

DESIGN AND FABRICATION OF DOMESTIC STEAM HEATED OVEN FOR SMALL SCALE PROCESSORS

^{*1}Ogunsola, F.O., ¹Oyeniya, A.O., ²Lasisi, D., ²Akintola, A. and ²Siyanbola, A.A.

¹Department of Food Technology, ²Department of Agricultural and Bio-Environmental Engineering, Oyo State College of Agriculture and Technology, Igboora.

^{*}Corresponding Author: olasunkanmifemi9@gmail.com

Abstract

Food production particularly, bread and cake production encountered certain challenges during production, and a prominent challenge is that bread normally gets burnt with increase in temperature with locally made oven. With regards to this, an attempt to develop an affordable machine that would eliminate the problems encountered with local oven was considered. The oven was powered by heat source containing charcoal with a blower to allow the air flow distribution through the baking chamber. The oven consists of an opening, two trays, galvanize steel pipe which was mounted into the drying chamber and connected to the steam drum and the steam drum contain distilled water connected with the heat source. The overall dimensions of domestic steam heated oven are 360 x 700 x 250mm. Domestic steam heated oven was developed and tested for the use of food processors, the result showed that domestic steam heated oven has an efficiency of 71.4% and capacity of 95.7 kg/hr. the output result falls within economic range, therefore, it is recommended for small scale processors.

Keywords: Design; fabrication; domestic steam; heated oven, small scale processors

Introduction

Baking oven is a complex simultaneous heat and mass transfer process equipment commonly applied in food industries. An oven can be described as a thermal insulated chamber used for the heating, baking, cooking, or drying of food substances, (Afolabi *et al.*, 2017).

Food is cooked by application of heat, which may be either dry or moist to make food more palatable, digestible, give it a characteristic taste or different, and sterilize the food either partially or completely (Anayo and Corneliu, 2021). A lot of research had been carried out on electric baking oven importance and ease of operation. Also, Temitope and Olowole, (2018) developed an improved electric baking oven that operate on the principle of electric resistance with a moisture content of 67.7%. Adegbola *et al.*, (2018) developed a dual powered baking oven that uses gas and electricity supply for baking food. They discovered that the system is more efficient and quicker compared with the existing one. Genitha *et al.* (2014) developed a domestic gas oven through which higher energy efficiency are obtained by reducing the energy, cost and time of baking.

Bread and Cake production encountered certain challenges and one of them is that the bread and cake normally gets burnt when with increase in temperature with locally made oven. Therefore, the aim of this

research work is to design and carried out performance evaluation of domestic stem heated oven which was efficient and cost effective both in production and operation.

Materials and Method

Design considerations

A number of points were considered during the design which included the cost of construction, power requirement, labour requirement in operating the machine, amount of moisture to remove, quantity of air required, suction fan design and capacity, rate of mass transfer, relative humidity, ambient temperature, ease of replacement of component part in case of damage or failure, durability, reliability, ease of construction and dismantling. Other factors include; Ability to with stand heat, vibration, humid air fatigue and stress without failure during operation. The materials selected to suit the design considerations are shown in Table 1.

Table 1: Material selection for the fabrication of the domestic steam heated oven

S/N	Machine component	Suitable engineering material	Criteria for material selection	Material selected	Remarks
1.	Drying chamber	Galvanize steel plate, stainless and aluminum sheet.	Corrosion resistance work ability and cost	Galvanize steel plate	High strength and cost effectiveness
2.	Frame	Mild sheet, square pipe and Angle Iron	Strength, rigidity and lightness	Angle Iron	Lightness
3.	Steam drum	Galvanize steel plate, stainless and aluminum sheet.	Corrosion resistance work ability and cost	Galvanize steel plate	High strength and cost effectiveness
4.	Heat source	Galvanize steel plate, stainless and aluminum sheet.	Corrosion resistance work ability and cost	Galvanize steel plate	High strength and cost effectiveness
5.	Tray	Rod, mild sheet and square pipe	Strength, rigidity and lightness	Rod	High strength
6.	Door	Galvanize steel plate, stainless and aluminum sheet.	Corrosion resistance work ability and cost	Galvanize steel plate	High strength and cost effectiveness

Mode of operation of the machine

Charcoal was poured into the heating drum and ignited, the blowers blows the air and transferring the heated air from heat drum to the oven, through which the air circulated inside the oven and materials fed into the oven when the ambient temperature and relative humidity are 31°C for drying bulb temperature, 28°C for wet bulb temperature and 35% relative humidity. After the heat has been supplied, the temperature of the products rises to 50°C given the final humidity ratio. After which the products were removed from the oven.

