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Research Article

Fabrication and Performance Evaluation of Designed Multipurpose Domestic Gas Baking Oven

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Abstract: Akinnuli and Caleb designed a multipurpose domestic gas baking oven due to irregular power supply common in developing countries. The study reported the design and predicted cost of production of a proposed domestic gas oven. The simulation, fabrication and performance evaluation of the proposed machine were left. The proposed gas oven was limited to its design concept and predicted production cost. This study made use of their drawings as well as their design analysis values which are : outer dimension 860 mm length × 660 mm width × 1150 mm height and the inner dimension is 759 mm length × 559 mm width × 835 mm height. Proposed material to be used are mild steel and fiber glass as an insulator. Total cost of its production was predicted to be ₦56, 470.00 ($156.86 as at time of the design concept at the exchange rate of N360.00 to a Dollar). This study find out the level of reality, produce-ability , and performance level involved in this design concept by fabricating the designed oven and evaluate its performance to determine its, functionality, use-ability and marketability. When the gas baking oven was tested, high efficiency was obtained. The performance test gave oven efficiency of 90.7 per cent. The oven can be adapted for both domestic and industrial purposes and have been found very useful in bakery industries. Actual amount spent for the oven production was ₦ 59,880.40 ($166.33) compared to the proposed cost of ₦56, 470.00 by designers which is about 5.69% increase, this might have been change in some material cost in the market. The oven can be adapted for both domestic and industrial purposes and have been found very useful in bakery industries. Therefore, it can be deduced that the designed project is cost effective, faster and thus bakes and roasts effectively.

Keywords: multipurpose, gas oven, cost, fabrication , performance evaluation, functionality establishment.

INTRODUCTION

A baking oven is the most widely used appliance in food service industry. An oven can be simply described as a fully enclosed thermally insulated chamber use for the heating, baking or drying of a substance (Merriam-Webster Dictionary, 2011**)**. The moisture in the food material simultaneously diffuses with continuous movement of the oven ambient air (Tong and Lund 1990; Ozilgen and Heil 1994) and between the product and its environment (Carvalho and Martins 1993), which theoretically are well known. Commercially, ovens are available in the various configurations like electric ovens, micro oven and wood oven etc.

Study of baking oven is important because it could lead to a more efficient process of baking favorable to energy efficiency and better product quality (Fellows, 2000). Analysis and optimization of baking process and equipment have been conducted for minimizing energy consumption (Therdthai *et al.*, 2003). The first historical record of an oven being built is in 1490, in Alsace, France. This oven was made entirely of bricks and tile (*Mary*,2017). Count Rumford (aka Benjamin Thompson) invented a working iron kitchen stove that was designed for very large working kitchens (Rumford, 1928).

One successful and compact cast iron design was Stewart's Oberlin iron stove, patented in 1834. The evolution of gas stoves was delayed until gas lines that could furnish gas to households became common (Mary, 2017). The microwave ovens were a byproduct of another technology (Mary, 2017). The significance attached to this research is to investigate the functionality of already designed gas baking gas oven by fabrication and evaluate the performance of the

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oven. Since fabrication and performance evaluation of the existing designed oven was carried out in t

his research, little was done on literature review.

METHODOLOGY

The method used here involve : Adoption of the existing engineering drawing and the designed values, of the designed oven, fabrication, performance evaluation as well as the current cost estimate for the proposed oven.

Assembly view of the Gas Oven

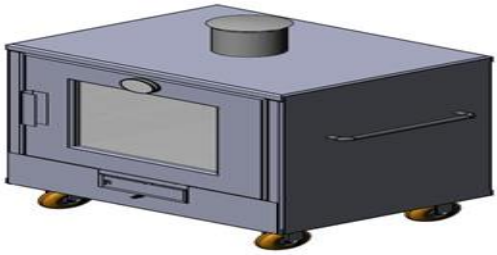
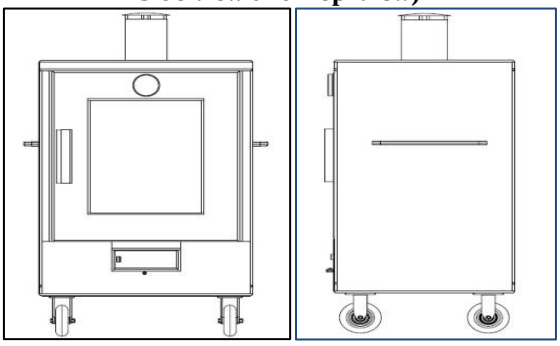


