PERFORMANCE EVALUATION OF A GAS (BUTANE) FIRED OVEN

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Abstract

A gas-fired oven for commercial production of bread was designed and constructed using locally available material and was subjected to various tests to come out with its performance characteristics. Its performance was evaluated and then compared with respect to the total time required to bake a specified mass of white flour dough using the gas oven with that used by clay wood fired oven for the same mass of white flour dough.

The outcome of the test result indicated that the maximum temperature attained by the oven was 400^{0}C with the gas control valves at close to the maximum point (without load). This temperature was attained seven minutes after firing the oven. The clay wood fired oven tested attained a peak temperature of 280^{0}C one hour after it was fired. White flour dough of mass 0.2kg was baked in the gas fired oven in thirty nine minutes (first load), this corresponds to the total baking time. The same unit mass of dough was baked in the wood fired oven in a total baking time of eight-five minutes.

A test carried out on the insulating machine, sawdust, showed that it minimized the heat loss from the oven by maintaining a high temperature gradient between the inside wall and the outer wall of the oven. The preliminary economic analysis of the cost of production of the oven and the cost of fuel showed that it is cost effective and viable.

Introduction

Baking has attained a commercial status for quite some time in this country in view of the fact that bread has become a staple food to be reckoned with. There are various types of ovens available depending on type of power source such as electricity, gas, microwave, coal and kerosene. However the choice of the type of oven has been limited over the years by factors such as erratic power supply for electric ovens and high cost of importation and maintenance of ovens.

Many bakers now are using the locally constructed clay-oven which are wood fired. These ovens while having the ability to bake large amounts of bread per batch to its advantage, also have many set backs in terms of man power requirements, total baking time, oven temperature control and negative impact on the environment.

Barring the high cost of procurement, a gas-fired oven is not being affected by the aforementioned factors. Hence the need for a simple, cheap, and easy to maintain gas-fired oven constructed using locally available materials. Bakers and entrepreneurs in the baking business like most businessmen and manufacturers are interested in minimizing expenditure and maximizing profit and at the same time producing high quality product which meet national standards in terms of processes involved and taste. They would prefer the better option in terms of faster work, greater efficiency and less cost Most bakers believe that the performance of a locally constructed gas oven cannot match that of imported ovens and that gas is too expensive to be used as fuel for baking bread commercially.

This paper outlines the component parts, optimum operating procedure and performance evaluation of a natural convection gas fired oven for the large-scale production of bread. The oven was designed to retain the maximum amount of heat produced by the combustion of commercial butane, possible within the baking chamber during baking.

Design Considerations And Scope

In the design of the ovens the following objectives were set and achieved:

the oven's internal temperature is to be able to attain and be maintained at 250^{0}C

the oven is not to have external temperature exceeding 59^{0}C

- the oven should be able to bake 192 loaves of 0.2kg bread at full capacity (dim. of bread).
- It is expected to bake a full load of bread in not more than 40 minutes.
- Simplicity: the oven was given a simple yet effective design to facilitate easy construction, maintenance, usage and cleaning.
- Availability and cost of materials: materials used in the construction are easily available for purchase and are relatively affordable.
- Durability: the oven was designed to withstand the strain generated during operation.
- Portability: the overall weight was designed to be at the barest possible minimum.

Design Features

Bearing the factor of simplicity in mind, the oven was designed and constructed with minimum complexity. The main components of the gas-fired oven are:

i) the oven frame
ii) connecting pipes (for gas supply)
iii) a pair of baking trays
iv) the flue
v) a pair of gas burners
vi) four castor wheels
vii) sawdust for insulation

The oven is rectangular in shape, the inner baking chamber is made of galvanized steel with dimensions 19 x 124 x 131cm. The outer walls are made of mild steel with dimensions 128 x 135 x 132cm. The insulation (sawdust) varies in thickness from 3.7 – 4.2cm. The base plate, which is made of galvanized steel, is perforated for the introduction of atmospheric air into the baking chamber.

Two round mild steel pipes (¼ inch) of length 91cm, convey the gas, which is first passed through rubber pipes from the gas regulator to the burners from under the oven through the perforated base. These pipes extend outside and in front of the oven, terminating at the gas entry valves. The air/fuel pre-mixing chamber for each pipe is located immediately after the nozzles of the gas entry valves. The burners, which are rectagular in shape, are made of mild steel with dimensions 92 x 5 x 2.5cm with 84 slits on each length and are located on the bottom of the oven. Gas is supplied via a high-pressure regulator connected directly to the gas cylinder. The whole oven frame is welded at the corners to four 5mm thick angle iron supports joined to metal plates, which are finally attached to the castor wheels by bolts.