Design calculation

The estimate of both the constant rate and falling rate. The estimate of both the constant rate and falling rate period are needed to estimate the total drying for given drying operation.

$$\phi t = \frac{\phi c}{\phi f} \quad i$$

Where;

ϕt = Total drying time

ϕc = Drying time for constant rate period

latent heat of vaporization could be determined using an equation given by Youcefet *al.*, (2001).

ϕf = Drying for falling rate period

Amount of moisture to be removed

Amount of moisture to be removed from a given quantity of dough to bring the moisture quantity to a safe edible level in a specified time.

$$M_w = M_p(M_i - M_f)(100 - M_f) \quad ii$$

Where;

M_p = The initial mass of the product to be dried (kg)

M_f = The final moisture content (% in wet basis)

M_i = The initial moisture content (% in wet basis)

Quantity of heat required to evaporate water

Quantity of heat required to evaporate water will be determined by using

$$Q = M_w \times hfg \quad (iii)$$

Where;

Q = the amount of energy required for the drying process. (KJ)

M_w = The mass of water (kg)

hfg = The latent heat of evaporation (KJ/kg H₂O)

The amount needed depends on the function of temperature and moisture content of the dough. The

$$Wg = 4.186 + 10^3(597 - 0 - 56 CT_{pr}) \quad (iv)$$

Where;

T_{pr} = The product temperature ($^{\circ}C$)

Air vent dimensions

The air vent was calculated by dividing the volumetric air flow rate by wind speed.

$$Av = \frac{V_A}{V_w} \quad (v)$$

Where;

Av = The Area of the air vent (m^2)

V_w = The wing speed (m/s)

V_A = Volumetric air flow.

Drying Rate

The calculation involving the design and analysis of dryers require the knowledge of length of time needed to dry a product from initial moisture content (Q_1) to final moisture content (Q_2) and the rate at which drying is taken place.

The rate and time of drying equation are expressed by;

$$RC = \frac{M_d (M_I - M_f)}{AS \quad T} \quad (vi)$$

Where;

RC = The drying rate (Kg/mol)

M_d = The total weight of dried product (kg)

AS = The surface area of dried solid (m^3)

M_I = Initial moisture content

M_f = Final

T = Drying time

Test procedure

The domestic steam heated oven was designed, fabricated and tested in order to know the capacity and the efficiency of the oven. Different size of bread dough was used to determine the efficiency and time taken for baking was recorded.

$$\text{Efficiency} = \frac{\text{wet basis}}{\text{dry basis}} \times 100 \quad (vii)$$

$$\text{the machine capacity (kg/hr)} = \frac{\text{throughput}}{\text{Time taken to baking}} \quad (viii)$$

Results and Discussion

Results

Table 2: The Dough Size and Time Required to Bake Bread and Cake

weight of dough (g)	time required to bake cake (min)	Timerequired to bake bread (min)
200	22	19
400	29	26
600	37	33
800	43	40
1000	54	48