Figure 1: Assembly View of the Gas oven

Orthographic view of the Gas Oven (Front view, Side view and Top View)



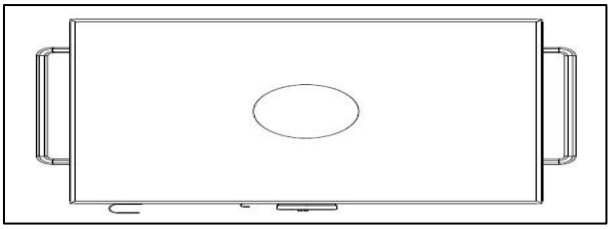


Figure 2: Orthographic View of the Gas oven

Explosive drawing of the designed oven.

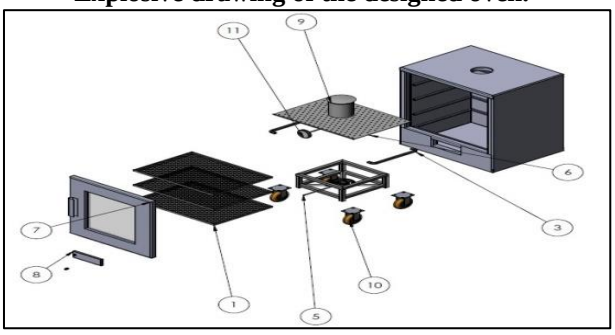


Figure-3: Exploded View of the Gas oven

Table-1: Component Parts of the Oven

ITEM NO.	COMPONENT	QUANTITY
1	Tray	3
2	Gas valve or regulator	1
3	Handle	2
4	Frame	1
5	Burner	1
6	Perforated plate	1
7	Oven door	1
8	Oven firing door	1
9	Chimney or vent	1
10	Caster wheel or rollers	4
11	Thermometer	1

Fabrication Description of the Gas Baking Oven

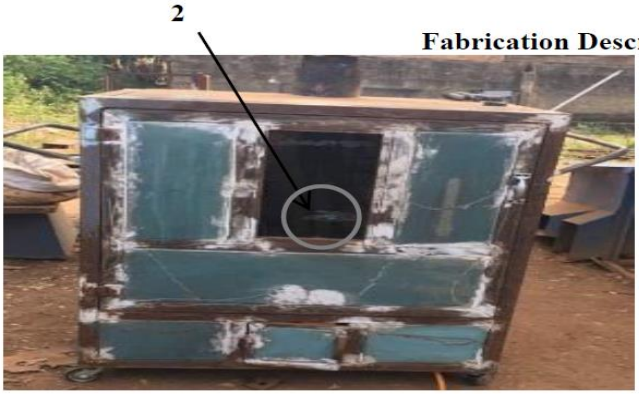


Figure 4a : Fabricated Gas oven

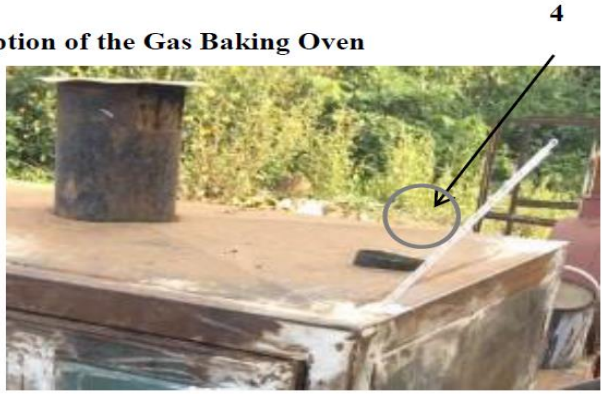


Figure 4b Thermometer

The gas oven was fabricated with the use of indigenous material according to the conceptual design. The oven consists of housing unit (frame), thermometer, gas regulator, tray, oven door and oven firing door, perforated plate, heating gas burner, chimney or vent, rollers. The housing unit which is the frame represents the entire out look of the baking oven. The housing unit of the gas oven was made up of three layers, the body (outer layer) is made of well coated mild steel of thickness 1mm with the dimension 860×660×1150 (Length × Width × Height respectively) in mm, inner layer is made of mild steel of thickness 1mm with the dimension from the end of the perforated sheet 759×559×835 (Length × width × height respectively) in mm. Fiber glass of thickness 40 mm is the lagging material (insulator) which is stuffed in-

between the outer layer and inner layer and which acts as a thermal insulating material to prevent loss of heat (insulation), from the inner baking chamber to the outside and also ensure even baking of the product in the baking chamber, and this fiber glass makes up the middle layer of the gas oven. Fiber glass is known to have light weight, high strength and high thermal shock resistance characteristics.

