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DESIGN AND CONSTRUCTION OF GAS - POWERED GARRI FRYING MACHINE

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ABSTRACT

Food rank first in the scale of human basic needs. Man in his quest to provide the important need has explored his environment by planting, harvesting, and processing of various food crops. Like cassava which has secured a prominent space in the food chain of African countries most especially in Nigeria with various advantage mode of preparation for consumption. One of the most natural preserving states of cassava food is the garri state which is obtain from various processing from planting, uprooting, peeling, washing, grating pressing and sieving to frying. Frying is the most critical unit of operation while processing cassava into garri as a result of the simultaneous cooking and dehydrating the moisture content by the application of heat. Traditional method of frying garri has been established, this has been exposing the fryer to various health disorder due to the use of fire wood and manual labor in frying garri. This work highlights the design of a gas powered garri frying machine fabricated with locally sourced materials at a relatively low-cost using gas as the mean of generating heat which is capable to produce the desired and acceptable cassava products for the consumer produce garri in commercial quantity at a faster rate with an environmental / operational friendly machine which will help to alleviate these health disorders, by making garri frying appealing to the farmers.

KEYWORDS: Consumption; Dehydrating, Frying, Heat

INTRODUCTION

Food ranks first in the scale of human basic needs. Man in his quest to provide the important need has explored his environment by planting, harvesting and processing of various food crops. The use of Cassava as food in South America began around 18th century BC.

Cassava which is known biologically as “manihot esculentacrantz” is a crop which has many varieties. Cassava, is a perennial woody shrub in the Euphorbiaceous (Spurge family) native to South America, but now grown in tropical and sub-tropical areas worldwide for the edible starchy roots (tubers) which are a major food source in the developing world, including Africa. It is a major food crop in Nigeria. It supplies about 70% of the daily calorie of over 50 million people (Agbetoye, 1999) and about 500 million people in the world. It is a basic staple food to more than 70% of Nigerian population and it is consumed at least once every day (Adeniji, et al., 2011). Cassava, however, did not become important in the country until the end of the nineteenth century when processing techniques were introduced, as many more slaves returned home. The cassava root is long and tapered, with firm, homogenous flesh encased in a detachable rind, about 1mm thick, rough and brown on the outside. Commercial varieties can be 5cm to 10cm in diameter at the top and around 15cm to 30cm long

(Igbeka, 1988). The cultivation of the cassava crop is by the propagation of stem cuttings. Roots can be harvested between 6 months and 3 years after planting depending on the cassava variety. It is rich in carbohydrates, calcium, vitamin B and C, and essential minerals. The roots are dug up from the soil, removed from the plant and washed before being processed.

Cassava is largely consumed in many processed forms in Nigeria. Its use in the industry and livestock feed, is well known, but is gradually increasing, especially as import substitution becomes prominent in the industrial sector of the economy. Cassava as food for man has long been available making it possible for man to explore varying methods of its preparation and preservation as food. Cassava as Food around the world is prepared in variety of ways according to local customs including Cassava flake (garri). Garri is a processed fermented product from cassava and is consumed in Nigeria as well as in most countries of the West African coast and in Brazil.

It is known that garri is widely consumed by Nigerian and mostly student in particular. However, most people cannot afford the best grade of garri because of hike in cassava and mostly the hike in the cost of processing garri. The garri fryer is also one of the major causes for not having a best grade of garri because of the local method that always employ to fry the garri. The locally fried garri is dangerous for human consumption because of the smoke that may likely mixed with it and also change the taste and odour, also the manual frying of garri is not quite hygienic as there is ample opportunity for contamination from sundry sources, including drops of sweat from the body of the operator.

The process of this important food has attracted the attention of many scholars as a department from the traditional methods that involves the use of fire wood and manual labor in frying garri to design a mechanically driven machine to reduce the exposure of the operator to heat, however the design does not require human effort to drive the pedal. In this design, human involvement is limited to minimum by introducing an automatic control system to regulate rotation and heating of garri frying process.

A need to design a frying machine that will be fabricate with locally sourced material at a relative low cost that use gas as the mean of generating heat which is capable of producing the desired and acceptable cassava product for the consumer, produce garri in commercial quantity at a faster rate and an environmental/ operational friendly condition with aid of machine.

The garification process (garri frying), is not a straight forward drying process (Igbeka, 1995). The product is first cooked with the moisture in it and then dehydrated. The sieved cassava grit is spread thinly in the pan 3-5kg per batch, the paddle helps to stir the gari constantly to prevent the food produce from getting burnt, until frying is complete, when it reaches a temperature of 80 to 85^{o}C, the rapid heating partially gelatinizes the garri, which is dried during the operation of frying; the moisture content of dewatered and sieved cassava mash is between 40 to 45% which has to be reduced to 10-12% moisture content in a time of 15 minutes.