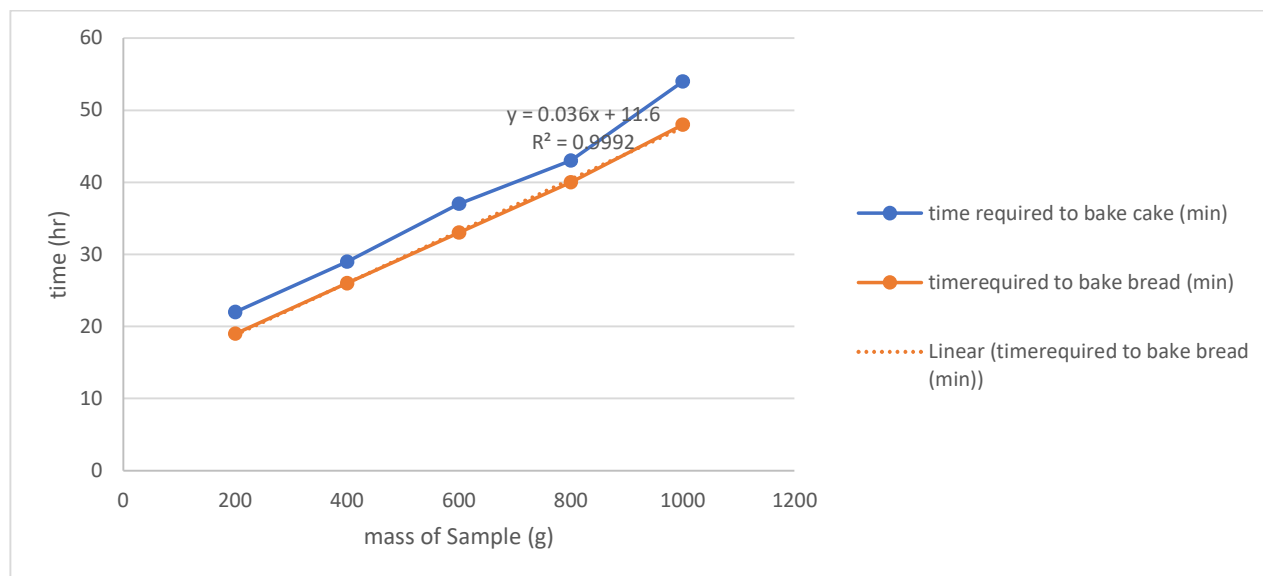


Figure 1 Variation of time against size of dough

Figure 1 above shows the baking time required for different sizes of dough. It was revealed that, there is

an increase in baking time as the size of dough increases as reported by Olugbade and Ojo (2018).

Table 3: Bill of Engineering Measurement and Evaluation (BEME) for domestic steamheated oven

S/no	Items	Description	Quantity	Unit	Rate(₦)	Total price(₦)
1	Galvanized Steel plate	Thickness: 0.7	5	mm	5,500	27,500
2	Hinges		2		500	1,000
3	Angle Iron	102×102×64	4	mm	3,500	14,000
4	Drilling bit	12mm	4		1,200	4,800
5	Grinding disc		3		300	900
6	Cutting disc		3		250	750
7	Electrode		120 pieces		50	6,000
8	Quarter rod		4		800	3,200
9	Saw bladder		2		300	600
10	Washer		4		100	400
11	Blower		1		10,000	10,000
12	Stem Pipe		5		3,000	15,000
	Thermometer		1		3,500	3,500
13	Logistics	Transportation, workmanship and other expenses			12,500	12,500
Total						100,150
VAT 5%						5,007.50
Grand total						105,157

Discussion

The steam heated oven was developed and fabricated from galvanize steel of 2mm thickness and the fibre was use as insulator to control heat loss by conduction. The drying chamber has two slots for each drying tray. The trays are perforated to effectively allow the air flow within the chamber. Performance evaluation was carried out by using different sizes of bread and cake dough. It was observed that, there was an increase in baking time as the weight of dough increases as shown in table 2 and figure 1 since more time is needed for sensible heat to penetrate through the dough before complete baking can be achieved (Olugbade and Ojo, 2018).. The result showed that domestic steam heated oven has an efficiency of 71.4% and capacity of 95.7 kg/hr. The output result falls within economic range, therefore, it is recommended for small scale processors.

Conclusion

The domestic heated oven was designed, fabricated and was able to bake bread and cake. The oven eradicated burning of foods and loss in nutritional content of the foods. The efficiency and the capacity of the oven respectively are 71.4%, 95.7kg/hr. It was therefore recommended for the use of small scale food processors.

Reference

Adegbola A.A., Adogbeji O.V, Abiodun O.I And S. Olaoluwa (2012). *Design, Construction and Performance Evaluation of Low Cost Electric Baking Oven* Innovative Systems Design And Engineering. Vol 3, No.11, 2012.

Afolabi Tunde Morakinyo, Babatunde Omidiji, and Hakeem Owolabi (2017). *Development and optimization of operational parameters of a gas-fired baking oven*. Leonardo Journal of Sciences, Issue 31, July-December 2017 p. 45-64.

AnayoAgbo, Cornelius Ogbodo (2021) "*Economic Design, Fabrication, and Performance Evaluation of Conventional Ovens Made of Glass-Fiber-Reinforced Thermoset Composites*," Makara Journal of Technology : Vol. 25 : No. 3 , Article 4. DOI: 10.7454/mst.v25i3.3853.

Genitha, I., Lakshmana, G.B.T., and John, D.R. (2014). *Design, Fabrication and Performance evaluation of Domestic Gas Oven* .IOSR Journal of Engineering (IOSRJEN),4 (5): 35-38.