The oven has two door chambers. The upper door chamber of the gas oven was made up of mild steel and fiber glass of thickness 40 mm was placed in between the steel plate to avoid the loss of heat through the door and in front of the door was provided with a heat treated (resistive) glass which can withstand very high temperatures to monitor the baking product inside the oven without opening the door. And the lower door chamber also known as oven firing door houses the burner compartment. Inside the oven firing door is an oven burner stand on which the burner is welded to, the stand kept at a height of 190 mm from the ground level so that an opening is created under the body in the same direction with the burner to enable the entrance of required amount of air (oxygen) for easy and neat burning/combustion of the gas flame. The opening of about 200 mm by 200 mm length by width respectively is created through which the burner head is connected to the gas pipeline / hose i.e. Gas inlet. It is regulated with gas knobs.

The oven burner is an O shaped pipe drilled/perforated with small opening at intervals. It is mounted inside the oven lower chamber and tightened with nuts and bolts. Perforations are created just below the burner to allow for heat dissipation. Heat energy is caused to escape through holes created just below the burner and circulates round the oven chamber. The base of the inner baking chamber was provided with a deflector plate of the thickness of 1mm with dimension of 800×580 (length × width) mm placed at a height of 280 mm from the base of the oven to avoid the direct flame coming from the burner to the baking chamber and to provide even distribution of the heat throughout the baking chamber.

The thermometer was attached to a drilled surface on top of the oven. The thermometer sensor was placed in the center portion of the baking chamber to ensure that the thermometer should detect the temperature of the both the lower and the upper layer of the baking oven. The oven is also provided with a vent/chimney at the top of the baking oven connected from the inner baking chamber for the continuous removal of hot and humid air from the inner baking chamber. The baking oven was provided with the handles in both the sides for mobility, easy carriage and to prevent the rollers (wheels) from wearing out due to bad terrain. The oven supports have rollers for easy movement and to absorb shock as well as sustain the weight of the oven.

Three trays were provided in the baking chamber of the oven, each having the dimension of 770×570 (length × width respectively) in mm, galvanized wire mesh was welded to provide base or support for the baking trays and the oven works by natural convection; it helps for the movement of hot air from the lower tray to the upper tray of the oven. The distance between the top of the oven and the upper tray was kept at 230 mm, also the distance from the upper tray to the middle tray was kept at also 230 mm and also the same distance (230 mm) was kept between the middle tray and lower tray, while the distance between the lower tray and the base of the oven was kept at a height of 410 mm.

Principle of Operation

The major operational principle of the fabricated gas oven is the process of heat transfer. Heat transfer tends to occur whenever there is a temperature difference, and the ways in which heat may be transferred in the gas oven that is convection.

Convection is the transfer of energy from one place to another by the motion of a mass of materials between the two points. Convection occurs when particles with a lot of heat energy in a liquid or gas move and take the place of particles with less heat energy. Heat energy is transferred from hot places to cooler places by convection (BBC – GCSE Bitesize, 2014). Naturally, convection occurs when a solid surface is in contact with a fluid of different temperature from a surface. Density differences provide the force required to move the fluid (moisture) in the food. In the oven, the fluid involved is the enclosed air and the burner surface, which provides the solid surface, while the oven walls serve as the solid surfaces.

Usually this equipment has a gas inlet through which it is connected to a medium size gas cylinder via a regulator with low pressure flexible hose. The regulator of gas flow rate into the pipeline from the gas cylinder is turned open.

With gas in the pipeline, the gas burner is activated by turning on the temperature knob after turned on from the gas cylinder. This creates a gap through which the gas rushes to the nozzle. The gas then passes through the nozzle after which the pressure drops with increased velocity. The low pressure high velocity gas then flows into the burner gas compartment together with the air (oxygen) from the opening created below the oven stand into a channel where it spreads out through the holes around the burner to glow in flame when lighted up by a lighter. The intensity of the heat generated from the flames depends on the amount of gas that is being burnt. The gas flow rate is altered or controlled by the continuous adjustment of the valve (gas knob).

The pre – set of the gas regulator has made it possible to obtain a stoichiometric mixture with a constant flow at various level of gas flow rate. This continuous adjustment has therefore provided a wider limitation of range whereby the equipment can be operated provided that the temperature gauges still accommodate that.