A mechanical “garifier” or a mechanized system of frying and drying, usually takes the form of an aluminum drum or trough, paddles fixed to a steel shaft and rotating on the axis of the drum, the rotating paddles sweep the gelatinizing mesh from the trough wall to prevent sticking and burning and at the same time to move the material through the chamber to the discharge port, or outlet.

The main component of the machine

The gas garri frying machine consists of frying pan, paddle, fiberglass, belt and pulley, gas burner, fasteners, metal framework and electric motor. The various parts that make up the gas garri frying machine are described below.

Frying pan

The frying pan will be made of stainless steel frying pan in place of cast iron pan used in village technique because it disperses heat faster than the stainless steel and does not buckle under high temperature.

Paddle

The Paddle is connected directly in the frying pan which drives by an electric motor through a gear assembly system to eliminate human hand used in stirring cassava flakes (garri) in the village method.

Industrial gas burner

The Industrial Gas Burner series can be fired, will be place at the bottom of the frying pan that is fed with Liquefied Petroleum Gas (LPG) used in frying the garri. The industrial burner chamber is constructed using cast steel.

Power source

The electric motor will be used to drive the paddle which is connected directly to the frying pan through a shaft to eliminate human hand used in stirring garri in the village method.

Machine frame

This part is mainly made with the mild steel angle bars. The mild steel is used to make two 'H' shaped flat profiles. This is set up on a stand made of angle bars; upon which the motor and the frying compartment will be placed.

MATERIALS AND METHOD

This methodology of this research took care of the design analysis of the garri frying machine using LPG, material selection for each component designed, operating description of the system, engineering drawing and required assembly as well as the estimated production cost.

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, heating perimeter

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 comments so that they will perform properly with high degree of reliability. The material selection is summarized in the Table 1 as well as the reason for the selection.

Fabrication procedure

After the designed working drawing for the respective sections was made, sorting of the materials we be done. Step turning of shaft for the stirrer, selection of right belts and pulleys and sorting for electric motor. The angle bars will be cut to the required size for the frame and mild steel plate material will then be cut and rolled to form a cylindrical compartment to cover the frying pan. A stainless steel material will also be cut at the required length and rolled to form the frying pan for the frying of garri. Required drilling will be done on frame before welding and then before the major joining and assembling processes commenced.

Design calculations

These calculations were carried out to ensure that the garri frying machine using gas achieves its aim: analysis of the inner chamber, mass of cassava in the cylinder, determination of power transmitted by the paddle shaft, calculation of the size of the paddle blade, torque transmitted by the shaft, calculating the speed of paddle system, speed transferred to the drive gears.

Analysis of the Inner Cylinder

Frying compartment

Density ρ = 7500kg/m^3 (Ejiko et al. 2015)
Material = stainless steel
Number = 2 units 0.974m

Volume = $v = \pi r^2 h$ (1)

Diameter = 974.21mm = 0.97421m
Radius = 0.97421/2 = 0.473605
Height = given height of frying chamber is ¼ h of the cylinder 0.09m
Height = ¼ x 38 = 9.5cm = 0.095m
Volume = 22/7 x (0.473605)^2 x 0.095
= 3.1428 x 0.22430 x 0.095
= 0.0669 m^3

Mass of inner cylinder = ρ x V (2)

Where ρ is the density of the material of which the Compartment is made from
= 7500kg/m^3

Volume of the cassava mesh (V_{gc})

V_{gc} = 3.142 x (5.0407)^2 x 0.38
= 30.3369 m^3

Volume of cassava mesh in the cylinder = 30.3369m^3

The cassava mesh in the cylinder is one third of the volume of the cylinder which means 1/3 of V_{fc} = 1/3 x 0.0669 = 0.0223 m^3

iv. Mass of The Cassava Mash in the Cylinder

To calculate the mass of mash in the cylinder
m = ρ x V_m

Where ρ is the density of the cassava mash = 1509kg/m^3(Ejiko et al. 2018)

V_m is the volume of the frying chamber = 0.0223
m = 1509 x 0.0223
= 33.6507kg

v. Work done required from the paddle shaft

Let Wd = Work done by paddle shaft
rδθ = distance covered along the peripheral circle

since work done = force x distance
Wd = f x d
Wd = f x rδθ

But force F = torque/radius = T/r

Work done = $\frac{T}{r}$ x rδθ

So therefore: Wd = Tδθ (3)

Determination of Power P Required to be Transmitted by the Paddle Shaft

$$P = \frac{\text{workdone(Wd)}}{\text{time}(\delta t)}$$

(Gbasouzor & Maduabuma 2012).

