Design And Fabrication Of A Gari Frying Machine

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***Abstract*— In this paper, design and fabrication of a garri frying machine is presented. The procedure encompasses materials selection and the design analysis which entails detailed analytical models for the computation of the design parameters associated with the various components of the garri frying machine that is being design. Sample numerical computations were presented for the case study machine. Specifically, the design concept adopted for the case study machine uses a 1 horsepower (single-phase) electric motor as a source of mechanical power and two (2) electric heaters of 1 KW as sources of thermal power. The gari frying pot is designed to carry a payload (gari) of 9.84 kg which is approximately 10kg per operation. The machine operates with stirrer speed range of 10 rad/sec to 15 rad/sec) which gives the range of values for the resisting torque at the stirrer to be from 0.285 N-m to 0.428 N-m. After the analytical computation and specification of the various parameters associated with the machine design, the Computer-Aided Design (CAD) models of the various components of the Gari frying machine were also developed. Also, the isometric drawing and the 3D photo realistic rendering of the gari frying machine are presented.**

***Keywords*— Gari Frying Machine, 3D Photo Realistic Rendering, Stirrer Blades, Isometric Drawing, Epicyclic Gear Train , Computer-Aided Design (CAD) Models**

1. INTRODUCTION

Cassava (*Manihot esculenta* C) is an important root crop consumed as a major staple food in Nigeria (Fathima, Sanitha, Tripathi and Muiruri, 2023). Cassava has several uses which make it an attractive crop in Nigeria and such uses of cassava include the production of gari, starch, cassava flour, fufu, cassava chips (Musa, Samuel, Sani and Mari, 2022; Ngoualem Kégah and Ndjouenkeu, 2023).. Cassava has a conservation life that is widely recognized to be of the order of 24 hours to 48 hours after harvest (Andrew, 2002). It undergoes post-harvest physiological deterioration (PPD) once the tubers are cut off from the main plant (Onyenwoke and Simonyan, 2014). Post-harvest deterioration simply means the instant the crop is harvested or cut off from its parent plant; it begins to disintegrate to the point where it spoils. Therefore, cassava needs to be consumed or processed as soon as possible.

Gari is one of the many distinct types of food products that newly uprooted cassava roots can produce (Adekunle, 2023; Nyamekye, 2021). Gari is dry, crispy, white-creamy, and granular. It is produced of roots of cassava crushed into a mash, fermented and sieved into tiny bits (known as grits). To create the final crispy item, the grits are then cooked or fried. Gari is a famous food in Nigeria and West Africa and quickly becoming a marketable product (IITA, 2012). Gari frying (Grafication) is the main terminal unit in the manufacturing of gari. The frying of gari is a complicated method. Simply stirring the pulverized and sifted mash in a pot over a fire would produce a product that, although visually similar to gari, would not be gari (Adegbite, Asiru, Salami, Nwaeche, Ebun and Ogunbiyi, 2019; Odigboh, 1982).

Gari is traditionally fried by females over a wood fire in shallow earthenware or cast-iron pans. Women use wood or calabash spatula-like paddles to press the sifted mash against the warm surface of the frying pan, scrape the mash off the hot surface rapidly to prevent burning, stir the mash strongly and repeat the sequence (Adegbite, Asiru, Salami, Nwaeche, Ebun and Ogunbiyi, 2019; Odigboh, 1982). Due to the inherent limitations of the traditionally approach to fry gari, researchers have come up with some design of gari frying machine. According, this work presents the design of gari frying machine. The detailed design analysis is presented which entails detailed analytical models for the computation of the design parameters associated with the various components of the gari frying machine that is being design. Sample design calculations are also presented for a case study case study gari frying machine that uses a 1 horsepower (single-phase) electric motor as a source of mechanical power and two (2) electric heaters of 1 KW as sources of thermal power. The Computer-Aided Design (CAD) models of the various components of the Gari frying machine are also developed. Also, the isometric drawing and the 3D photo realistic rendering of the gari frying machine are presented.

2. METHODOLOGY

The procedure used in the work is first presentation of the selection of materials followed by the design analysis. The design analysis entails detailed analytical models for the computation of the design parameters associated with the various components of the gari frying machine that is being design. Specifically, the following machine components design are presented; design of the pot (payload analysis), design of stirrer blades, gear design and selection and the design of the pulley drive. Furthermore, the description of the machine is presented which include the description of the main frame, the cantilever, the support rig, the pot support frame, the frying pot, the heating system frame, the rotary frame and the description of the Stirrer. Eventually, the Computer-Aided Design (CAD) models of the various components of the Gari frying machine are presented along with the isometric drawing and the 3D photo realistic rendering of the gari frying machine.

2.1 Design Concept

The gari frying machine is to have an oval-shaped drum/ trough with electrical filament heating medium. In order to produce quality gari, the following features are considered to be basic requirements for the gari fryer:

1. A continuous process operation that results in the mass production of small and medium scale quantities of gari.
2. A temperature controller which ensures simultaneous cooking and dehydration, without roasting, until the desired moisture content is attained.
3. An effective mechanism that provids both stirring and lump breaking actions so that uniform cooking and dehydration in the entire mass are ensured and the desired texture produced.

2.2 Selection of Materials

The selection of materials for a design plays an important role in the functionality of the design. Materials selected for the frying pot have good thermal properties, transmit heat without getting destroyed and also are not toxic in any way to avoid transmitting the germs as they will come in direct contact with the germ. Also, the stirrer block and shaft are made of food-grade materials. Materials used for the heat shield has good refractory properties to consume thermal energy and increase the overall efficiency of the machine. High strength materials were suitable for the main support frame and the support leg, materials with good tonsorial strength was employed for the shafts (main shaft and stirrer shaft. Materials for other parts were chosen based on functionality and cost. Specifically, the materials selected for the gari frying machine are locally available and are listed in Table 1.

Table 1: Material selection

S/N	Component/Part	Material
1.	Frying pot	Stainless steel
2.	Stirrer blade	Stainless steel
3.	Stirrer shaft	Stainless steel
4.	Main support frame	Mild steel
5.	Support leg	Mild steel
6.	Transmission belt	
7.	Rotary Frame	Stainless steel
8.	Main shaft	Stainless steel
9.	Pulley	
10.	Support shaft	Stainless steel
11.	Gearbox	Standard part
12.	Pinion gear	
13.	Spur gear	
14.	Electric motor	Standard part
15.	Support bearing (flat)	Standard part
16.	Heat retainer	

2.3 Design Analysis

The design concept adopted in this work uses a 1 horsepower = electric motor (single-phase) as a source of mechanical power and two (2) electric heaters of 1 KW as sources of thermal power. The mainframe forms the main support that supports a greater fraction of the total load (weight) of the machine having a box plate that can be billed to the ground. It forms the frame for the components and provides a base for the frying pot to rest on. The parts are analysed as follows.

