

# Design Concepts Towards Electric Powered Gari Frying Machine

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**ABSTRACT-** The most critical unit of operation while processing cassava into gari is the gari frying which occurs as a result of the simultaneous cooking and dehydrating the moisture content present by the application of heat. Traditional method had been established of frying gari, this has been exposing the fryer to various health disorders. This paper highlights the design concept of the electric gari frying machine which will help to alleviate these health disorders, by making gari frying appealing to the farmers. Gari frying should be done on hygienic principles with modern available technology therefore the frying process was analyzed; required components were identified and designed to specification. The required engineering drawings that will aid its production were produced as well as the projected production cost of the machine specification. The machine mode of operation was discussed and it can be concluded that the machine will be highly efficient and will ease the work of the farmers.

**Index Terms:** Design, analysis, engineering, drawing, cost, estimate, gari fryer, machine

## I. INTRODUCTION

Design in relation to food processing is the application of engineering knowledge, creativity and technical perception to produce machine or equipment for food processing. Researchers have confirmed that after rice, wheat and maize, the fourth most staple food in the world especially common to the African people is Cassava (*Manihot esculenta*) (IFAD/FAO, 2000). Several local products can be derived from cassava depending on how they are processed. These include cassava flour (gari), "lafun", "fufu", chips/ pellets and industrial products like starch and alcohol (RAIDS/IFAD, 1991).

Gari, a processed fermented product from cassava tubers, is consumed in Nigeria as well as in most countries of the West Africa coast and in Brazil. Gari can be described as a free flowing particulate product consisting of cassava particles, that have been dried and gelatinized. The nutritional value of gari is carbohydrates which symbolizes that it is an energy giving food. The preparation of gari is done according to village processing techniques. Made from cassava tubers (also called cassava roots), gari can be described to be a fine to

coarse granular flour that may be of different texture which are peeled after harvesting. The harvested cassava tubers will be later washed to remove pebbles from it to make it good for eating. After the washing, it will be grated, packed into sacks and starch squeezed out of it. It will be left to ferment for some few days and then fried either along with or without palm oil known as red oil. Some parts of the sub-Saharan Africa popularly refer to it as garri or gali [1].

In the developing world, most especially in West Africa, gari serves a daily meal to so many people in that there are several ways in which it can be prepared for meal. For instance, some people can determine to soak it in cold water on a very hot day before taking it; or some other people can prefer to soak it in hot water to make meal called "Eba" which will be taken along with soup depending on the choice of individual [4]. However, there are different types of gari based on the processing methods, its grain size and the region of Africa where it was produced. In Nigeria, the Standards Organization of Nigeria (SON) classified gari into three major categories which are (i) extra fine grain gari, where more than 80% of the grain passes through a sieve of less than 350 micrometer aperture; (ii) fine grain gari in which more than 80% of the grains pass through the sieve of less than 1000 micrometer aperture; (iii) coarse grain gari, where not less than 80% of grains passes through a sieve of 1400 micrometer or less than 20% of weight passes through a sieve of 1000 micrometer aperture; and (iv) extra coarse grain gari in which not less than 20% of grain is retained on a sieve of 1400 micrometer aperture (SON, 2000). Also based on the fermentation length of days and whether palm oil is added or not, we have the red gari- which is also called the "Bendel gari". This is derived from the inclusion of red oil after the cassava has been grated and allowed to ferment for two to three days which aids the reduction of the cyanide content

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and gives the gari a pleasant aroma; and the white gari-in which there is no addition of red oil during the processing.