But work done = Tδθ

$$P = T\frac{\delta\theta}{\delta t}$$

Where $\frac{\delta\theta}{\delta t}$ = angular velocity

P = Tω (4)

Torque, T required on the paddle

Torque = g (m_1 + m_2) (r+1) (5)

M_1 = mass of raw garri
M_2 = mass of the paddle blade
g = gravitational acceleration
(r+1) = radius of the acting force makes from shaft centre

Mass of the paddle blade

M_2 = ρV

Where ρ = density of material from which the paddle is made
V = volume of the paddle blade (a x b x X)
V = abX ;
a = length of the paddle blade
b = width of the paddle blade
X = thickness of the blade

Calculation of the Size of the Paddle Blade

The paddle blade is to keep the volume of K constant.

Thus, in this project K is chosen to be 50mm for high machine performance.

Paddle size = K x th x L (6)

Where th = thickness of the blade
K = thickness of garri layer

L = length of paddle

Paddle size = 0.05 x 0.01 x 0.16718

$= 8.359 \times 10^{-5}$m

$m_2 = \rho V$

V = abx = 167.18 x 150 x 5 = 0.16718 x 0.15 x 0.005

$= 1.254 \times 10^{-4} m^3$

ρ is the density of the material of which paddle is made = 7500kg/m^3

$m_2 = \rho V = 7500 \times (1.254 \times 10^{-4})$

= 0.9403kg

But (r+1) = R – K/2: where R is the radius of the drum

= 0.50421m

K = 0.05m

(r+1) = 0.50421 – 0.05/2

= 0.50421 – 0.025

= 0.47921m

Torque = $g (m_1 + m_2) (r+1)$

= 9.81(12.5 + 0.9403) (0.47921)

= 9.81(13.4403 x 0.47921)

= 9.81 x 6.441

= 63.18Nm

Torque to drive the paddle shaft = 63.18Nm

Work done Wd = Tθn

θ = π /180 x 360

π x 2 = 2π

Wd = T x 2π = 63.18 x 2π

=63.18 x 6.2832 = 396.97joules

Calculating the Angle of Twist of the Shaft

This is determined using a relation as given by a textbook of machine design by Khurmi and Gupta (2005).

Torsion formula $= \frac{T}{J} = \frac{\tau}{J} = \frac{G\theta}{L}$ (7)

Where

T = torque

J = polar moment of inertia

G = modulus of rigidity of the mild steel

L = length of the shaft

θ = angle of twist

Power p

$$T = \frac{60 X P}{2\pi N} \quad (8)$$

$$\text{Power of the motor} = \frac{watts\ X\ ampere}{\sqrt{3.173}} \quad (9)$$

$$= \frac{220\ X\ 4}{\sqrt{3.173}} = \frac{880}{1.73}$$

= 508.7watts

Since power of the motor = 508.7watts, then

$$T = \frac{60 \times 508.7}{2\pi\ X\ 83.72} = \frac{30522}{526.03} = 58.02\ Nm$$

$$J = \frac{\pi}{32} \times d^4 \quad (10)$$

$$= \frac{3.142}{32} \times (0.4)^4$$

= 0.09818 x 0.0256

$= 2.513 \times 10^{-3} m^3$

G = g/factor of safety

$= \frac{80}{8} = 10$Gpa

$$\frac{T}{J} = \frac{\tau}{J} = \frac{G\theta}{L} = \theta = \frac{TL}{JG}$$

$$= \theta = \frac{58.02\ X\ 2.7}{0.002513\ X\ 1000000000}$$

$$= \frac{156.654}{2513000} = 0.0000623rad = 0.004^o$$

$\theta = 0.004^o$

Calculating the Speed of the Paddle System

This is determined using a relation as given by The electric motor generates 3600rev/min, while the gear reduction speed motor ratio is 1: 43. To calculate the speed required to drive the paddle system: Output speed $= \frac{3600}{43}$ = 83.72 r.p.m

Speed Transferred to the Drive Gears

This is determined using a relation as given by theory of machines by rs Khurmi

$N_1D_1 = N_2D_2$ (11)