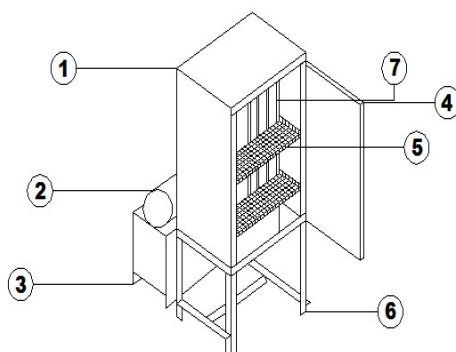
Ilesanmi, O.E., and Akinnuli, B.O. (2019). *Design, Fabrication and Performance Evaluation of a Domestic Gas*. Journal of Engineering Research and Report, 5 (1): 1-10.

Temitope, O.O., and Olowole, T.O. (2018). *Development and Performance Evaluation of an Improved Electric Baking Oven*. Leonardo Electronic Journal of Practices and Technologies, 3 (3): 189-206.

Youcef, Ali, S., Messaoudi, H., Desmons, J.Y., Abene, A. and Le Ray, M., (2001). *Determination of the average coefficient of internal moisture transfer during the drying of a thin bed of potato slices*. J. food Engin. 48 (2): 95. 101.

Appendix

Appendix I. Isometric view of the domestic steam heated oven.



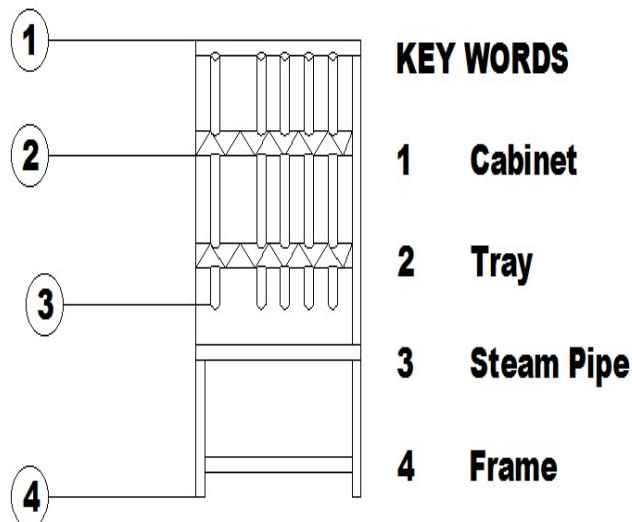
KEY WORDS

- 1 Cabinet
- 2 Steam Drum
- 3 Heat Source
- 4 Door
- 5 Tray
- 6 Frame
- 7 Steam Pipe

All dimensions in mm

Cabinet	Steam Drum	Heat Source	Door	Tray	Frame	Steam Pipe
360x250x700	210x60	240 x120x190	320 x240	170x200	230x250x200	600

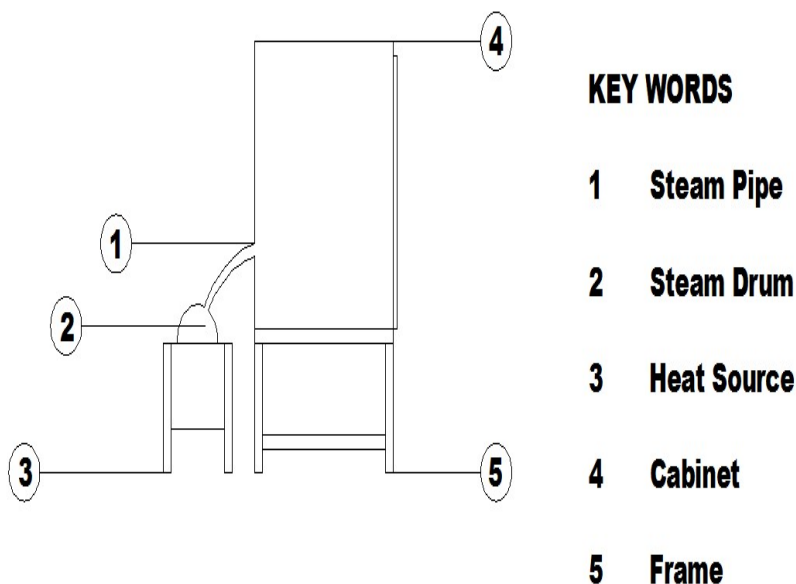
Appendix II Orthographic projection (End view) of the domestic steam heated oven.



All dimensions in mm

Cabinet	Tray	Steam Pipe	Frame
360x250x700	170x200	600	230x250x200

Appendix III Orthographic projection (side view) of the domestic steam heated oven.



All dimensions in mm

Steam Pipe	Steam Drum	Heat Source	Cabinet	Frame
600	210 x60	240 x120 x190	360x250x700	230x250x200