American Journal of Sciences and Engineering Research
E-ISSN -2348 – 703X, Volume 6, Issue 2, 2023

Development and Design Concept of Gas Operated Mani-oat Frying Machine with Electric Powered Reciprocating Paddler

Adejumo Patricia, Omonegho[1] , Ola-Afolayan Olubunmi [2]

[1]*Food Technology Department, Auchi Polytechnic, Auchi, Edo State.*
[2]*Department of Fashion Design and Clothing Technology, Auchi Polytechnic, Auchi, Edo State.*

Abstract: *The unit operations involve in the production of Mani-oat are peeling, washing, fermenting, grating, dewatering, pulverizing, frying, milling and cooling. The most critical unit operation for effective product is the frying which is paramount to retaining the nutritional quality and shelf life of the product. The reduction of human labour, time, variation in quality, smoky finished Mani-oat and also increase of total output were also considered. The Mani-oat fryer uses gas as the heat source and paddler powered by electric motor to ensure even distribution of heat during cooking, gelatinization and drying of the product. The machine consists of the cylindrical frying chamber made from stainless steel and paddles positioned eccentrically inside, discharge chute, heating chamber, electric motor, frame, shaft were identified. The engineering drawings and calculation for the machine production were produced and mode of operation was discussed. It was established that the machine will be efficient in the production process of Mani-oat in the pilot scale production process.*

Keywords: *Design, Mani-oat, Power, frying, analysis, Oat, cassava.*

I. Introduction

Mani-oat is a processed edible cream-white flour with slightly fermented flavour from fresh cassava roots and oat grains specifically formulated diet for diabetic patients and most of its preparations are done using local processing techniques. The unit operations involve in the production are peeling, washing of tubers, fermenting, grating, dewatering, pulverizing, frying, milling and cooling in to Mani-oat.

Manihot esculenta (Cassava) is a root crop majorly grown in many tropical parts of the world and Nigeria is the world's largest producer of the root with about 59.5 million tonnes per year as at 2018 (Ikuemonisan *et al.,*2020). It supplies about 70% of the daily calorie requirement for over 50 million people in Nigeria (Oluwole *et al.*, 2004). It supplies the livelihood for over 30 million farmers and countless processors and traders. The major roles of Cassava are famine reserve crop, rural food staple, cash crop for urban consumption, industrial raw material, and foreign exchange earner (Kolawole and Agbetoye, 2007). It is widely grown in tropical regions of Africa, Latin America and Asia; and ranks as one of the main crops in the tropical since it is able to grow with low nutrient availability and able to survive drought (Burrell, 2003). Unit operations involved in cassava processing depend on the end product desired. The processing stages in cassava generally include peeling, washing, grating, chipping, drying, dewatering/fermentation, pulverization and sieving and frying/drying.

Cereals such as Oat; the sixth most important cereal crop in the world (Arendt and Zannini, 2013) are functional foods rich in dietary fiber, protein, energy, minerals, vitamins, and antioxidants required for human

 Received-12-03-2023, Accepted- 03-04-2023

health. They have health properties against non-communicable diseases, such as diabetes, obesity, hypertension, or cardiovascular disease which made it an important ingredient in well-balanced human diet (Varma *et al.,* 2016). This is due to β-glucan (soluble fiber), avenanthramides, tocols, sterols, phytic acid, and avenacosides present in the crop (Brennan and Cleary, 2005). It is worth noting that a daily intake of soluble fiber (β-glucan) reaching at least 3 g is recommended by the U.S. Food and Drug Administration and the EU European Food Safety Authority. Charalampopoulos *et al.* (2002) reported that β-glucan are important components of fibers containing unbranched polysaccharides which consist of β-D-glucose units linked through glycosidic bonds β (1 → 4) and β (1 → 3) in cereals like oat which are generally concentrated in the bran, aleurone, and sub-aleurone layers. Oat and barley have the highest content of β-glucans grains, compared to other cereals such as wheat, rice, and millet as stated by Havrlentova *et al.* (2011).