Made from cassava, the tubers are harvested, peeled and grated in a gari grinding machine. However, before the invention of machines of cassava grating, cassava tubers are grated by hand. As part of the cassava processing into gari, the cassava grated produce is put into a jute sack and the sack is tied which is allowed to ferment between three to seven days. This step is very important due to the fact that the fermentation process aids in the reduction and detoxification of the high cyanide content of cassava [1] and [4]. While still in the sack, they are stacked up on each other, and a wooden board placed below and above the sacks. Tension is created by tightening the rope and thus allowing water to run of the grated cassava being processed. Within the stipulated number of days, some water would have been drained out from the grated cassava to a very reasonable drying amount which will be necessary so as to get to the next stage of frying. This can be achieved by using pressurizing machine that will compress and squeeze water out of the grated cassava. The squeezed water is rich in starch in which can be collected to obtain pure starch from it when it sediments. Large particles and small fine particles will be sieved using sieve. Frying is later done traditionally by using a big thick pot placed above fire in which you stir the grated cassava using spatula-like paddles of wood or calabash sections to press and mash against the hot surface of the frying pan (called "agbada", Nigerian Ibo) until it becomes crisp. It must be stirred continuously to avoid it getting burnt which gives off a pleasant cooked aroma.

Gari frying is a simultaneous cooking and dehydrating operation. The gari is first cooked with the moisture and then dehydrated. The heat intensity during frying affects the quality of the product. The moisture content of dewatered and sieved cassava mash is between 50 to 65 percent that has to be reduced after the frying [2]. In the traditional technique of frying, to avoid the formation of many lumps or caking, initial frying temperature needed is relatively low. As the temperature increases gradually, there is reduction in moisture content in which most of the small lumps developed would have been reduced by constant pressing and agitation. Further increase in heat supplied to the drying surface causes it to be cooked and dehydrate the product [10].

In the past years, a lot of research has been carried out to mechanize some aspects of the operation used in gari production, which include peeling and washing of the roots, grating, de-watering, fermentation, sieving, frying and cooling [3], [9]. The most critical operation that determines the quality of the final product in gari production is the frying operations [8]. It has been quite difficult to mechanize this operation correctly and rightly because the operation was not well understood by many designers and manufacturers. In Nigeria, many researchers have looked into ways to improve gari frying such as the UNIIBADAN improved dryer [2] in which the nuisance of smoke was totally eliminated, capacity

and rate of frying were increased and working environment was improved. Odigboh and Ahmed [11] designed a continuous process gari frying machine to simulate the traditional manual frying technique. Also the International Institute of Tropical Agriculture, Ibadan, Nigeria (IITA) and Rural Agro-Industrial Development Scheme (RAIDS) developed were improvement on the UNIIBADAN design. Other models include the Newell Dunford model which was collaboration between the Newell Dunford company in London and the Federal Institute of Industrial Research (FIIRO), Oshodi, the Brazillian model which seems better than the Newell Dunford; the Fabrico model done by a manufacturing company in Nigeria and the UNN model [8], [9]. Some had erroneously assumed the operation is the same as dehydration while others had taken it to be roasting. However, the traditional way of frying gari for large or commercial purpose is tedious, laborious, time consuming and prone to injury and health hazards. The design concept of this machine is necessary because every product or equipment in the world today is designed to suit a particular environment, performance and purpose. Hence it becomes imperative that gari frying machine undergo recent technological development to reduce or eliminate the problem encountered in the local way of frying; and to also fulfill human satisfaction especially those in the rural areas who fry gari for commercial purpose. This work will be a rationale for knowing much about the design concept of an electric gari frying machine so as to handle the challenge of traditional frying. It is of no doubt that this work will improve the technological level of the nation as well as attract more people to better appreciate agriculture thereby reducing the rate of unemployment in the country.

## II. METHODOLOGY

The methodology of this research took care of the design analysis of the electric gari frying machine, material selection for each component designed, operating description of the system, engineering drawings and required system assembly as well as the estimated production cost.

### a. Identified Components to be Designed for Production

The identified components to be designed are as follows: frying compartment, delivery chute, delivery chute cover, stirrer shaft, bolt and nut, machine base/ frame and heating compartment.

### b. Material Selection

The main objective of material selection is to minimize cost as well as selecting the appropriate material to be used for each component considering engineering factors as well as the environmental factors or service conditions of the components so that they will perform properly with high degree of reliability. The material selection is summarized in the Table 1 as well as the reasons for their selection.