Where,

N_1 is the speed of the driven gear

D_1 is the diameter of the driven gear

N_2 is the speed of the drive gear

D_2 is the diameter of the drive gear

N_1 = 83.72rpm, D_1 = 195 mm = 1.95m, N_2 = ? D_2 = 115mm = 1.15m

$N_2 = N_1 D_1 / D_2$

$= (83.72 \text{ X } 195)/115$

$= 141.96$ rpm

Determination of Heat Energy Required for Frying the Cassava Mash

The heat transferred to cause temperature change depends on the temperature change, the mass of the system, and the substance phase involved. Which mathematically described below:

$$Q = m \times C \times \Delta T \quad (12)$$

Where

Q = quantity of heat transferred to the cassava mesh

m = mass of cassava mesh

ΔT = change in temperature

m = 7.5kg,

C =1.45KJ/KGK (Allen et al. 1961)

$\Delta T = (T_2 - T_1)$ where T_2; 96°c T_1; 29°c

$T_2 = 96 + 273 = 869$k

$T_1 = 29 + 273 = 802$k

$Q = 7.5 \times 1.45 (869 - 802)$

$Q = 7.5 \times 1.45(67)$

$= 7.5 \times 97.15$

$Q = 728.6\text{J} = 0.729\text{kJ}$

RESULTS AND DISCUSSION

The activity was carried out as follows:

7.5kg of garri mesh was manually dried under fire and it weighs 6.5kg after 71mins (1hr 11mins). The same amount of 7.5kg of garri mesh was poured into the frying chamber and it weight 6.9kg after 71mins (1hr 11mins). The garri frying machine using gas will dry the garri 0.6kg/hr. Thus, 6.9kg was below the standard by dryness quality, and therefore the efficiency is determined by ratio of under-standard dried (output) sample to standard dried (input) multiplied by 100

Mathematically:

7.5kg – 6.5kg = 1kg (desired sample)

7.5kg – 6.9kg = 0.6kg (undesired sample)

Efficiency = x 100

= x 100 = 60%

Performance Evaluation

The garri frying machine using gas was tested. It was used to fry 7.5kg of cassava mesh. The gas cylinder was connected to a control valve, and the control valve fastened to a burner while the heating cylinder was ignited. The electric motor was connected to aid in the steering of the cassava mesh in the frying chamber of the garri fryer. The drying efficiency which is the degree of dryness of a given quantity of garri produced from the frying machine was determined.

CONCLUSIONS AND RECOMMENDATIONS

The design of garri frying machine using gas was designed, fabricated, and tested for garri frying. The garri fryer was durable and portable enough for production, operation, repair, and maintenance. The fryer was able to fry the garri in a fast period, producing a fine garri that is dry and good for consumption.

The Performance evaluation of the maize dryer was successfully carried out. The fryer has an efficiency of 60 percent. Additionally, its efficient operation has justified the time and material expanded while working on it, it has adequately imparted the right knowledge which project are expected to impact in students.

Essentially, this project report serves as useful source of information and reference for others who may desire to improve upon the project.

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Table 1: Material for components production before assembly

S/N	Machine parts	Materials selection	Reason for selection
1	Frying compartmenrt	Stainless Steel	Good corrosion resistance and thermal conductivity
2	Delivery chute	Mild steel	Better 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, easy to machine at low cost
6	Machine frame	Mild steel	It is very cheap, it can withstand shear and bending forces