The doors of the oven are two in number, with the inner layer made of galvanized steel and the outer made of mild steel. Heated air is prevented from escaping through the door by square pipes (mild steel) welded at the corners which act as an air seal. Mild steel was used when it was discovered that the former material failed during the operation of the oven. The temperature sensor is located at the center of the right hand door.

The flue is made from mild steel and is located at the upper left hand corner of the back of the oven. The baking trays are made of wire mesh of size 119.5x 119.5cm, with the edges welded to angle irons.

Evaluation Tests, Results And Discussion

Three major tests were carried out during the performance evaluation of the oven. In the first test, the oven was heated with no load to determine its heat rate and maximum temperature that is practically attainable. The gas supply was then switched off and the cooling rate monitored. The results were then compared with similar results obtained from the industrial wood fired oven and a small gas fired oven by Ogunnaike (1997). Figure one shows the rate of heating of the big oven versus the smaller gas oven before modifications were made to the gas burners of the big oven. Figure two shows the rate of heating

of the big oven after modification of the burners versus the small gas oven (Ogunnaike) and the initial test values for the big gas oven. Figure three shows the heating rate of the big oven (after modification of the burners) versus the clay oven.

For the second test, a specified mass of white flour dough was baked to completion to determine the time taken and the results compared to similar results from the aforementioned wood fired oven. Relative quantities were also compared in both cases. Table two shows the performance data of the big gas oven before and after modification of the burners and the clay oven. In the last temperature gradients were monitored during operation of the oven and compared with similar results obtained from a small gas fired oven by Ogunnaike (1997) which utilizes fiber glass wool as insulation. In this case it was discovered that external temperatures did not exceed design goals.

Economic Evaluation Of The Gas Fired Oven

Evaluating the gas oven in terms of economy was done by comparing the costs of running the gas fired oven to produce a specified amount of white flour dough with equivalent cost incurred by the wood fired oven. Details are given below:

Wood Fired Oven:

Capacity per batch (0.2 Kg of dough) = 420 loaves

Cost of fuel (wood) = ₦300 per dozen bundles.

Unit cost per bundle = ₦25

Minimum number of bundles required for baking = 5

Cost of five bundles = ₦ 125

Maximum number of batches that can be baked with five bundles = 3

Maximum number of loaves = 1260 loaves.

Total revenue = 1260 x ₦15 = ₦18,900 – 125 = ₦18,775

Analysis For Gas Fired Oven

Capacity per batch (0.2Kg dough) = 192 loaves

Cost of fuel (gas per Kg) = ₦152 per kg.

Mass of gas utilized per batch = 0.5 kg

Cost of fuel used per batch = ₦76

Number of batches required to produce 1260 loaves = 7 batches

Cost of fuel for seven batches = ₦532

Number of loaves produced in seven batches = 1344 loaves.

Total revenue = 1344 x ₦15 = ₦20,160.00

Profit based on above information = ₦20,160 – 532 = ₦19,628.00.

Table 1.

Time (mins)	Wood Fired Oven	Gas Fired Oven
Pre heating	60	10
1st batch	25	29
2nd batch	30	25
3rd batch	40	25
4th batch	-	25
5th batch	-	25
6th batch	-	25
7th batch	-	25
Total	195	189

* Assumptions:
i) the same quantity of flour is used in both cases.
ii) Both ovens operate in the same ambient temperature.
iii) Interest and inflation cost neglected.
iv) Cost of construction neglected.

- It should be noted that this analysis is subject to limitations brought about by the obvious dissimilarities in both ovens in terms of capacity, labour and time required for baking.