**Table 1: Proposed material for components production before assembly**

| S/No | Machine parts        | Material selection | Reason for selection   |
|------|----------------------|--------------------|--|
| 1.   | Frying Compartment   | Stainless steel    | Good corrosion resistance and thermal conductivity.                            |
| 2.   | Delivery Chute       | Mild Steel         | Better resistance to bending forces.   |
| 3.   | Delivery Chute cover | Mild Steel         | Better resistance to shear and bending forces.                                 |
| 4.   | Shaft                | Mild steel         | Better resistance to shear and bending forces.                                 |
| 5.   | Bolt and nut         | Mild steel         | Better resistance to shear and bending forces.<br>Easy to machine at low cost. |
| 6.   | Machine Frame        | Mild Steel         | It is very cheap, it can withstand shear stress and bending forces.            |
| 7.   | Heating Chamber      | Coil               | Better thermal conductivity  |

**c. Design Analysis of the Fryer**

**i. Design Analysis of the Mass of the Frying Chamber**

Material - Stainless steel

Density,  $\rho - 8 \text{ g/cm}^3$

Number - 1 unit

Length,  $l - 900 \text{ mm} = 90 \text{ cm}$

Breadth,  $b - 900 \text{ mm} = 90 \text{ cm}$

Height (thickness),  $h = 3\text{mm} = 0.3 \text{ cm}$

$$Volume = l \times b \times h \tag{1}$$

$$Volume = 90 \times 90 \times 0.3 = 2430 \text{ cm}^3$$

$$\rho = \frac{m}{v} \tag{2}$$

$$m = \rho V = 8 \times 2430 = 19440 \text{ g} = 19.44 \text{ kg}$$

The mass of the compartment = 19.44 kg

**ii. Volume of the Cylinder**

Diameter,  $d = 300 \text{ mm} = 30 \text{ cm}$

Height,  $h = 900 \text{ mm} = 90$

$$V = \pi r^2 h \tag{3}$$

$$= \frac{22}{7} \times 15^2 \times 90 = 63642.86 \text{ cm}^3$$

However, one-quarter ( $\frac{1}{4}$ ) of the volume of the cylinder will be needed to have effective frying i.e.  $\frac{1}{4} \times 63642.86 \text{ cm}^3 = 15910.7 \text{ cm}^3$

**iii. Design Analysis for Frame**

Material - Mild steel

Density - 7.84 g/cm<sup>3</sup>

Number - 2 units

Length - 670 mm = 67 cm

Breadth - 50 mm = 5 cm

Height (thickness) = 3mm = 0.3 cm

$$Volume = l \times b \times h$$

$$Volume = 67 \times 5 \times 0.3 = 100.5 \text{ cm}^3$$

$$\rho = \frac{m}{v}$$

$$m_f = \rho V = 7.84 \times 100.5 = 787.92 \text{ g} = 0.788 \text{ kg}$$

The mass of the frame = 0.788 kg

**iv. Design Analysis of the Inner Cylinder**

Material - Mild steel

Density - 7.84 g/cm<sup>3</sup>

Number - 2 units

Height - 470 mm = 47 cm

Diameter - 30 mm = 3 cm

$$Volume, V = \pi r^2 h = \frac{22}{7} \times 1.5^2 \times 47 = 332.35 \text{ cm}^3$$

$$\rho = \frac{m}{v}$$

$$m_i = \rho V = 7.84 \times 332.85 = 2605.68 \text{ g} = 2.61 \text{ kg}$$

The mass of the inner cylinder = 2.61 kg

**v. Design Analysis of the Outer Cylinder**

Material - Mild steel

Density - 7.84 g/cm<sup>3</sup>

Number - 2 units

Height - 470 mm = 47 cm

Diameter - 30.4 mm = 3.04 cm

$$\text{Volume, } V = \pi r^2 h = \frac{22}{7} \times 1.52^2 \times 47 = 341.27 \text{ cm}^3$$