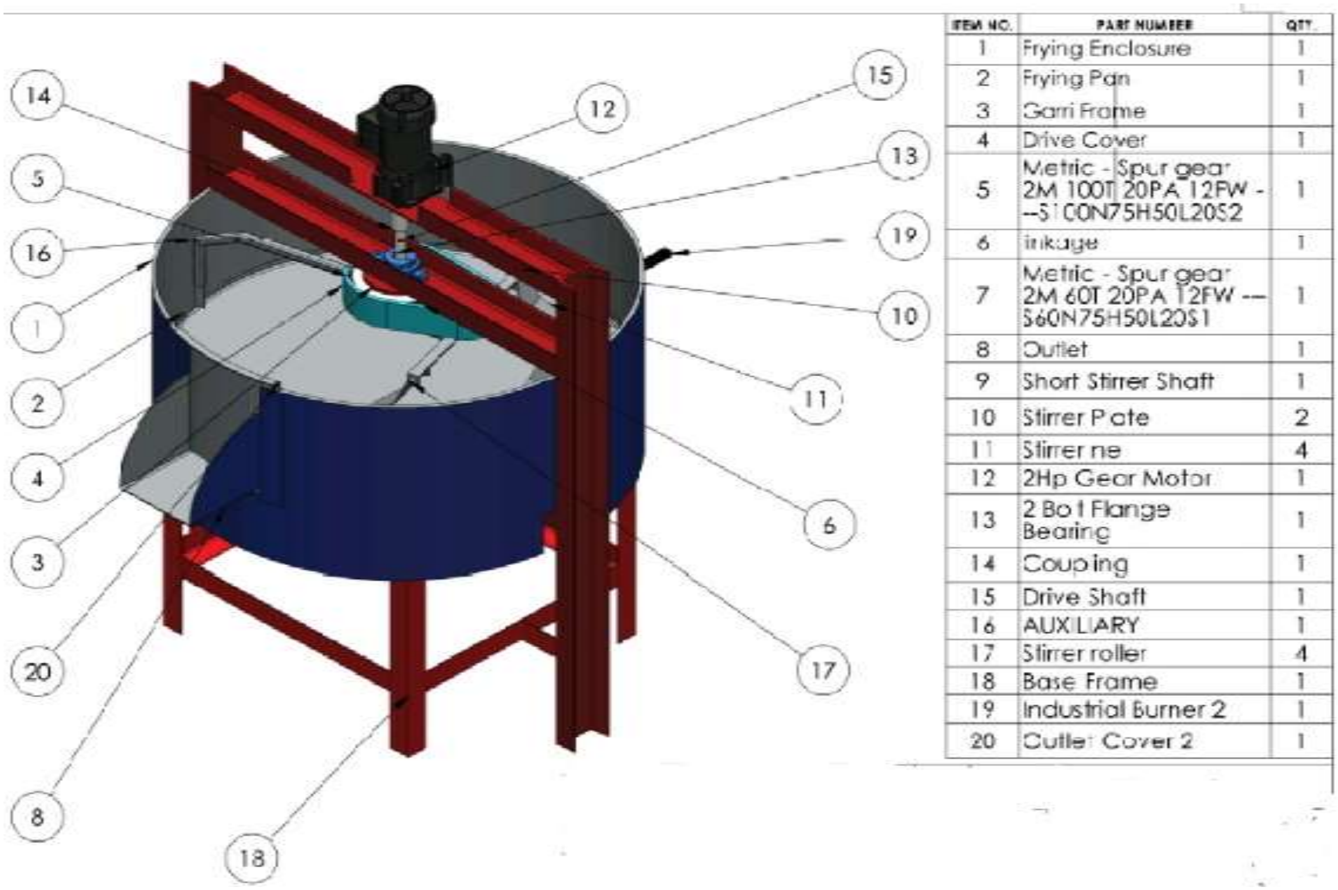
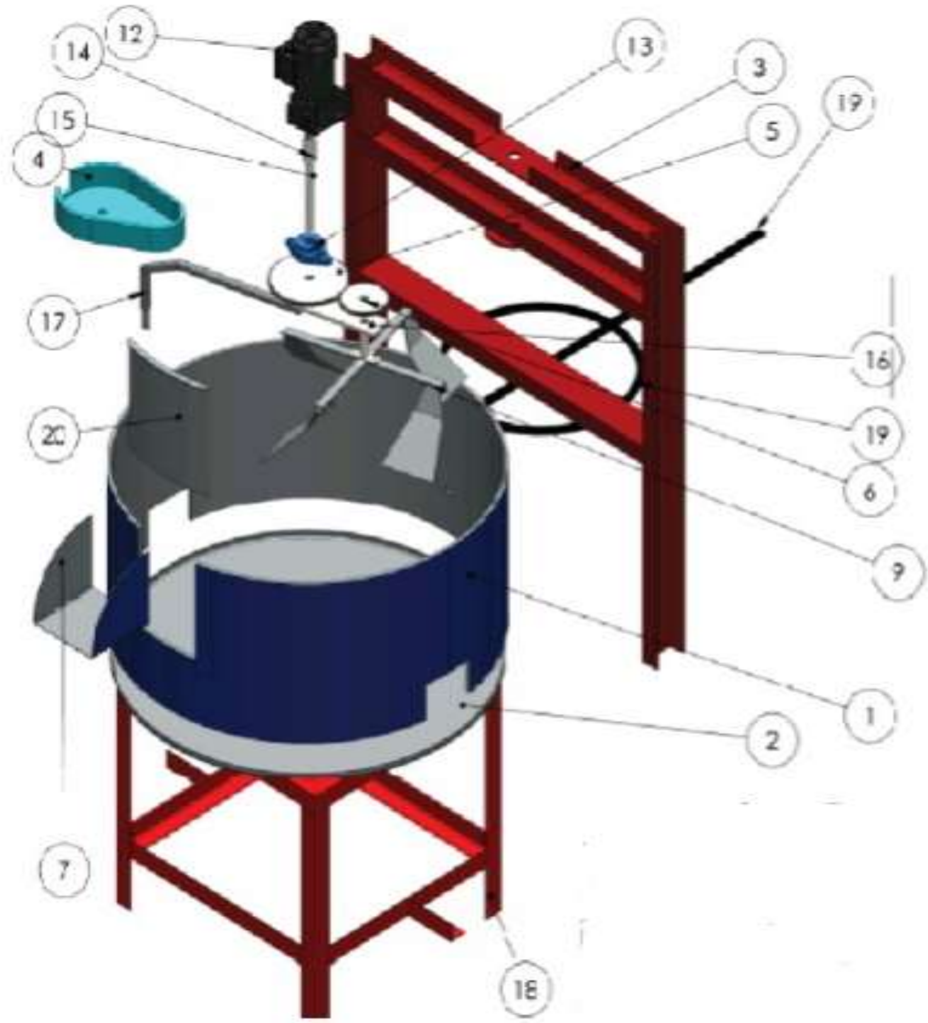