2.3.1 Source of Turning Motion

The turning shaft is used to stir the gari to prevent burning of the mash. An electric motor is used to provide rotating power to the main shaft which will cause the hot stirrer to revolve and rotate inside the frying pot. The electric motor solution is selected based on the calculation of the required torque and power needed to stir the minimum quantity (mass) of gari in the frying pot at any given time in addition to rotating the rotary frame carrying the pinion, stirring shaft, stirring blade and bearings.

2.3.2 Design of the Pot (Payload Analysis)

The gari fryer is designed to be portable and as such the maximum quantity of gari to be processed per operation is determined to form the maximum density of dewatered cassava. From literature review, the average values of density for dried solid cassava roots from different ages were ranged from 810 kg/m^3 to 870 kg/m^3 (Baharuddin, Nurul, Mazlan, and Noorhafiza, 2016). Therefore, the maximum quantity of gari processed per time is a processing volume of 1m^3 is 870 kg. The design of the pot is restricted in size to 600 mm (0.6 m) diameter with a height, h of 200mm (0.2 m), giving the pot a maximum volume of $V_{p.max}$

$$V_{p.max} = A_{p.max}.h \quad (1)$$

$$A_{p.max} = \pi r^2 \quad (2)$$

Hence, $A_{p.max} = 3.142 \times \left(\frac{0.6}{2}\right)^2 = 0.28278\, m^2$ where $A_{p.max}$ = Base area of the frying pot

$$V_{p.max} = \pi r^2 h \quad (3)$$

Hence, $V_{p.max} = 3.142 \times \left(\frac{0.6}{2}\right)^2 \times 0.2 = 0.056556\, m^3$.

However, the pot is not to operate at maximum volume (material are not to fill the pot all the way to the top), but rather the operational volume of the pot is at 20% of the maximum volume to enable proper and efficient turning and mixing of the dewatered cassava when frying it without the processed material fall off over the edge of the pot. Therefore, the pot operating volume V_p is computed as

$$V_p = 0.2(V_{p.max}) = 0.2(56.556) = 0.0113112\, m^3 \quad (4)$$

Therefore, the mass of gari m_g processed per operation cycle is calculated as follows:

$$m_g = \rho_g V_p \quad (5)$$

Where m_g = mass of gari; ρ_g = density of gari; V_p = Volume of gari, hence,

$$m_g = 870 kg/m^3 \times 0.0113112\, m^3 = 9.840744\, kg$$

Therefore, the pot is designed to carry a payload (gari) of 9.84 kg which is approximately 10kg per operation. This is however the mass at the start of the frying operation (i.e. when the cassava having a relatively high moisture content is first poured into the pot). After the frying operation, the moisture content is expected to reduce to a minimum therefore causing a reduction in the weight of the product discharged.

2.3.3 Design of Stirrer Blades

The blade of the stirrer mechanism is made rectangular in shape having a length, l *and* breath, b (representing the height of the stirrer blade). These dimensions give the stirrer blade an area A_b where;

$$A_b = l \times b \quad (6)$$

With approximately 9.84 kg of cassava being processed into gari per operational cycle, the stirrer blade mechanism is designed to move and reposition at least 95% of that mass as it travels one complete revolution in the frying pot for effective frying. To achieve 95% repositioning per revolution, the blade is designed and positioned to come in contact with all surface areas of the frying pot's base in one revolution

From Equation 2, the base is calculated as follows; 0.28278 m^2 and from equation 4, the active volume of the pot is calculated as follows; 0.0113112 m^3, therefore the maximum height of material being processed in the pot is given as;

$$H_{g.max} = \frac{V_p}{A_{p.max}} \quad (7)$$

Hence, $H_{g.max} = \frac{0.0113112\, m^3}{0.28278\, m^2} = 0.04\, m$. Therefore, the minimum height of the blade (breath, b) is 0.04 m (40 mm). The length of the blade is chosen to be 100 mm (0.1 m), making the blade area 0.004 m^2. The bulk density of gari ranges from 0.55±0.10 g/cm^3 to 0.82±0.21 g/cm^3

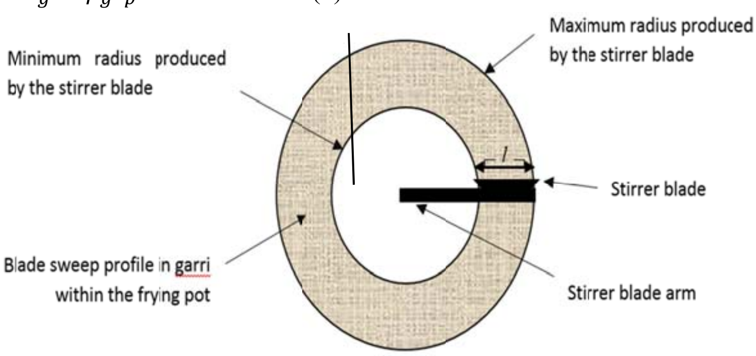

Figure 1: Stirrer Sweep Area Analysis

From Figure 1, a single stirrer blade will sweep out an area bounded by the edges of the stirrer blade. The difference between the two radii is the length of the stirrer blade, this forms the area of the sweep of the blade in one rotation. Assuming the gari in the pot to be a solid continuum, the energy required to move the mass of this volume is evaluated as;

$$R_{max} = Length\ of\ stirrer\ blade\ arm \quad (8)$$

$$R_{min} = Length\ of\ stirrer\ blade\ arm - l \quad (9)$$

Where R_{max}= Maximum radius produced by external edge of stirrer blade, R_{min} = Minimum radius produced by internal edge of stirrer blade, L = *length of stirrer blade. Then, the* area of sweep, A_s is evaluated as;

$$A_s = \pi(R_{max})^2 - \pi(R_{min})^2 \quad (10)$$

$$A_s = \pi[(R_{max})^2 - (R_{min})^2] \quad (11)$$

$A_s = \pi[(0.18)^2 - (0.08)^2]$ = $A_s = \pi[0.0324 - 0.0064]$ = $A_s = 3.142[0.026]$ = $A_s = 0.0817\, m^2$. However, the active area of gari moved per time is assumed to be a quarter of this area as the blade can only actively move mass in a quadrant of a circle based on its dimension. Therefore, the area of sweep for a single blade stirrer based on the design dimension is 0.0817 m^2.