Performance Evaluation

The gas baking oven after fabricated was put to test in order to determine its functionality and the effectiveness through baking some food items like bread and meat items.

Baking of bread

Breads of different sizes were baked in the gas oven at a temperature range of the 170-180˚C.The time taken by the gas oven for the baking of the breads is shown in Table-2

Table-2: Baking Time of the Bread

Product	Size	Time Taken For Baking at 170-180˚C
Bread dough (small size)	300 grams (0.3 kilograms)	30 minutes
Bread dough (medium size)	400 grams (0.4 kilograms)	37 minutes

Figure-5 : Baking of Bread in the oven
Source: Study, 2017

Different sizes of dough were baked to examine the effect of dough size on baking time. Figure 6 shows the result obtained.

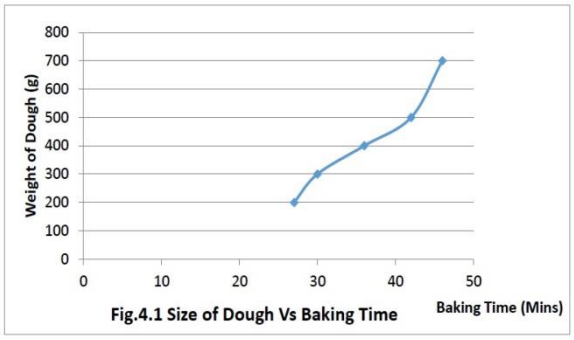


Figure-7: Size of dough vs. Baking Time
Source: Study, 2017

DISCUSSION

There is observed sharp increase in baking time as the weight of dough increases. This is quite understandable since as the dough size increases more time is needed for sensible heat to penetrate the dough. It is further observed that there is less marginal increase in baking time as the size of dough is increased beyond a certain point. Too much heat will burn the dough whilst leaving the inside undone. In industrial (large) ovens, baking time can be improved a great deal by introducing forced air to increase heat flux within the system.

The high efficiency record of 90.7% can be attributed to the 20 per cent allowance for sensible heat transfer considered in the design.

Estimated /Actual Production Cost

The proposed design values were un-bolded figures while the actual fabricated values as at time of fabrication were bolded in Table 4.

Bill of Engineering Measurement and Evaluation (BEME)

Table -4: Material Cost

S/N	QUANTITY	MATERIAL DESCRIPTION	UNIT COST	TOTAL COST
1	3	Mild steel sheet metal (1mm)	₦2, 000.00 **₦2,240.00**	₦ 6,000.00 **₦ 6,720.00**
2	1	Roll of fibre glass	₦ 3, 500.00 **₦ 3,920.00**	₦ 3, 500.00 **₦ 3,920.00**
3	1	Temperature sensor / thermometer	₦ 2, 500.00 **₦ 2,800.00**	₦ 2, 500 **₦2,800.00**
4	1	Gas burner	₦2, 800.00 **₦ 3,136.00**	₦ 2, 800 **₦ 3,136.00**
5	4	Length 40 x 40 square pipe	₦ 450.00 **₦ 504.00**	₦ 1800.00 **₦ 2,016.00**
6	2	Angle iron	₦ 875.00 **₦ 980.00**	₦ 1750.00 **₦ 1,960.00**
7	4	Lock bolt (10mm)	₦ 30.00 **₦ 33.60**	₦ 120.00 **₦134.40**
8	1	Handle	₦ 250.00 **₦ 300.00**	₦ 250.00 **₦ 300.00**
9	1	Filler	₦ 1500.00 **₦ 1,680.00**	₦ 1500.00 **₦1,680.00**
10	2	Sand paper	₦ 125.00 **₦ 140.00**	₦ 250.00 **₦ 280.00**
11	2	Yards gas hose	₦ 200.00 **₦ 224.00**	₦ 400.00 **₦ 448.00**
12	2	Clips	₦ 50.00 **₦ 56.00**	₦ 100.00 **₦ 112.00**
13	1	Gas regulator	₦ 1, 000.00 **₦ 1,200.00**	₦ 1, 000.00 **₦ 1,200.00**
14	1	Gas cylinder (3kg)	₦ 4, 500.00 **₦ 5040.00**	₦ 4, 500 **₦ 5040.00**
15		Gas	₦ 500.00 **₦ 560.00**	₦ 500.00 **₦ 560.00**
16	1 (240 pieces in a pack)	Electrode (gauge 12)	₦ 1, 500.00 **₦ 1,680.00**	₦ 1, 500.00 **₦ 1,680.00**
17	3	Drill bit (5m)	₦ 150.00 **₦1,68.00**	₦ 450.00 **₦ 504.00**
				₦28, 420.00 **₦ 31,830.40**

Note: The bolded figures are the fabricated cost while the un-bolded figures are the designed cost.