Unit operations involved in Mani-oat production include peeling, washing, fermenting, washing, grating, dewatering, pulverizing, frying and milling. Frying is the most critical unit operation that determine the nutritional value of Mani-oat production. It involves removal of some amount of moisture from the pulverized material to reduce the substances or residual liquid to an acceptable low value by first gelatinizing and then dehydrating or roasting that is a concurrent process which involve the cooking and drying occurring together to get the final product. Mechanization of the production process becomes inevitable as Production of Mani-oat manually using the traditional method is laborious, time consuming, and predisposes the processor to some form of danger, especially the hot fire from the firewood used during the frying process. Also the difficult in stirring when the quantity per batch is much using the spatula resulting to discomfort and sometimes burning of hands. Most importantly the nutrient is reduced either due to the improper application of the frying unit operation or contamination from operator's sweat. The importation of machineries to aid most of this process are usually futile as this can be traced to the near-total dependence on agricultural machinery that has been designed and manufactured by the industrialized countries for their own farmers and mostly temperate crops (Adegun *et al*., 2011). These alien machinery and equipment are unsuitable to our tropical crops, and are so complex and costly that they are beyond the technical competence and financial reach of the average Nigerian farmer. This statement was confirmed by Davies *et al.* (2008) who conducted survey on abandoned machines and concluded that over 40% of machines in the small-scale processing industries have been redundant due to scarcity of spare parts, high operational and maintenance costs. In order to revert this trend, food process mechanization in Nigeria must depend on indigenous engineering initiative and effort (Agbetoye *et al*., 2006) by devoting time and resources to the design and development machinery like the fabrication and adaptation of Mani-oat fryer equipment, which will work to perform more hygienically, safely, faster and efficiently. Mega amount of work that is hectares cultivated, transported tons of weight will be performed within a shorter period of time in comparism to the same work performed using local method. Therefore, the aim of this study is to develop Mani-oat frying machine which would help to retain more nutrient in the product, consistence of final product and enable mass production of high quality within minimum time usage.

II Materials and methods

1 Mani-oat fryer fabrication consideration

The fabrication of Mani-oat fryer involves the consideration of the following

- Raw materials used were locally sourced and inexpensive, frying chamber was made up of stainless steel to prevent contamination of the food due to corrosion.
- moisture content of the Mani-oat must not be below 40^{o}C to prevent sticking with the machine base while heat must be constant and regulated with appropriate timing.
- Ensure the machine is environmental friendly hence the use of gas.

2 Methodology

The materials used in the fabrication of Mani-oat fryer include; stainless steel, mild steel, (stainless steel and mild steel possesses characteristics such as high corrosion resistance, a suitable modulus of elasticity, ease of fabrication, standard sizing, and a favourable relative costing rate as reported by Osaretin (2021); Antosz and Stadnicka (2015) angle bars, bolt and nuts. The fabrication consists of techniques of various kind such as lathe machining, drilling, boring, slotting, oxyacetylene gas welding, grinding, and electric welds to ensure effective performance between parts. The main components of the fryer as shown in figure 1 below include Frying chamber, heating chamber electric motor, frame support carries all the other components of the fryer, the rotating shaft and paddle which is joined to a shaft rotated via bearing which is fixed to a driven pulley from which rotation its transmitted as the electric motor drives the belt via the driver pulley and outlet (discharge chute) which provides a collection means after frying is completed and it has an handle at the top of the frying chamber for enabling the operator to tilt-collect fried Mani-oat. Gas burner is fixed underneath the frying chamber from which heat is transferred to the chamber.

III Description of parts of the Mani-oat fryer

The description of the parts of the Mani-oat frying machine are as shown in figure 1 to figure 3.