$$\rho = \frac{m}{V}$$

$$m_0 = \rho V = 7.84 \times 341.27 = 2675.6 \text{ g} = 2.676 \text{ kg}$$

The mass of the outer cylinder = 2.676 kg

#### vi. Design Analysis of Connecting Rod

Material - Stainless steel

Density - 8 g/cm<sup>3</sup>

Number - 1 unit

Height - 1000 mm = 100 cm

Diameter - 20 mm = 2 cm

$$\text{Volume, } V = \pi r^2 h = \frac{22}{7} \times 1^2 \times 100 = 341.2 \text{ cm}^3$$

$$\rho = \frac{m}{V}$$

$$m = \rho V = 8 \times 341.2 = 2514.3 \text{ g} = 2.5 \text{ kg}$$

The mass of the connecting rod = 2.5 kg

#### vii. Determination of Belt Speed

$$\frac{N_1}{N_2} = \frac{D_2}{D_1} \quad (4)$$

where  $N_1$  = speed of driven pulley = ?

$N_2$  = speed of driving pulley = 1420 rpm

$D_1$  = diameter of driven pulley = 250 mm

$D_2$  = diameter of driving pulley = 80 mm [6]

$$N_1 = \frac{N_2 D_2}{D_1} = \frac{1420 \times 80}{250} = 454.4 \text{ rpm}$$

#### viii. Determination of Belt Length

Length of belt can be derived using the formula

$$L = 2C + 1.57(D + d) + \frac{(D-d)^2}{4C} \quad (5)$$

where L = Length of belt

C = Centre distance = 0.336 m

D = Diameter of the driven pulley = 0.25 m

d = Diameter of the driving pulley = 0.08 m [6]

$$L = 2(0.336) + 1.57(0.25 + 0.08) + \frac{(0.25 - 0.08)^2}{4(0.336)} = 1.21 \text{ m}$$

#### ix. Determination of Power to Drive the Shaft

$$P_s = \frac{2\pi N_1 T_s}{60} \quad (6)$$

Where  $P_s$  = Power of the driven pulley

$N_1$  = Speed of the driven pulley

$T_s$  = Torque

$$T_s = (W_{CR} + W_f) \times R_f \quad (7)$$

Where  $W_{CR}$  = weight of the connecting rod = 2.5 kg × 9.81 m/s<sup>2</sup> = 24.525 N

$W_f$  = weight of the driven pulley = 8.5 N

$R_f$  = radius of driven pulley = 0.125 m

Therefore,  $T_s = (24.525 + 8.5) \times 0.125 = 4.128 \text{ Nm}$

$$P_s = \frac{2\pi N_1 T_s}{60} = \frac{2 \times \frac{22}{7} \times 454.4 \times 4.128}{60} = 1733.76 \text{ W} = 1.73 \text{ kW}$$

#### d. Summary of the Design Analysis

The components, their designed factors, models used as well as the designed values are as shown in Table 2.

**Table 2 Summary of the models, source and design values**

| S/No | Component          | Design Factor  | Mathematical models used            | Equation number | Source | Design value           |
|------|--------------------|----------------|-------------------------------------|-----------------|--------|------------------------|
| 1.   | Frying compartment | Weight         | $\rho = \frac{m}{v}$                | .... (1)        | [7]    |                        |
|      |                    |                | $m = \rho v$                        | .... (2)        | [7]    | 19.44 kg               |
| 2.   | Cylinder           | Capacity       | $V = \pi r^2 h$                     | .... (3)        | [5]    | 15910.7cm <sup>3</sup> |
| 3.   | Front Frame        | Capacity       | $V = lbh$                           | ....(4)         | [5]    | 100.5 cm <sup>3</sup>  |
|      |                    | Weight         | $m = \rho v$                        | .... (2)        | [5]    | 0.788 kg               |
| 4.   | Inner cylinder     | Capacity       | $V = \pi r^2 h$                     | .... (3)        | [5]    | 332.35 cm <sup>3</sup> |
|      |                    | Weight         | $m = \rho v$                        | .... (2)        | [5]    | 2.61 kg                |
| 5.   | Outer cylinder     | Capacity       | $V = \pi r^2 h$                     | .... (3)        | [5]    | 341.27 cm <sup>3</sup> |
|      |                    | Weight         | $m = \rho v$                        | .... (2)        | [5]    | 2.676 kg               |
| 6.   | Connecting rod     | Capacity       | $V = \pi r^2 h$                     | .... (3)        | [5]    | 314.2 cm <sup>3</sup>  |
|      |                    | Weight         | $m = \rho v$                        | .... (2)        | [5]    | 2.5 kg                 |
| 7.   | Drive system       | (a) Belt speed | $\frac{N_1}{N_2} = \frac{D_2}{D_1}$ | .... (5)        | [6]    | 454.4 rpm              |
|      |                    | (b) Power      | $P = \frac{2\pi NT}{60}$            | .... (6)        | [6]    | 1.73 kW                |
| 8.   | Electric motor     | Power          | $P = \frac{2\pi NT}{60}$            | .... (6)        | [6]    | 2.5kW                  |