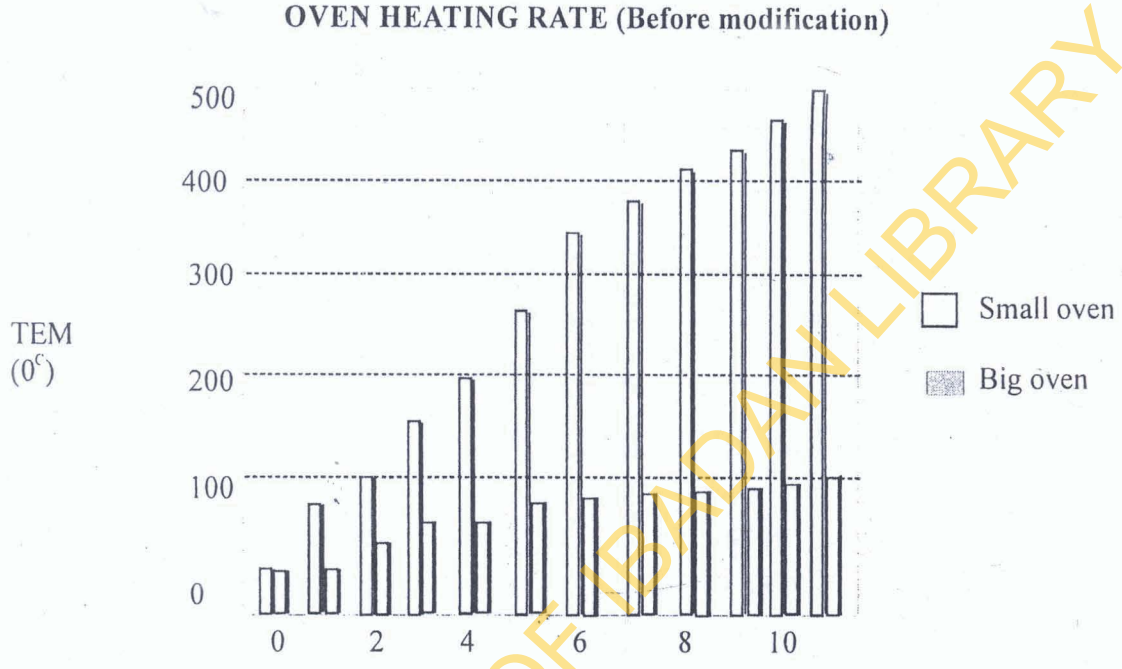


Figure 1

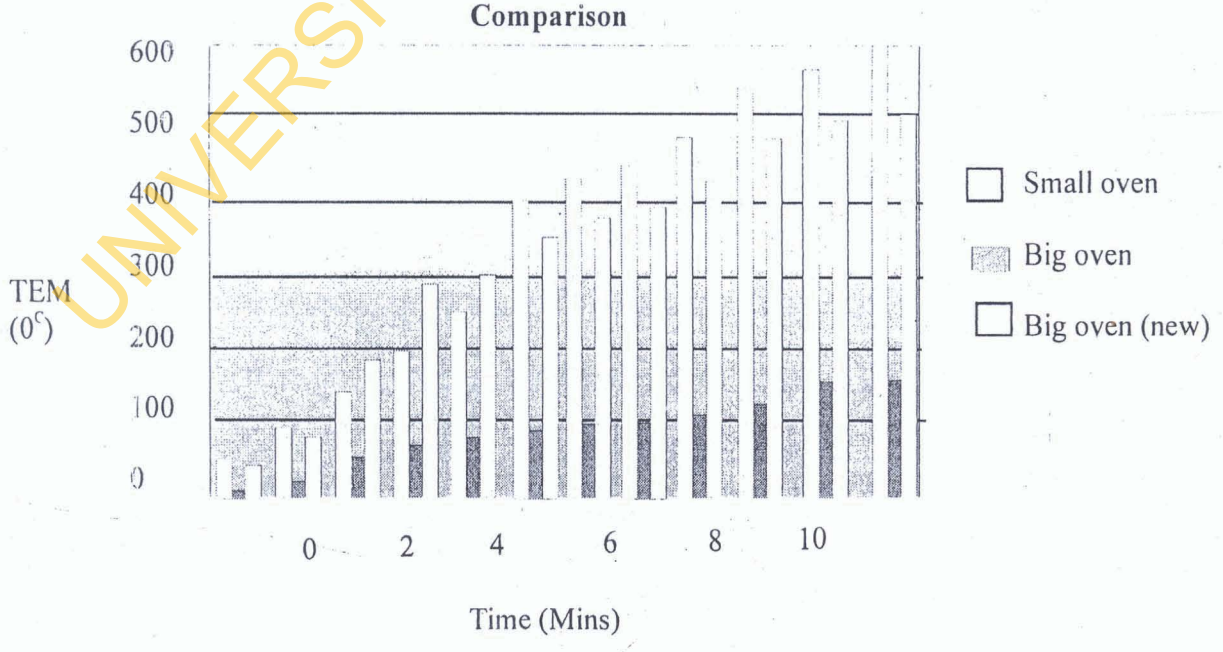


Figure 2

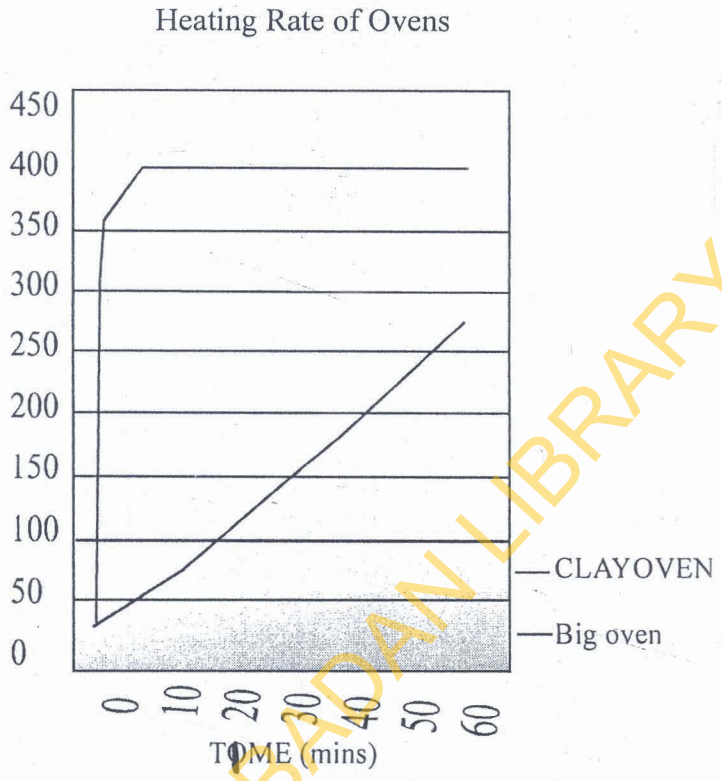
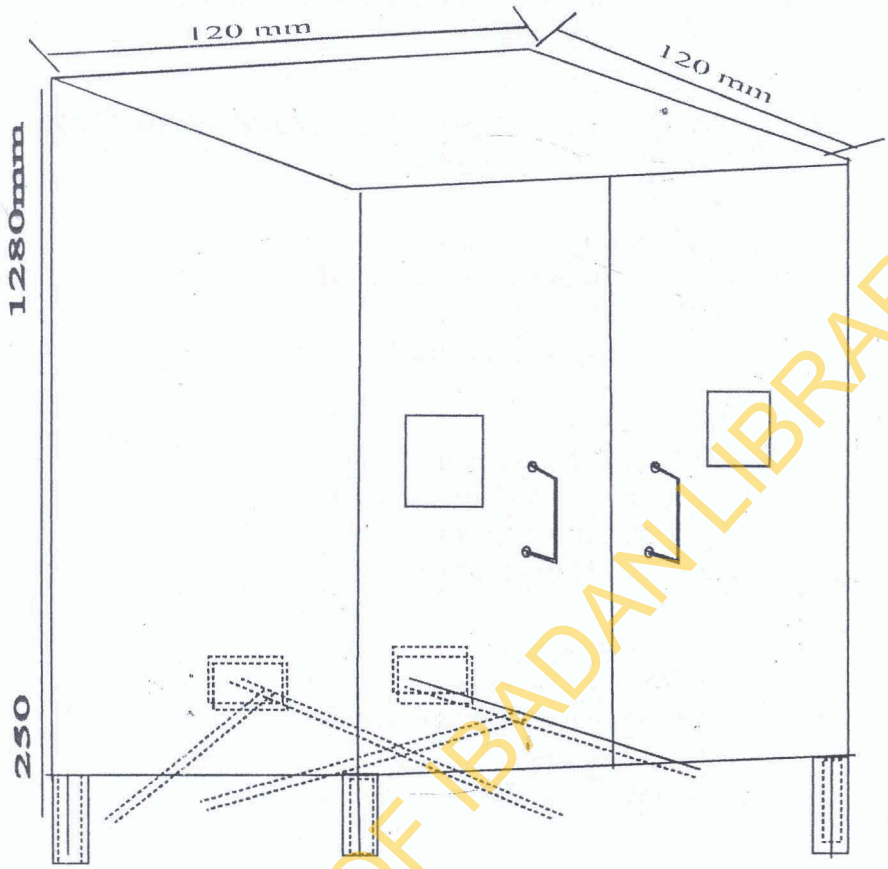


Figure 3

Table 2

	Big Oven (before Modification)	Big Oven (After Modification)	Clay Oven
Highest temperature attained	160^{0}C	400^{0}0C	280^{0}C
Time to attain maximum temperature	13 minutes	7 minutes	60 minutes
Pre-heating time before baking	15 minutes	10 minutes	60 minutes
Baking period	65 minutes	29 minutes	25 minutes
Total baking time	80 minutes	39 minutes	85 minutes
Average Temperature during baking	160^{0}C	260^{0}C	180^{0}C
Maximum external temperature	40^{0}C	55^{0}C	35^{0}C



ISOMETRIC VIEW OF A GAS FIRED OVEN
LARGE SCALE PRODUCITON OF BREAD

Scale 1:15

Conclusion

The major advantages of the gas fired oven, in terms of economy, include:

i) Decreased labor cost as it only requires two operators as against the wood fired oven, which requires four operators (minimal requirements).

ii) The insulator used is sawdust which is available locally in large quantities all year round.

iii) Preheating time of the ovens is very short compared to others.

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