1 Mani-oat fryer frame

The frame is fabricated using angle iron from mild steel. It gives support to the machine by carrying its parts to stand without the aid of the operator. The frame gives the requisite support to all other component parts of the machine without the aid of the operator. It also gives base for appropriate set up for the machine. It is fabricated from angular bar and some flat bar by welding and or use of bolt & nuts.

2 Frying Chamber

it is cylindrical in shape and houses the pulverized Mani-oat flakes, conducts heat generated by the gas burner and uses it for frying within a specific time range. it is made of stainless steel which has exceptional corrosion resistance and high resistance to wear and. In the food industry where food will contact the metal, stainless steel is the specified metal material used. Padded with sand and covered with mild steel to reduce heat loss. It has an outer diameter of 60 cm and inner diameter of 50 cm, with height 30 cm for frying chamber and total case height of 40 cm.

3 Heating Chamber: The source of heat is gas. It generates the quantity of heat with the temperature range required for Mani-oat frying.

4 Electric Motor

Electric motor helps in transmitting a rotational power to the paddler for consistent stirring of the Mani-oat. Electric motor used is the gear reduction electric motor of 1 hp power rating

5 BELT

V-belt was used for the transmission of rotational power which is fixed unto the driver and driven pulleys

6 Discharging Chute (Outlet)

This is an opening at the bottom end of one side of the cylindrical frying chamber which discharges the Mani-oat after frying to the collector.

7 Outlet Cover

The outlet cover is a stopper located at the opening of the outlet or discharge chute to help avoid the loss of product during processing.

8 BEARING

The bearing used were pillow and ball bearing having inner diameter of 2.5 cm and outer diameter of 6 cm. Bearings in the Mani-oat frying machine were used as part of transmission element for rotating the paddle efficiently.

9 PULLEY

The driven pulley is made of a rod which is circular in shape with a groove at the center of rod where belt is laid unto for transmission of power. Its outer diameter is 15 cm. also, the driver pulley is made of mild-steel of diameter 6 cm.

10 PADDLER

The paddler is made of stainless steel of length 21 cm, height 8 cm, and thickness 0.4 cm. it is used for the staring of the Mani-oat in a clockwise-circular motion.

11 SHAFT

The paddler shaft and electric motor shaft is made of cylindrical rod of diameter 2.5 cm and 2 cm, height 32 cm and 30 cm respectively. The paddler shaft is fixed unto it and its function is to transmit rotational power via the driven pulley.

12 GAS BURNER

It is the source from which heat is supplied to the base of the frying chamber when ignited as the gas cylinder regulator is opened and gas is supplied through the hose.

13 OUTLET

The outlet is the part through which the processed Mani-oat is discharged or collected. It is made of stainless steel plate because it has contact with the Mani-oat.

14 BELT CASING

This part is made with a mild-steel. It gives a safety covering to the belt in order to avoid injury to the operator during operation of the Mani-oat fryer.

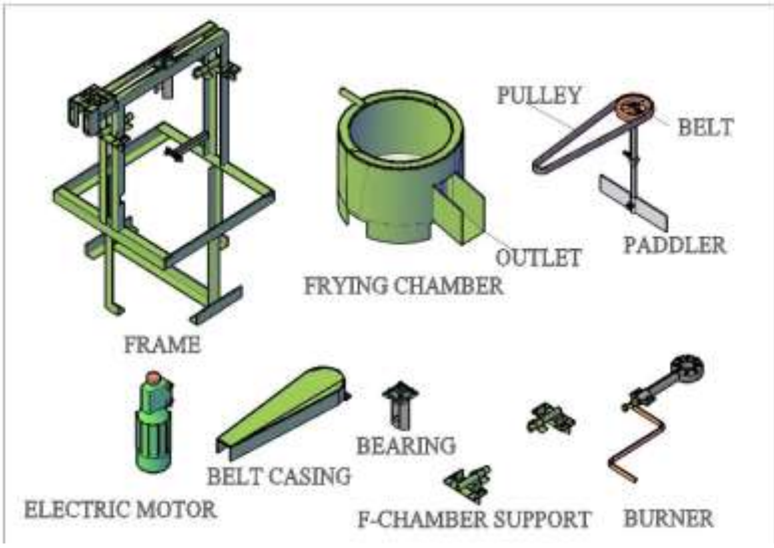

Figure 1: Components of Mani-oat frying machine.