**e. Expected Production Cost of the Fryer**

The expected production cost of the fryer estimate is as shown in the table below:

**Table3: Expected production cost**

|                      |                           | #     | USD\$ |
|----------------------|---------------------------|-------|-------|
| i.                   | Bought-out component cost | 30000 | 150   |
| ii.                  | Material cost             | 18000 | 90    |
| iii.                 | Machining cost            | 10000 | 50    |
| iv.                  | Non-machining cost        | 7000  | 35    |
| Total Estimated cost |                           | 65000 | 325   |

**f. Engineering Drawings for Production**

The isometric drawing of this machine is as shown in Fig.1. The orthographic views as well as the exploded

drawing and other drawings of the component parts are as shown in Figs. 2, 3,4,5,6 and 7.



THE 3D ISOMETRIC DRAWING OF A GARRI FRYING MACHINE

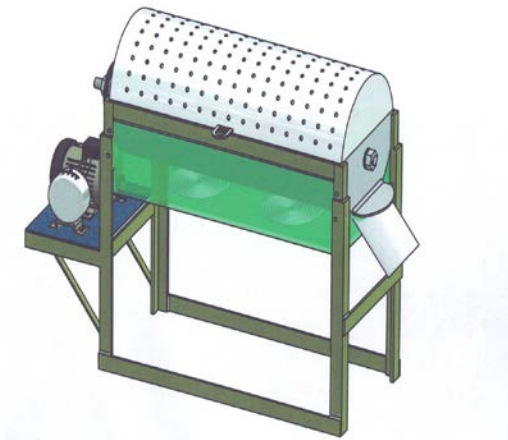


Fig. 1: Isometric view of proposed electric powered gari frying machine.