Figure 1. Garri Frying Machine Using Gas



ITEM NO.	PART NUMBER	QTY.
1	Frying Enclosure	1
2	Frying Pan	1
3	Garri Frame	1
4	Drive Cover	1
5	Metric - Spur gear 2M 100T 20PA 12FW --S100N75H50L20S2	1
6	linkager	1
7	Metric - Spur gear 2M 60T 20PA 12FW ---S60N75H50L20S1	1
8	Outlet	1
9	Short Stirrer Shaft	1
10	Stirrer Plate	2
11	Stirrer ne	4
12	2Hp Gear Motor	1
13	2 Bolt Flange Bearing	1
14	Coupling	1
15	Drive Shaft	1
16	AUXILIARY	1
17	Stirrer roller	4
18	Base Frame	1
19	Industrial Burner 2	1
20	Outlet Cover 2	1

Figure 2. Exploded View of Garri Frying Machine Using Gas

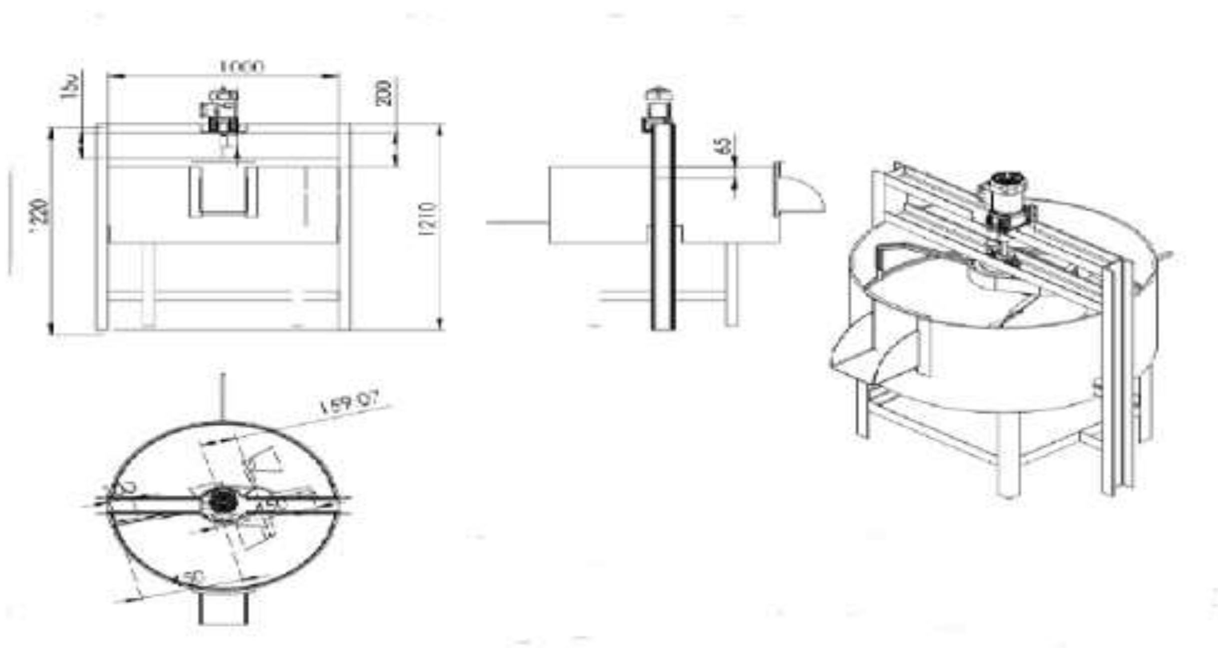


Figure 3. Isometric and View of Garri Frying Machine using Gas

ITEM NO.	QTY.	DESCRIPTION	LENGTH
1	2	C CHANNEL 100 X 10	1210
2	1	C CHANNEL 100 X 10	1000
3	1	C CHANNEL 100 X 10	1000
4	1	C CHANNEL 100 X 10	1000