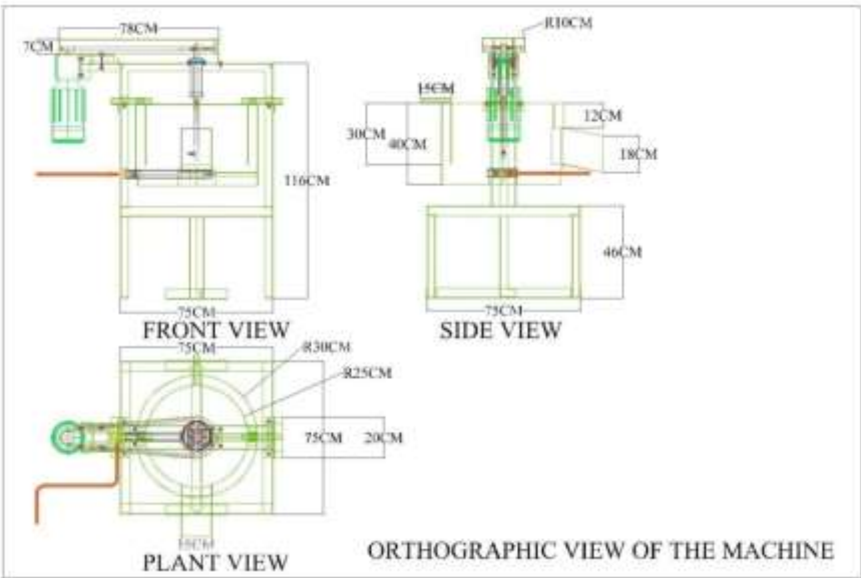

Figure 2: Orthographic view of the Mani-oat frying machine.

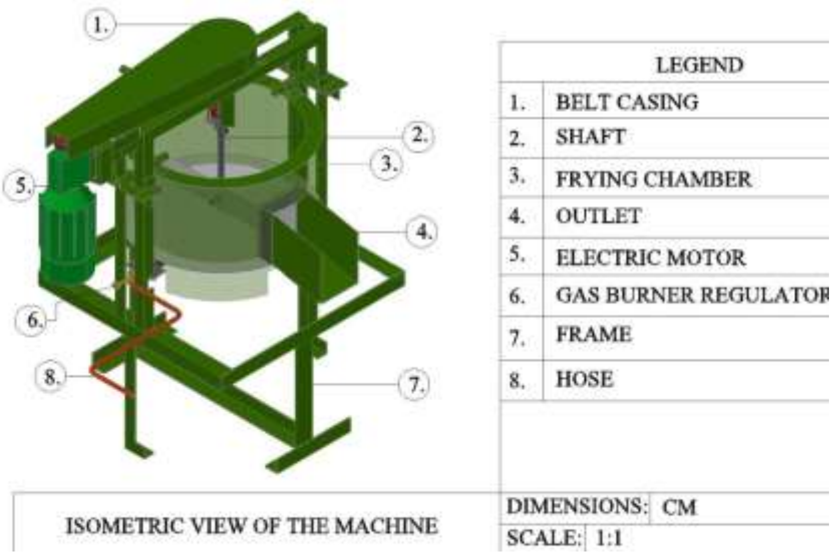

Figure3: Isometric view of Mani-oat frying machine.