$$A_s = \frac{0.0817m^2}{4} = 0.020425\, m^2$$

For multiple blade stirrers having identical dimensions as in the case of this design, the total area of sweep is multiplied by the number of blades which in this case is three (3). Therefore, the total area of sweep is given as;

$$A_{s_T} = 0.020425\, m^2 \times 3 = 0.0613\, m^2$$

Total volume of gari moved by the blade in one complete rotation is given as;

$$V_{s_T} = A_{s_T} \times H_{g.max} \quad (12)$$

Hence; $V_{s_T} = 0.0613m^2 \times 0.04\, m = 0.002452\, m^3$. From the literature review, the bulk density of gari is found to range from 381.78 to 487. 24 kg/ m^3 (Olaosebikan, Aregbesola, & Sanni, 2016), from 490 to 580 kg/m^3 (Apea-Bah, Oduro, Ellis, & Safo-Kantanka, 2009), and 550 to 820 kg/m^3 (Komolafe and Arawande, 2010). Taking an average of the lowest and highest values for the analysis, which is 600.89 kg/m^3. Therefore, the mass of gari moved per complete rotation of the stirrer is given as;

$$m_{g_s} = \rho_{gB} V_{s_T} \quad (13)$$

Hence; $m_{g_s} = 600.89\, kg/m^3 \times 0.002452m^3 = 1.47\, kg$. From the shape profile of the mass distribution, the moment of inertia of the mass is that of a solid hollow cylinder with length $H_{g.max}$,internal radius R_{min} and external radius R_{max}, having a total mass of m_{g_s}. Therefore, the moment of inertia I_g is given as

$$I_g = \frac{1}{2} m_{g_s} (R_{max})^2 + (R_{min})^2 \quad (14)$$

From Equation 13, the resisting torque is calculated as follows:

$$T = I_g \alpha \quad (15)$$

$$T = \frac{d(I_g \omega)}{dt} \quad (16)$$

$$T = I_g \frac{d\omega}{dt} + \omega \frac{dI_g}{dt} \quad (17)$$

With I_g constant, Equation 15 becomes;

$$T = I_g \frac{d\omega}{dt} \quad (18)$$

$$T = \left[\frac{1}{2} m_{g_s} (R_{max})^2 + (R_{min})^2\right] \frac{d\omega}{dt} \quad (19a)$$

$$T = \left[\frac{1}{2} m_{g_s} (0.0324 + 0.0064)\right] \frac{d\omega}{dt} \quad (19b)$$

$$T = \left[\frac{1}{2} m_{g_s} (0.0388)\right] \frac{d\omega}{dt} = \left[\frac{1}{2} (1.47)\, (0.0388)\right] \frac{d\omega}{dt}$$

$=\left[\frac{1}{2} (1.47)\, (0.0388)\right] \frac{d\omega}{dt}$. Hence,

$$T = [0.0285] \frac{d\omega}{dt} \quad (19c)$$

Choosing a low-speed range for the stirrer (10 rad/sec to 15 rad/sec), from Equation 17, the resisting torque at the stirrer ranges from 0.285 N-m to 0.428 N-m.

2.3.4 Gear Design and Selection

From the design of the rig, a pinion gear which is free to move and travel around a stationary gear that is attached to the rig supplies rotary motion to the stirrer about its axis as it travels around the stationary gear, causing the stirrer to revolve around the axis of the main gear as well. This setup forms an epicyclic gear train with the stirrer coupled to the smaller gear that rotates about and upon the stationary gear (larger gear), as shown in Figure 2. The arm that holds the stirrer frame shares its centre of rotation with the centre of the stationary gear. The mating ration of the gear and pinion must be such that it leaves a reoccurring decimal to ensure the stirrer's rotational path does not repeat in every revolution of the stirrer. To achieve the reoccurring decimal, a pinion to the gear ratio of 1:3 is chosen.

The output torque that is required to be produced by the gear train is a minimum of 0.428 N-m, approximately 0.5 N-m. Taking the factor of safety into consideration, the torque is increased by a factor of "2" to give 1.0 N-m. The output speed range of 40 rpm to 120 rpm was chosen.

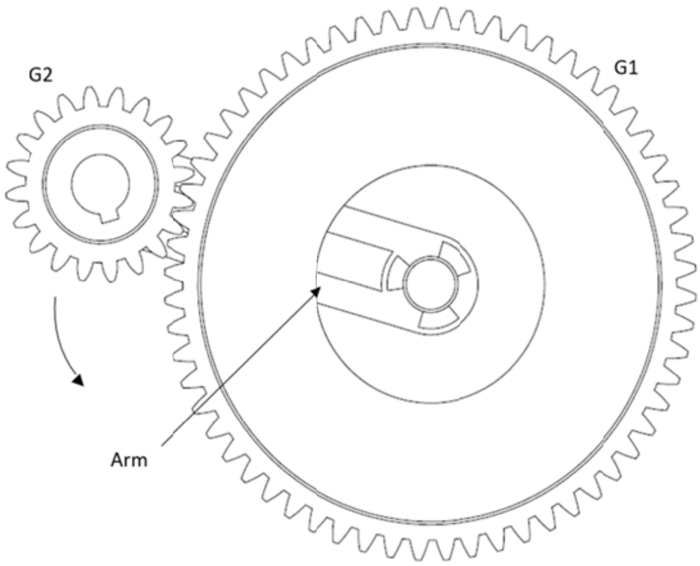

Figure 2: Epicyclic Gear Train for Stirrer Mechanism

$$T_1 = 60$$

$$T_2 = 20$$

$N_{Arm\,(min)} = 10\, rpm$ (Anticlockwise) and $N_{Arm\,(max)} = 30\, rpm$ (anticlockwise). The details of gear train motion are as given in e Table 2.