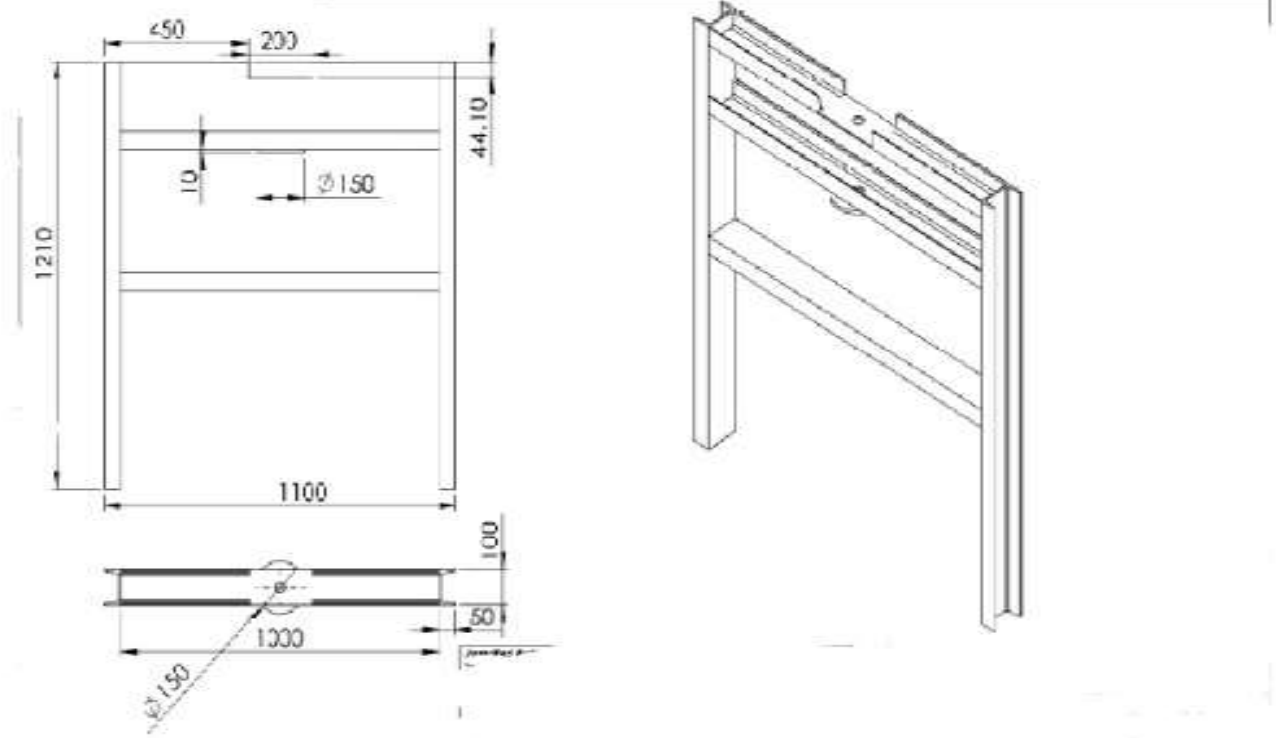


Figure 4. Isometric and View of Machine Frame

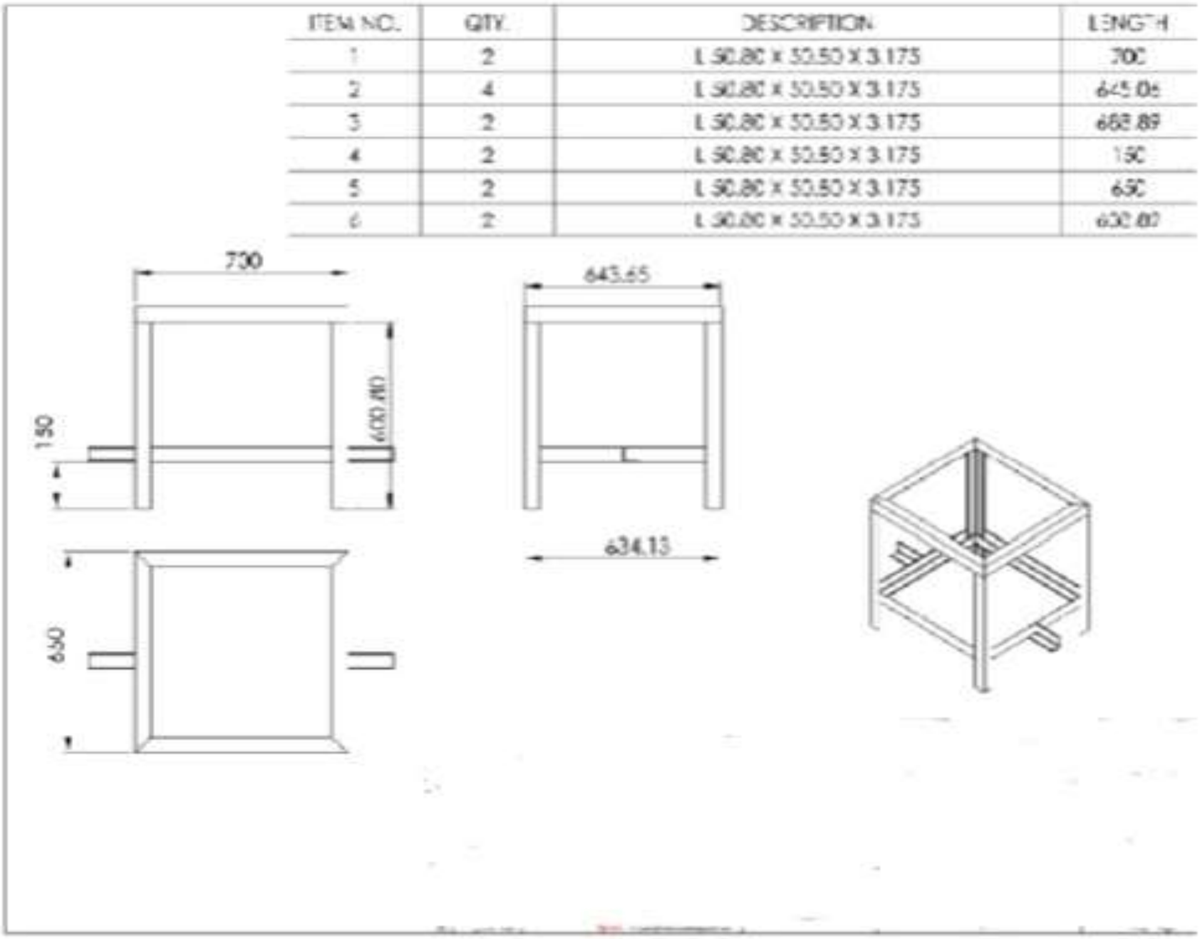