VI. Analysis of the Mani-oat Frying Machine.

1 Analysis for Frame carrying other components

Length – 116 cm, Breadth – 75cm and Height (thickness) = 0.3 cm

$v = l\, xb\, xh$

$V = 116\ x\ 75x\ 0.3$ = 2610cm^3

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

$$m = \boldsymbol{\rho x\ v} m = 7.84\ x\ 2610 = 20462.4g\ (20.46kg)$$

Frame mass = 20.46kg

2 Mani-oat frying chamber volume

$$v = \boldsymbol{\pi r^2 h}$$

Where; π = 3.142, r = 25 cm, h = 30 cm.

$v = 3.142\ x\ 25^2 x\ 30$

= 58912.5 cm^3 or 589.125 m^3

3 Effective volume of chamber for frying Mani-oat

Assumption that ½ of the volume of the frying chamber will be required for effective frying hence ½x58912.5 = 29456.25cm^3

4 Selection of machine speed and power requirement

Speed selection of belt for the paddle as reported by Khurmi and Gupta (2005)

$$\frac{N_1}{N_2} = \frac{D_2}{D_1}$$

Where $N1$ is the speed of driven pulley, $N2$ is the speed of driving pulley (1420 rpm), $D1$ is the diameter of driven pulley (15cm) and $D2$ is diameter of driving pulley (6cm)

$$N_1 = \frac{N_2\ x\ D_2}{D_1}$$

$$N_1 = \frac{1420\ x\ 60}{150} = 568rpm$$

5 Length of belt selection

The length of belt required to transmit power from the electric motor was calculated to know the actual size of the belt required to grip the pulleys firmly to prevent slip of belt. The selection of belt length can be calculated using the formula below as stated by Khurmi and Gupta (2005)

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

Where L is the length of the belt, C is the Centre distance, D is Diameter of the driven pulley and d is Diameter of the driving pulley.

$$L = 2(0.605) + 1.57(0.15 + 0.06) + \frac{(0.15 + 0.06)^2}{4(0.605)} = 1.78m$$

6 Calculation of the connecting rod

$$v = \boldsymbol{\pi r^2 h}$$

Diameter = 2.5 cm, height 32 cm and density= 8g/cm^3

$v = 3.142\ x 1.25^2\ x 32$ = 157.1m^3

$$m = \boldsymbol{\rho x\ v}$$

$$m = 8\ x\ 157.1 = 1256.8g = 1.26kg$$

7 The power required to drive the shaft

The power required to drive the shaft is calculated according to Khurmi and Gupta (2005) as stated below

$P = \frac{2\pi N_1 T}{60}$

$$T = (W_r + W_f)\ x\ R_f$$

T = ((9.81x1.26) + 8.5) x 0.125 = 2.61Nm

$$P = \frac{2\ x\ 3.142\ x\ 568\ x 2.61}{60} = 155.27W$$

Where, P is the Power, T is the Torque, Wf is weight of the driven pulley (8.5 N), Rf is radius of driven pulley (0.125 m)

V Result/ Discussion

Mani-oat fryer has been fabricated with the necessary locally available materials for production and the design drawings are as shown in fig1 to fig3. The result computed revealed that for the major components of the fryer the frame supporting the components was calculated as 2610cm^3 for the volume and 20.64kg as the mass. Frying chamber has volume of 589.12 m^3 for effective frying while the volume of Mani-oat for effective result was calculated as 29456.25cm^3. The connecting rod volume and mass were 157.1m^3 and1.26kg respectively. The length of belt and power required to drive the shaft were calculated as 1.78m and 155.27W respectively. The frame was made high for easy of ignition, maintenance of the gas burner and prevention of loss heat when in contact with bare floor. It also will prevent spoilage of the frying chamber. The operation mechanism when using this fryer must be adhered to that is the volume of Mani-oat per batch should not exceed the prescribed volume to ensure the effectiveness of the paddler leading to homogeneous quality product. The operator must be educated on the operation techniques of the fryer before using. It is very important to carry out the routine care of the Mani-oat fryer such as immediate cleaning of the necessary parts especially the frying chamber operation, all moveable parts must always be lubricated when necessary to prevent stiffness. The electrical connection should be checked before commencement of operation and the hose connecting the gas to the burner should be changed when worn out. The fryer durability should be ensured by keeping it off from moisture.