Table 2. The details of gear train motion

Step No.	Conditions of motion	Revolutions of elements		
		Arm	Gear G1	Gear G2
1.	Arm fixed, gear G1 rotates through + 1 revolution (i.e. 1 rev. anticlockwise)	0	+1	$-(T_{G1}/T_{G2})$
2.	Arm fixed, gear G1 rotates through + x revolutions	0	+x	$-x\ (T_{G1}/T_{G2})$
3.	Adding + y revolutions to all elements	+ y	+ y	+ y
4.	Total motion	+ y	+x +y	$y-x\ (T_{G1}/T_{G2})$

The Speed of Gear G2 When Gear G1 is Fixed

Since the speed of the arm is to vary from 10 rpm (minimum speed) to 30 rpm (maximum speed) anticlockwise, the speed calculation is done for the two extremes; at minimum speed and at maximum speed.

a) At Minimum Speed

When operating at the minimum speed of 10 rpm, the fourth row of Table 2 (item no.3), y = + 10 rpm. Also the gear G1 is fixed, therefore x + y = 0 or x = – y = – 10 rpm. Therefore, the speed of gear G2,

$$N_{G2} = y - x\left(\frac{T_{G1}}{T_{G2}}\right) \quad (20)$$

$N_{G2} = y - (-y)\left(\frac{T_{G1}}{T_{G2}}\right) = y + y\left(\frac{T_{G1}}{T_{G2}}\right)$. Hence, $N_{G2} = 10 + 10\left(\frac{60}{20}\right) = 10 + 10\left(\frac{60}{20}\right) = 40\ rpm$

b) At Maximum Speed

When operating at the maximum speed of 40 rpm, the fourth row of the table (item no.3), y = + 30 rpm. Also the gear G1 is fixed, therefore x + y = 0 or x = – y = – 30 rpm. Therefore, Speed of gear G2;

$$N_{G2} = y - x\left(\frac{T_{G1}}{T_{G2}}\right) \quad (21)$$

$N_{G2} = y - (-y)\left(\frac{T_{G1}}{T_{G2}}\right) = y + y\left(\frac{T_{G1}}{T_{G2}}\right)$. Hence, $N_{G2} = 30 + 30\left(\frac{60}{20}\right) = 120\,rpm.$

2.3.5 Design of Pulley Drive

A pulley drive system is used to transmit power to the central shaft of the epicyclic gear train which powers the arm of the gear train to achieve the required motion. The shaft is meant to rotate at a speed of 10 rpm to 30 rpm and as such, the pulley system is designed to reduce speed and increase torque. With space constrain in mind, the pulley system is made to reduce the speed by half and increase torque by a factor of two (2).

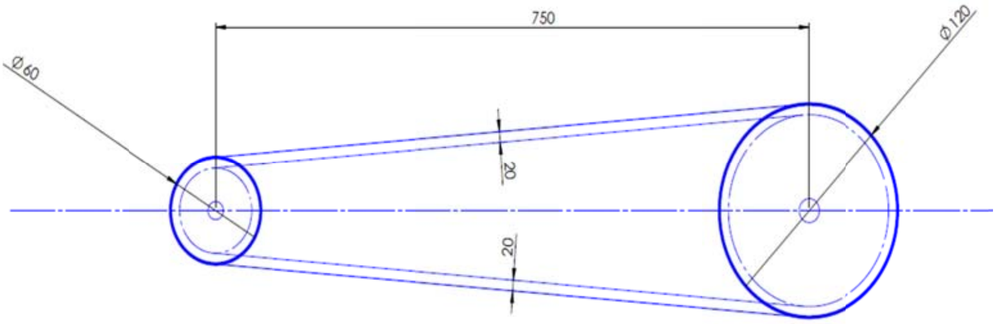

Figure 3: Pulley System

A small pulley of diameter 60mm is driven by a larger pulley of 120 mm diameter which is coupled to the output of the variable speed gearbox, as shown in Figure 3 and Figure 4.

$D = 120\,mm = 0.12\,m$, $d = 60\,mm = 0.06\,m$ and $N_{big} = 30\,rpm$ (max), hen

$$N_{small} = ?$$

$$D\,N_{big} = d\,N_{small} \quad (22a)$$

$$N_{small} = \frac{D\,N_{big}}{d} \quad (22b)$$

Hence, $N_{small} = \frac{0.12\times30}{0.06} = 60\,rpm$.

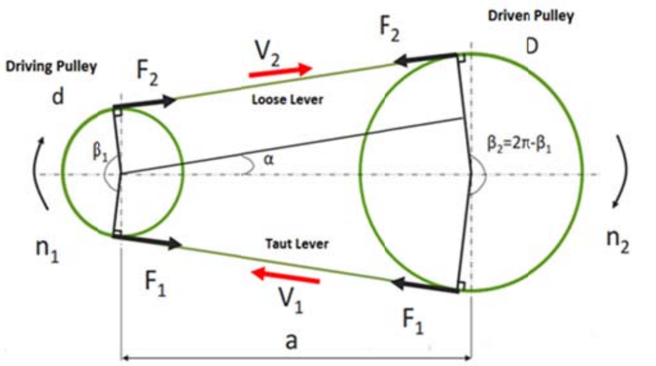

Figure 4: Pulley Analysis

Where a = distance between pulley; β_1 = wrapping angle of the belt on the small pulley; β_2 = wrapping angle of the belt on the large pulley; α = belt inclination angle and v = velocity of the belt

Determination of the Wrapping Angle, B_1 and B_2: The wrapping angle, β_1 for the belt on the pulley small is calculated as follows:

$$\beta_1 = 180 - \frac{180\,D}{\pi\,d} \tag{23}$$

$\beta_1 = 180 - \frac{180 \times 0.12}{3.142 \times 0.06} = 180 - \frac{21.60}{0.18852} = 180 - 114.58 = 65.42°$. The wrapping angle, β_2 for the belt on the pulley large is calculated as follows:

$$\beta_2 = 2\pi - \beta_1 \tag{24}$$

Hence, $\beta_2 = 2(180) - 65.42 = 294.58°$.

Determination of the Belt Length, L: The belt length for the pulley drive system is calculated as follows:

$$L = 2a\cos\alpha + \frac{\pi}{2}(d + D) + \frac{\pi a}{180}(D - d) \tag{25}$$

The practical belt length for the pulley drive system is calculated as follows:

$$L = 2a + \frac{\pi}{2}(d + D) + \frac{(D-d)^2}{4a} \tag{26}$$

Hence, $L = 2(750) + \frac{(3.142)}{2}(60 + 120) + \frac{(120-60)^2}{4(750)} = 1500 + 1.571(180) + \frac{(60)^2}{3000}$

$L = 1500 + 282.78 + 1.2 = 1783.98\ mm$.