Figure 5. Isometric and View of Base Frame

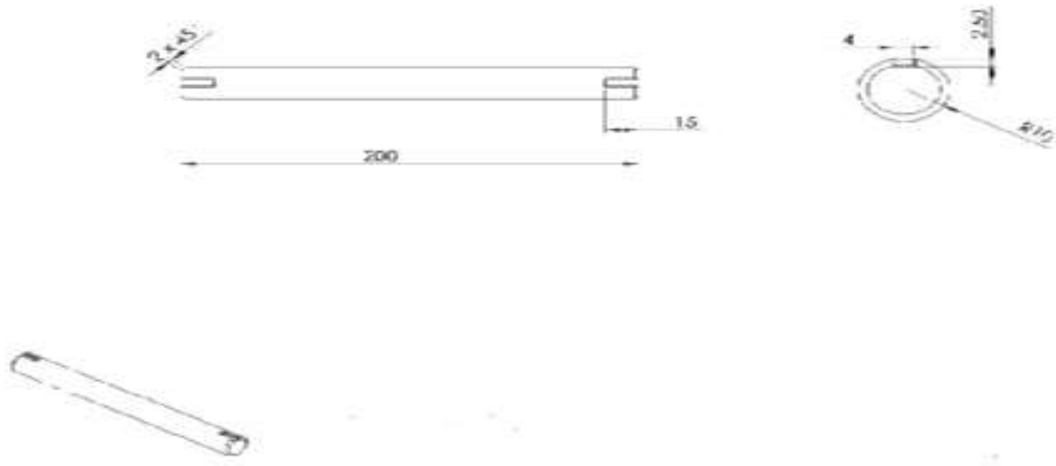


Figure 6. Isometric and View of Drive Shaft