VI. Conclusion

In the production of Mani-oat pilot processing plant the design of gas operated Mani-oat fryer was important to compact the difficulty that could occur during the various unit operation. The different parts of the fryer have been identified and calculation of the parts have been generated for the achievement of Mani-oat production. This will make the production of Mani-oat easier, faster and higher yield with consistent nutritional quality which will go a long way in improving health status of the consumers especially the diabetic patient also there will be no unnecessary sitting for long period by the operator.

VII Acknowledgements

Profound gratitude goes to TETFUND for the Institutional Based Research (IBR) grant that funded this project.

VII References

1. Adegun, I. K., Ajimotokan, H.A. Akinlosoye, A. A. & Babarinde M.S. (2011) Development of a cassava processing plant for producing improved stone-free Gari. *Journal of AgriculturalTechnology;* 7(5): 1193-1198.
2. Agbetoye L.A.S., Ademosun O.C., Ogunlowo A.S., Olukunle O.J., Fapetu O.P. & Adesina A., 2006. Developing Indigenous Machinery for Cassava Processing and Fruit Juice Production in Nigeria. *Conference Paper.*
3. Antosz K. & Stadnicka D. 2015. Evaluation measures of machine operation effectiveness in large enterprises: study results. *Eksploatacja i Niezawodnosc – Maintenance and Reliability*; 17(1): 107–117.
4. Burrell, M.M. (2003). Starch: the need for improved quality or quantity - an overview. *Journal of Experimental Botany,* 54 (382):451-456.
5. Brennan, C.S. & Cleary, L.J. (2005). The potential use of cereal (1–3, 1–4) β-D-glucans as functional food ingredients. *Journal of Cereal Science, 42:* 1–13.
6. Charalampopoulos, D., Wang, R., Pandiella, S.S. & Webb, C. (2002). Application of cereals and cereal components in functional foods: A review of *International Journal of Food Microbiology*, *79*: 131–141.
7. Davies, R. M., Olatunji, M. O. & Burubai, W. (2008). A Survey of Cassava Processing Machinery in Oyo State. *World Journal of Agricultural Sciences*, 4(3): 337-340.
8. Havrlentova, M., Petrulakova, Z., Burgarova, A. Gago, F. & Sturdik, E. (2011). Cereal β-glucans and their significance for the preparation of functional foods—A review. *Czech Journal of Food Science*, *29*:1–14.
9. Ikuemonisan, E. S., Mafimisebi, T. E., Ajibefun, I. & Adenegan, K. (2020). Cassava production in Nigeria: trends, instability and decomposition analysis (1970–2018), *Heliyon*, 6(e05089): 1-9.
10. Khurmi, R.S. & Gupta, J.K., (2005). "A Textbook of Machine Design", 14th Revised Edition, Eurasia Publishing House Ltd. Ram Nagar, New Delhi-110 055.
11 Kolawole, O. P. & Agbetoye, L. A. S. (2007). Engineering Research to Improve Cassava Processing Technology. *International Journal of Food Engineering*, 3(6): 1-15.
12. Oluwole, O.B., Olatunji, O.O. & Odunfa, S.A. (2004). A process technology for conversion of dried cassava chips into garri. *Nigerian Food Journal*, 22: 65 – 73.
13. Osaretin, E. (2021). The Design of a Tomato Powder Processing plant with a capacity of 75,000 tonnes per annum in Oyo state, Nigeria. Https://Medium.Com/@osaretinebuehicareer/the-Design-of-aTomato-Powder-Processing-Plant-with-a-Capacity-of-75-000-Tonnes-per-Annum-in-Oyo-Be2e145ad6df
14. Varma, P., Bhankharia, H. & Bhatia, S. (2016). Oats: a multi-functional grain. Journal of Clinical and Preventive Cardiology, 5(1):9-17.