then

F = 0.8 x 3.11 x 8

F = 19.9 N.

The mass of the flat bar holding the two stirrers and the weight of the two stirrers were determined as approximately 0.4kg.

Therefore converting the total mass in kg to Newton = 4N.

Hence, the total force required to drive the shaft = 24.88+19.9+4 = 48.78N.

The overall power consumption was calculated (see the below table for the result) Single phase, Voltage – 220 V, 50 Hz.

Table 2: Power consumption table

S/N	Constituent Part	Current consumption (A)	Power rating (W)
1	Electric heater	4.2	1000
2	Electric gear motor	1.6	373
3	All electronic components	0.42	100
	Total	6.22	1473

The device is as shown in Plate 1.

Various electrical testing was carried out on the equipment to assess its performance. The first testing stage was carried out by testing the component parts that constitute the whole system separately (i.e. each component was tested in isolation). The tested parts included the electric heater and the electric motor. Also, the PIC16F for water temperature monitor with feedback which compares the states of the water temperature with the set point was tested with the other components interfaced to it.

Plate 1: Solid Food Processing Machine

Results and Discussion

After conceptualization and subsequent design of this machine, it was constructed and tested to ascertain its performance. The process was initiated by manually pouring the water into the stirring chamber, as the water reaches a preset level, the electric heater automatically started as programmed and heated up the water from room temperature to its boiling point within a period of 12 minutes. The food powder was subsequently manually added and the stirring process starts automatically also. The slow speed of the electric motor enhanced through the gear mechanism ensured thorough mixing of the constituents together for about three minutes. The ejection process was then done manually by pushing forward the iron rod placed between the shafts which makes the processed material rush out from the ejection point in slurry form.

The output obtained was examined, it was compared with the one prepared with crude method and it was found that the one prepared with the machine was better than the one prepared by the crude method of preparation in terms of its texture and time taken. The machine took less time (17 min including the boiling process) to prepare the solid food and produced higher quality and quantity than the crude method. The output was good, easy and convenient than when using the manual method.

Conclusion

A solid food processing machine which employs the use of different technologies in its design, development, and implementation has been produced and tested in this work. The system used a microcontroller (PIC16F) to control the process by detecting the water temperature in the cooking/stirring chamber. It switches on/off the electric heater and an electric gear motor and manual ejection of the final product from the stirring chamber was employed. This device has successfully provided an improvement on existing methods of preparation of solid foods by its use of calibrated circuit to indicate the water temperature and use of an ejecting mechanism thereby reducing the time taken to prepare solid food in large quantity and to improve a healthy and hygienic condition of food processing. For improvement, the heater in the heating chamber can be made into a cylindrical shape to reduce the heating period and thus improve the efficiency of the process. Also, the ejection process can be modified for proper discharge. The need to fully automate the whole process is also paramount to achieve the ultimate gain of automation.

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