THE COVER CASING

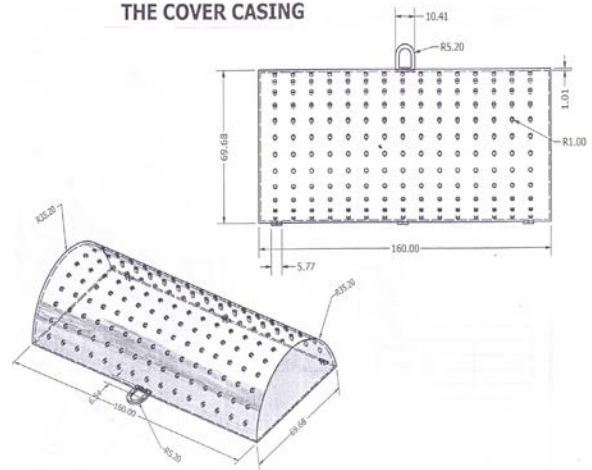


Fig. 3: Cover casing for the machine

THE GARRI CASING

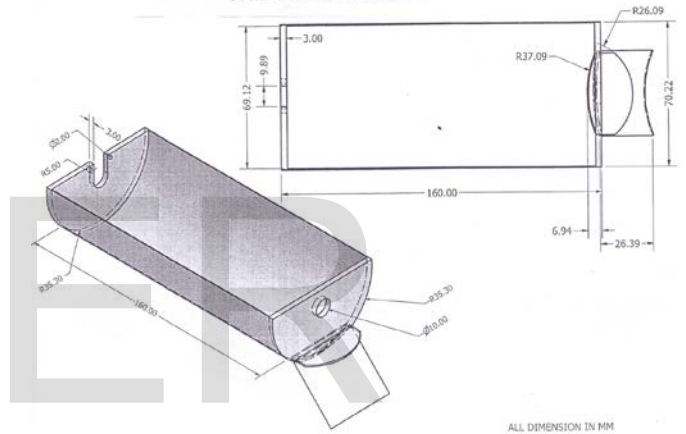


Fig. 4: Lower part of the gari casing

THE FRYING BLADE

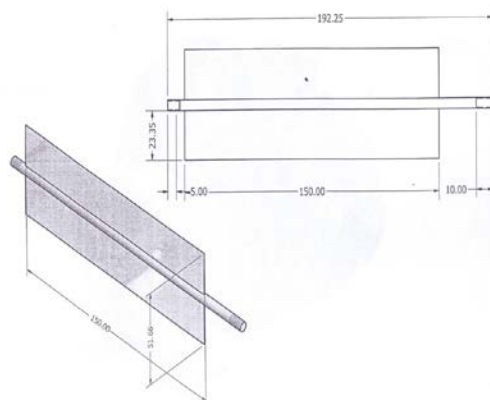
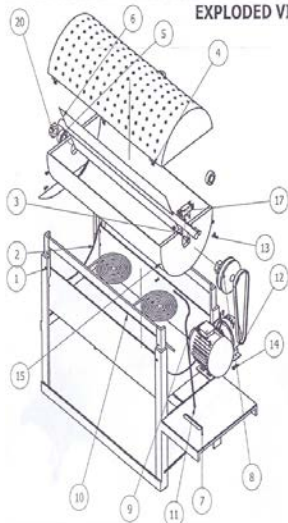


Fig. 5: The frying blade

EXPLODED VIEW OF A GARRI FRYING MACHINE



| PARTS LIST |     |             |                  |
|------------|-----|-------------|------------------|
| ITEM       | QTY | PART NUMBER | DESCRIPTION      |
| 1          | 1   |             | FRAME            |
| 2          | 1   |             | HEATER CASING    |
| 3          | 1   |             | BLADE CASING     |
| 4          | 1   |             | BLADE CASING TOP |
| 5          | 2   |             | BEARING          |
| 6          | 1   |             | BLADE SHAFT      |
| 7          | 1   |             | PLATE            |
| 8          | 1   |             | PULLEY           |
| 9          | 1   |             | MOTOR            |
| 10         | 2   |             | HEATER           |
| 11         | 1   |             | ELECTRICAL WIRE  |
| 12         | 1   |             | BELT             |
| 13         | 12  |             | BOLT             |
| 14         | 4   |             | NUT              |
| 15         | 4   |             | BOLT_MIR         |
| 16         | 1   |             | TEXT             |
| 17         | 1   |             | BRACKET          |
| 18         | 2   |             | BRACKET BOLT     |
| 19         | 2   |             | BRACKET NUT      |
| 20         | 2   |             | BLADE NUT        |

Fig. 2: Exploded view of the machine

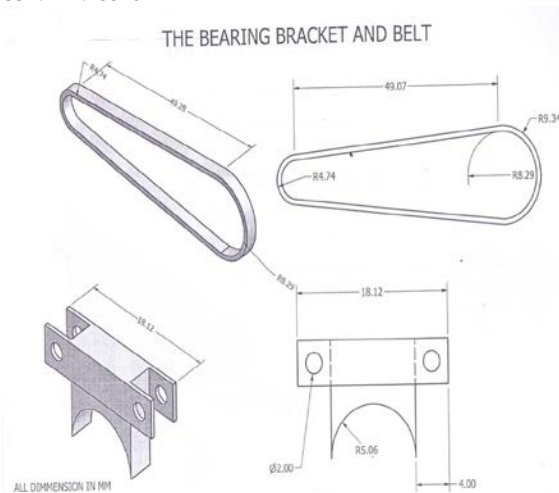


Fig. 6: The bearing bracket and belt

### g. Expected Machine's Principle of Operation

The design concept for this machine consists of five basic components, these are: such as the frying compartment, connecting rod with paddle, electric heater, prime mover (electric motor) and reducing gear.