Determination of the Belt Inclination Angle, α: The belt inclination angle, α is calculated as follows:

$$\sin\alpha = \frac{D-d}{2a} \tag{27}$$

Hence, $\sin\alpha = \frac{120-60}{2\,(750)} = \sin\alpha = \frac{60}{1500} = 0.04$. Then, $\alpha = \sin^{-1}(0.04) = \sin^{-1}(0.04)$

Determination of the Belt Velocity: The speed of the belt can be calculated according to the formula;

$$v = \frac{\pi d N}{60} \tag{28}$$

Using the speed and diameter of the large pulley, N_{small} and d respectively,

$$v = \frac{\pi d N_{small}}{60} \tag{29}$$

Hence, $v = \frac{3.142 \times 0.12 \times 30}{60} = \frac{11.3112}{60} = 0.18853\ m/sec$.

***Determination of the Belt Tension*:** The tension in the belt is dependent on the belt velocity and the transmitting power P:

$$F = \frac{P}{v} \tag{30}$$

Power transmitted by belt is calculated as follows:

$$P = \frac{2\pi NT}{60} \tag{31}$$

Where N = rotational Speed in rpmand T = Torque generated, then;

$P = \frac{2 \times 3.142 \times 30 \times 0.428}{60} = \frac{80.69}{60} = 1.345\ W$. Therefore, tension in belt $F = \frac{1.345}{0.18853} = \frac{1.345}{0.18853} = 7.13N$.

A. 3. The Description of the Machine

The CAD model of the Gari frying machine is shown in Figure 5. As shown in Figure 5, the gari frying machine developed in this work is made up of the following main parts and components; the heating pot, the frame which is divided into the mainframe and the pot support frame, the cantilever support, epicyclic gear train, support rig, stirrer, belt drive system, heating system, electric motor and the control panel.

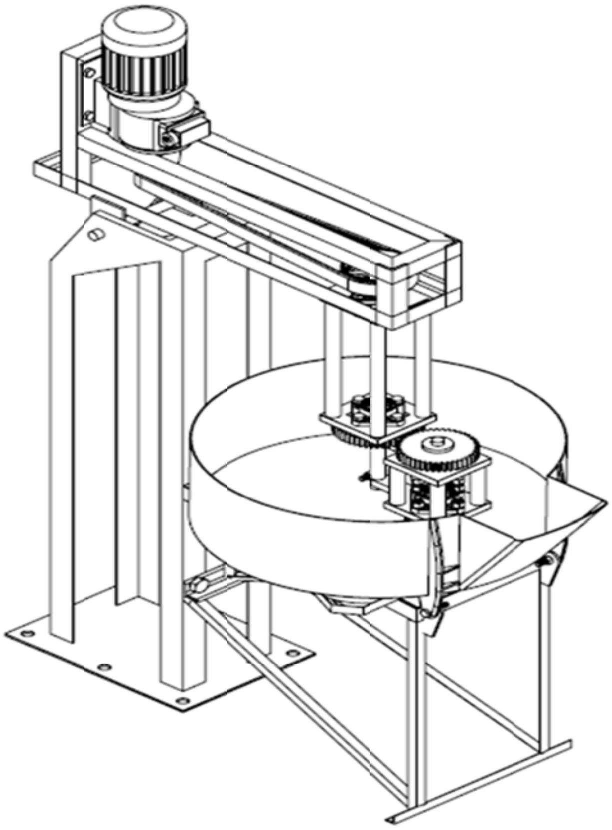

Figure 5: CAD Model of the Gari Frying Machine

The machine is operated from the control panel which has a motor control unit for controlling the electric motor which serves as the prime mover for the system, and the heating system controller with integrated temperature measurement and controller module. A digital temperature controller (ST-100) is used to monitor and control the frying temperature of the pot by setting the desired temperature value. The stirring speed is controlled using the speed control knob of the variable speed gearbox.

The machine cantilever frame supports the electric motor, belt drive system, epicyclic gear train, support rig, and stirrer. Mass distribution was taken into consideration in the placement of components/parts to ensure balance, even distribution of load, and achieve ergonomics during operation. The cantilever is designed to swing back, away from the pot in a way as to retract the stirrer from the frying pot when discharging the fried gari. The pot swings in the opposite direction of the cantilever to discharge the fried gari via its discharge by gravity. Every part of the machine that comes in contact with the gari being processed is made of food-grade stainless steel (S304). However, due to cost constrain, all other parts of the machine is primarily made of mild steel. Standard parts were used in implementing the design and the parts and components were fabricated using standard engineering procedures.

3.1 The Description of the Main Frame

The mainframe supports all other components of the machine and is made of mild steel. The CAD model of the mainframe is shown in Figure 6.

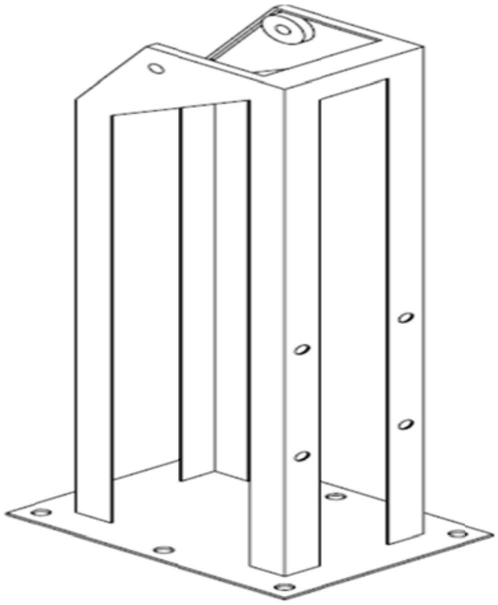

Figure 6: CAD Model of the Main Frame

An angle section with a profile of 45 mm x 45 mm x 3 mm was used for the support members of the structure. A mild steel sheet of 6mm thickness measuring 300 mm x 250 mm was used as the base of the mainframe with 20 mm holes drilled through the base plate for bolting down onto a foundation for prolonged stationary operation in the case of a factory setup. The angle section is welded to the base plate to achieve a total height of 1000 mm and an anchor hole of 20 mm is made towards the top of the frame for anchoring the cantilever. Holes are drilled on one side of the frame for bolting the pot support frame to the mainframe. The holes for anchoring the cantilever at the top are made such that they can be fitted with bushings for supporting the lock rod.

3.2 The Description of the Cantilever

The cantilever supports the support rig, pulley drive system, epicyclic gear train, main rotary shaft, stirrer and bearings. It is designed to protrude 600 mm from the edge of the mainframe on which it rests. As such, the cantilever frame is designed to withstand vibrations and bending moments due to a load of various components. The CAD model of the cantilever frame is shown in Figure 7.