Total Material Cost Proposed is (₦ 28,420.00)
WHILE ACTUAL COST IS **₦ 31,830.40**

Labour cost

Cost Per hour	= ₦450.00
Number People	= 4
Working Hours	= 5 hours
Labour cost for 4 people	= (5 x 450) x 4
= 2250 x 4	= ₦ 9, 000.00
Total Labour Cost	**= ₦9, 000.00**

Design Cost

3D Solidworks software = ₦ 5, 000.00
Simulation using ANSYS = ₦ 8, 000.00

Total Design Cost = ₦ 13, 000.00

Machine Cost = ₦ 1, 050.00

Typing and Binding = ₦ 5, 000.00

Total Engineering Evaluation of the Gas Baking Oven

- Material Cost = **₦ 31,830.40 (₦** 28,420.00)
- Labour Cost = ₦ 9, 000.00
- Design Cost = ₦ 13, 000.00
- Machine Cost = ₦ 1, 050.00
- Typing and binding = ₦ 5, 000.00

TOTAL COST = ₦ 31,830.40, (₦ 28,420.00) + **₦** 9, 000.00 + **₦** 13, 000.00 + **₦** 1, 050.00 + **₦** 5, 000.00

TOTAL COST = ₦ 59,880.40 ($166.33) ; (₦56, 470.00; $156.86.). The Dollar values was based on the exchange rate of **₦** 360 per USSD as at the time of this fabrication.

The percentage cost change for the proposed design value is

(**₦** 59,880.4 - ₦56, 470.00 / **₦** 59,880.40) X 100 = **5.69%**

RESULTS AND DISCUSSION

The the fabrication of the designed oven was accomplished and performance of the oven was evaluated the following were deduced from the evaluation: Oven of (860 x 660 x 1150) mm external dimension, (759 x 559 x 835) mm internal dimension was fabricated using 1 mm thick mild steel sheet. This system was incorporated with thermometer for oven temperature measurement and lagged with fiber glass of 40 mm thick. Average time for baking 300g of dough for bread was 35 minutes while for 400g average time was 37 minutes at temperature range of 170 – 180 degree Celsius. From the graph it shown that as the mass of dough increases, the baking time also increases. Concerning the meat; 1kg each of beef, chicken and fish were used to evaluate the fabricated gas oven at a monitored temperature of 120 degree Celsius. The average roasting time for the beef, chicken and the fish are: 50, 43 and 38 minutes respectively. This shows at same mass and constant temperature fish roasts faster than chicken while beef roasting rate is the slowest. The efficiency of the oven comparing the design baking temperature with the actual baking temperature was 90.7% . The final and actual production of cost for the oven was **₦** 59.880: 40 while the designed estimate was ₦56, 470.00 these are equivalent of $156.86 and $ 166.33 respectively at exchange rate of **₦** 360 per Dollar as at the time of design and fabrication of this oven, this shows an increase of 5.69 %.

CONCLUSION

The fabrication and performance evaluation with the current cost of fabrication as at the time of production of this oven has been achieved. The materials were carefully selected to meet the needs of each respective part. It was to be operated manually by a spark lighter to provide flames from the burner to the oven chamber.

From the fabrication and performance evaluation of this system, is evidently clear that the designed gas oven was sufficiently designed and all the calculated parameters were fund satisfactory. The oven can be used for the baking of the cakes, cookies and all the bakery products with good quality parameters like color, texture and the taste and good volume in the fermented products and also the pre heating time of the gas oven was also reduced this in turn consumes very less energy and the time of the baking and reduces the overall working cost. This can be used for small entrepreneurs and can be popularized in areas where power cuts are more frequent and power is available for limited hours. The design and construction of this project has been satisfactorily completed with the capability of providing high performance heat energy for effective baking. The design of the gas baking oven was produced with locally soured raw materials in its totality, with the exception of bimetallic thermometer, sensor and knobs due to their scarcity.

Nevertheless, the designers cannot claim that the gas baking oven is hundred percent efficient, since from the knowledge of thermodynamics, it is impossible for any heat transferring device to deliver heat with a 100% efficiency due to some heat losses. But the designers ensured that a good finish was given to the design and development of the equipment.

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