The frying compartment consists of the paddle in form of a rectangular blade attached to the connecting rod for the gradual movement of the gari from one side in it. The paddle is attached to the connecting rods on both sides. When the machine is switched on, electric power is supplied to the electric motor; torque is transmitted through the belt to the shaft holding the paddle in a reciprocating motion.

The speed of the electric motor is reduced by the reducing gear to allow for the slow and gradual movement of the gari from the inlet side to the outlet of the frying compartment thus, creating room for retention period for the effective frying. The electric heater supplies the necessary heat required to fry the gari. When the gari is well fried, the machine is switched off and the electric motor is adjusted (relief tension on the belt) so as to tilt the frying compartment at an angle so as to discharge the gari from it into a receiving bowl.

## III. RESULTS AND DISCUSSION

The proposed electric gari drying machine has been designed stating the necessary materials for its production with the reasons for the selection of the materials. The engineering drawings required for the production of this electromechanical machine based on the design values computed has been made available. The expected machine working principle has been discussed for the machine production.

Based on the computations done, the following are some attainable designed values for the major components for this

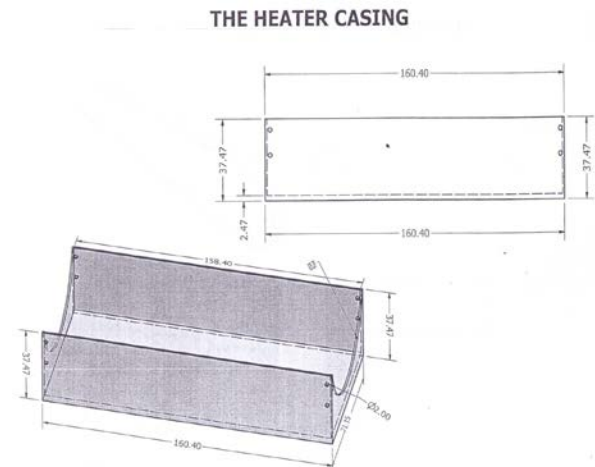


Fig. 7: The heater casing

machine which will be of help in the production of the machine and in the assembling of these components parts. These are: mass of frying chamber (19.44 kg), volume of cylinder for effective frying (15910.7 cm<sup>3</sup>), volume and mass of the front frame are 100.5 cm<sup>3</sup> and 0.788 kg respectively, volume and mass of the inner cylinder are 332.35 cm<sup>3</sup> and 2.606 kg respectively, volume and mass of outer cylinder are 341.27 cm<sup>3</sup> and 2.676 kg respectively. While the volume and mass of the connecting rods are 314.2 cm<sup>3</sup> and 2.5 kg respectively. The length of the belt was computed to be 1.21 m and the power required to drive the shaft was 1733.76 W (1.73 kW).

In the production of this machine, according to [8], it must be noted that: (i) a continuous operation leading to mass operation of moderate capacity is required, (ii) to ensure simultaneous cooking and dehydration, it must be ensured that temperature regulating mechanism must be incorporated so as to avoid roasting, (iii) stirring and lump breaking mechanism that will ensure uniform cooking and dehydration in the entire mass is ensured and the texture produced; and also an arrangement of paddles to produce a conveyor effect which will give the product a forward movement during the process, should be incorporated while producing the machine.

## IV. CONCLUSION

The design concept for an electric gari drying machine for usage in the agricultural sector of the nation such as Nigeria has been achieved. Various components to be used in the production have been identified and the designed values for each component have been generated through computations using different models available for the achievement of the desire purpose.

In an effort to make life easier and better for the rural farmers, this concept will go a long way in improving their health status because there will be no unnecessary sitting for

a very long time beside the fire when frying gari. Exposure to smoke and direct heat from the fire can cause various health disorders which will be taken care of, when this electromechanical system is finally produced.

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