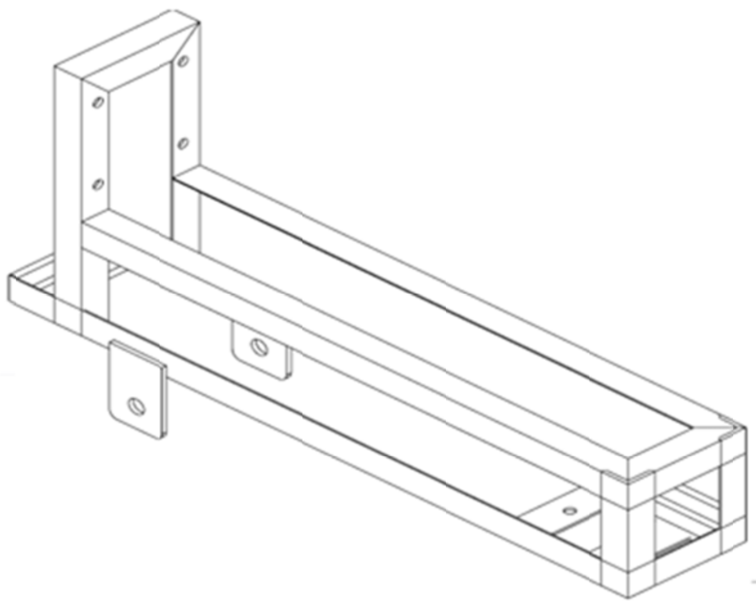

Figure 7: CAD Model of the Cantilever Frame

The cantilever frame is made of a mild steel angle section with a profile of 45 mm x 45 mm x 3 mm. It is designed to saddle on the mainframe and swing about the bushing hole where the lock rod holds it in place giving it a degree of freedom. The cantilever as shown in Figure 7 forms a structure with a height of 200 mm and width of 220 mm. it has a total length of 810 mm. it provides mounting holes for the electric motor at one end and holes for mounting the support rig and its peripheral components at the opposite end.

3.3 The Description of the Support Rig

The support rig is designed to support the main rotary shaft, the stirrer and other associated components/parts. The CAD model of the support rig is shown in Figure 8.

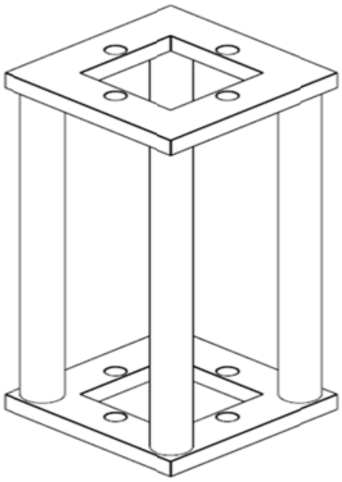

Figure 3.8: CAD Model of the Support Rig

The support ring is made using stainless steel (S304). A 15 mm x 30 mm rectangular section stainless steel pipe is used to form the square at the top and bottom end of the support ring by welding. Four holes of 12 mm diameter each are drilled on the squares for mounting flange bearings (F204). Four (4) 30 mm diameter stainless steel pipes of length 298 mm each is welded in-between the squares formed from the 15 mm x 30 mm section to achieve the support rig as shown in Figure 8.

3.4 The Description of the Pot Support Frame

The pot support frame is made up of two different sections of angle iron; 45 mm x 45 mm x 3 mm and 25 mm x 25 mm x 2.5 mm. The material used here is mild steel. The CAD model of the Pot Support Frame is shown in Figure 9.

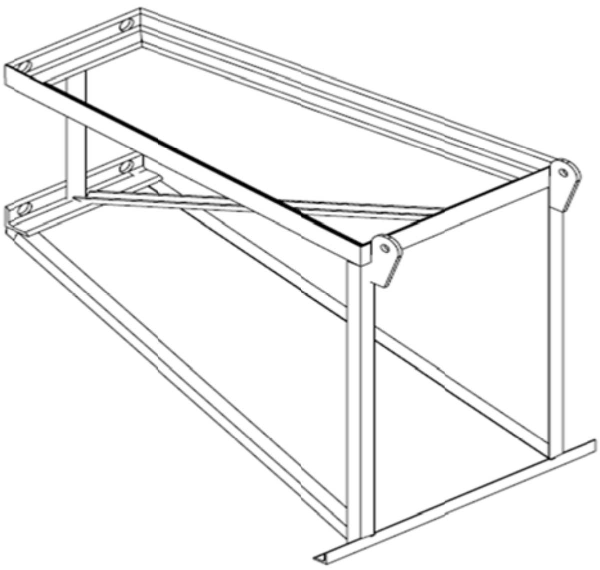

Figure 9: CAD Model of the Pot Support Frame

As shown in Figure 9, the pot support frame provides support for the pot and has got provision to attach the pot to it allowing only a single degree of freedom for the pot. The pot support frame is attached to the mainframe with 17 mm bolts and nuts through four (4) matching holes drilled on both frames.

3.5 The Description of the Frying Pot

The frying pot is where the cassava mash is heated and stirred to make gari. The CAD model of the Frying Pot is shown in Figure 10. It is made entirely of stainless steel. S304 Stainless steel sheet of 1.5 mm thickness was cut to form a circle of 600 mm diameter for the base of the pot. S304 stainless steel sheet was cut into a rectangle with a height of 200 mm and length equal to the circumference of the 600 mm diameter base circle. The rectangle was then wrapped around the circular pot base for a cylinder of 600 mm diameter and 200 mm height with one open end as shown in Figure 10. The discharge channel is integrated into the pot as shown in Figure 10. The pivot hole location is 50 mm away from the base of the pot for swinging the pot to discharge the finished product.

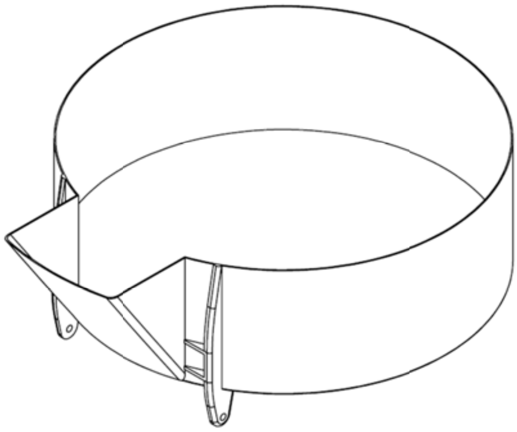

Figure 10: CAD Model of the Frying Pot

3.6 The Description of the Heating System Frame

The frame for the heating system is made up of 25mm x 25mm x 2.5mm angle section mild steel. It forms a triangular frame as shown in Figure 11 for holding the three (3) heating elements. The heating system frame ensures the heating elements are held firmly in position on the frying pot. It is bolted to the pot through bolts and nuts via holes drilled on it as indicated on the working drawing.

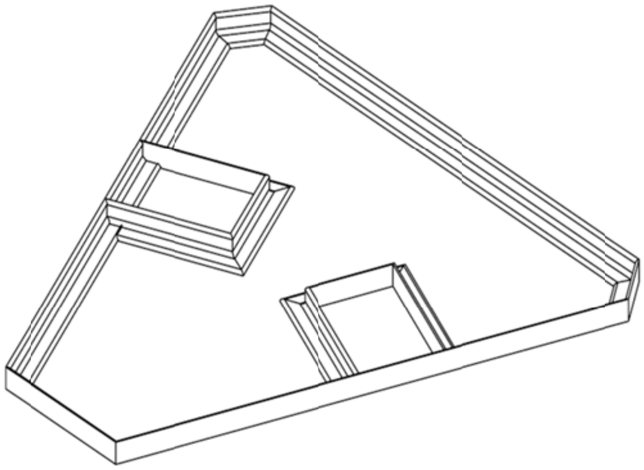

Figure 11: CAD Model of the Heating System Frame

3.7 The Description of the Rotary Frame

The rotary frame is designed to clamp onto the main rotary shaft through lock bolts and nuts which prevents it from having relative motion for the main rotary shaft. The CAD model of the Rotary Frame is shown in Figure 12.

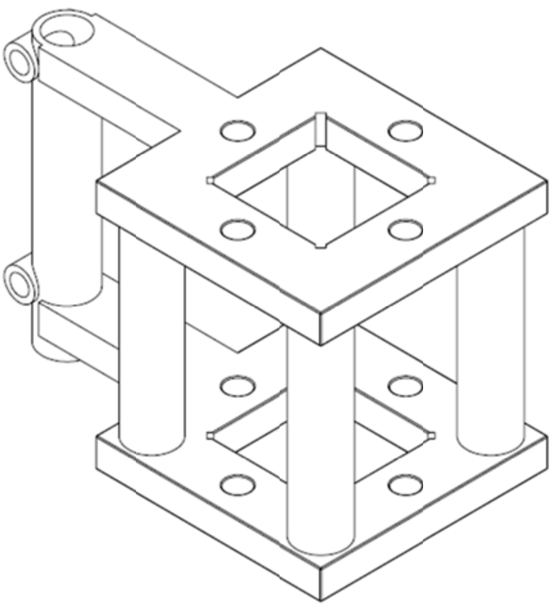

Figure 12: CAD Model of the Rotary Frame

The rotary frame is made using stainless steel (S304). A 15 mm x 30 mm rectangular section stainless steel pipe is used to form the square with a protruded 'T' at the top and bottom end of the support rig by welding. Four holes of 12 mm diameter each are drilled on the squares for mounting flange bearings (F204). Four (4) 30 mm diameter stainless steel pipes of length 120 mm each is welded in-between the squares formed from the 15 mm x 30 mm section to achieve the support rig as shown in Figure 12.

3.8 The Description of the Stirrer

The stirrer is the part of the machine that turns the gari in the pot to ensure even distribution of heat during frying operation. It is entirely made up of stainless steel (S304) to avoid contaminating the gari during processing. The stirrer has three (3) arms equally spaced at angles of 120 degrees to each other, and protruding a length of 120 mm from the rotating shaft on which they are attached to. The CAD model of the rotary frame is shown in Figure 13. As shown in Figure 13, the stirrer has a 20 mm diameter shaft with of length of 300 mm on which the stirrer blades are attached at an inclined position at one end.

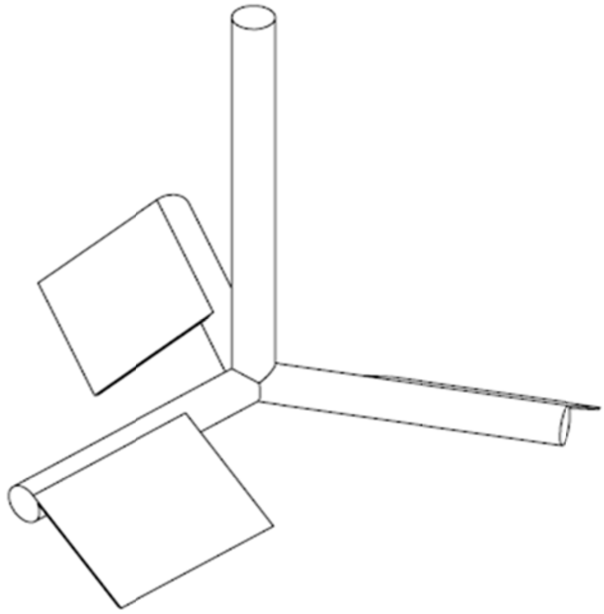

Figure 13: CAD Model of the Rotary Frame

3.9 The isometric drawing and the 3D photo realistic rendering of the developed gari frying machine

The isometric drawing of the designed gari frying machine is presented in Figure 14 while the 3D photo realistic rendering of the developed gari frying machine is presented in Figure 15.

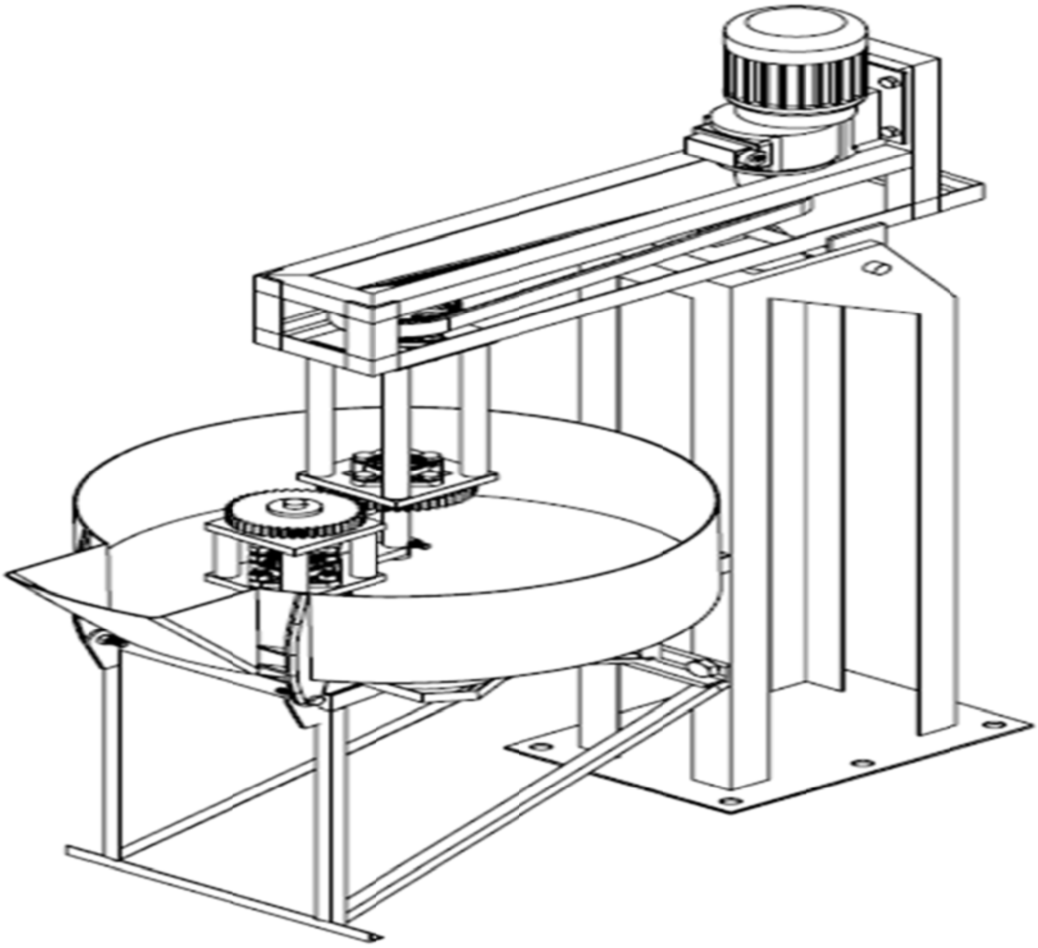

Figure 14 The isometric drawing of the gari frying machine

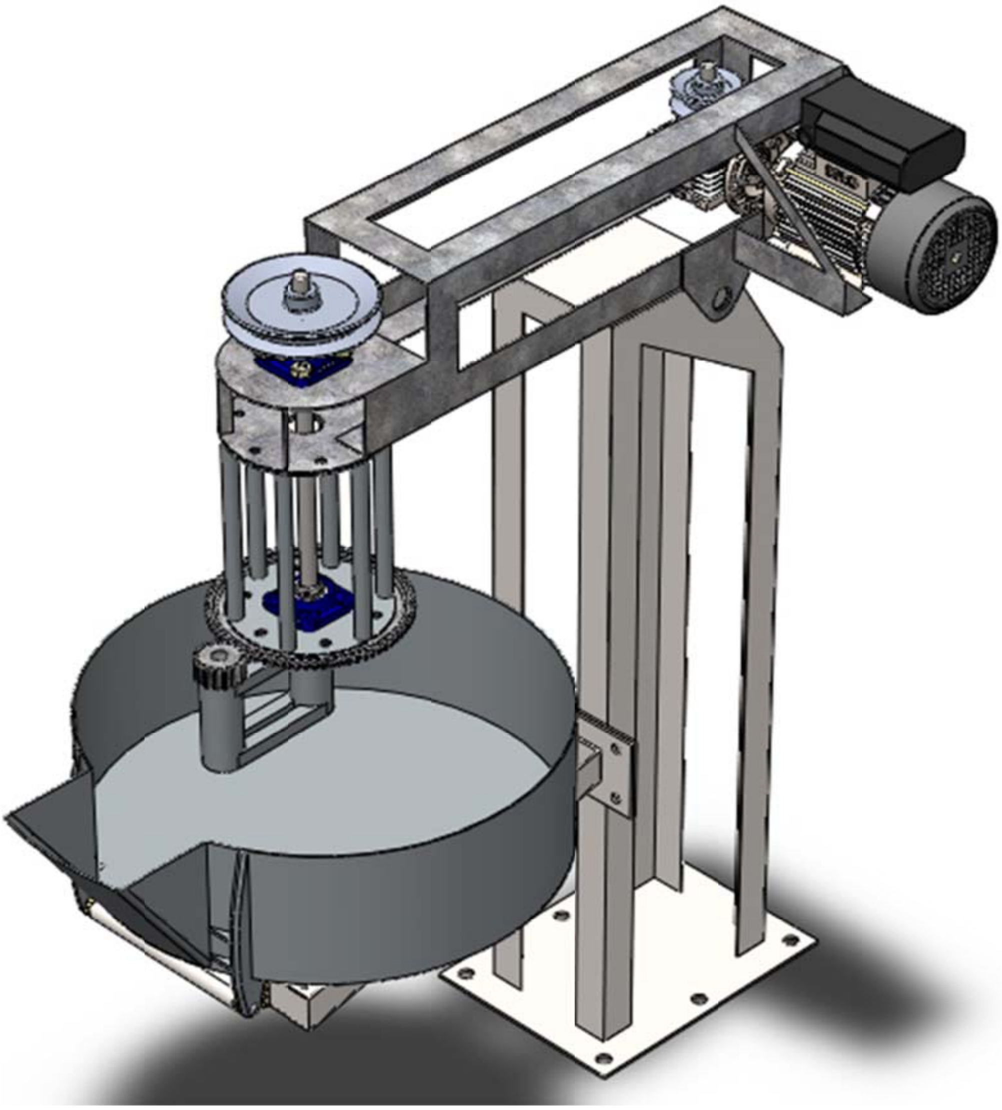

Figure 15 The 3D photo realistic rendering of the developed gari frying machine

4. CONCLUSION

The description of the design details for gari frying machine is presented. Notably, the selection of materials for the design and the detail design analysis which include machine components description, design parameter specifications and analytical models for the computation of many of the design parameters associated with the various machine components are presented. Sample numerical computations were presented for the case study machine. The Computer-Aided Design (CAD) models of the various components of the Gari Frying Machine are also presented. Also, the isometric drawing of the designed gari frying machine is presented along with the 3D photo realistic rendering of the gari frying machine.

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