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Research Article

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Design, Fabrication and Performance Evaluation of a Domestic Electric Oven

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Abstract The bulk of the energy used for cooking and baking for most household in Nigeria is mainly derived from fossil fuel. Irrespective of Nigeria's position as the sixth largest oil producing country, fossil fuels used mainly for baking is produced and delivered at a cost most Nigerians cannot afford, thus the need for alternative means of energy. This research work is focused on the design and fabrication of a domestic electric oven. The domestic electric oven was designed and fabricated with an outer dimension of 430mm×330mm×220mm made with mild steel and inner dimension of 380mm× 280mm × 190mm made with aluminum sheet, silicone rubber, and asbestos that served as an insulator. The gas burner was fixed in the stand for heating. The deflector plate is placed in the bottom of the heating chamber and the bimetallic thermometer fixed in the oven where it is provided with the vent for the removal of humid air. The domestic electric oven was tested for functionality. Its effectiveness was analyzed by using it to dry plantain chips, cassava chips and fish. The results obtained show that the oven was performance was satisfactory.

Keywords Design, fabrication, domestic electric oven, foodstuffs, performance, energy

1. Introduction

Energy consumption for heating in Nigeria is a major problem. Average Nigerian used wood fuel and fossil fuel as their major source of energy for heating [1-4]. The demand for wood fuel, charcoal combined with the high cost of kerosene, and natural gas has pushed the low income earners residing in towns to use charcoal as the cheaper option. Wood energy is becoming scarce and more expensive and is of great concern since the depletion of forests leads to serious consequences such as soil erosion, floods and desertification [5-7]. Wood and fossil fuels have significant negative impacts on the health of those nearby, primarily through the emission of soot. Burning these fuels also has a negative climate impact by releasing a significant amount of greenhouse gases [8-10]. These technologies also operate at a very low efficiency, with only a small amount of the stored chemical energy being converted into heat for baking or light for working.

This research work is focuses on improving heating for those in developing countries such as Nigeria. In this research work, electric heating which is cleaner than wood and fossil fuel that has negative effect on our ecosystem will be adopted in electric oven for baking of food. Electric heating emits no soot or greenhouse gases. Electric heating also allows fine heat control than wood and fossil fuel means of heating [11]. Moreover, electric heating can be significantly more efficient, with a much higher percent of energy going into heating the food.

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 [12]. In a baking oven, the hot air flows over the baking material either by natural convection or forced by a fan, the convection heat transfer from the air, and the radiation heat transfer from the oven heat the surfaces and the conduction heat transfer across contact area between product and metal surface [13]. The moisture in the food material simultaneously diffuses toward the surfaces where it is transfers from the surface by convection. The product loses moisture with continuous movement of the oven ambient air [14]. The earliest ovens were found in Central Europe and dated to 29,000 BC, it was used as roasting and boiling pits located within yurt structures. Ovens have been used since prehistoric times by cultures that lived in the Indus Valley and pre-dynastic Egypt. Settlements across the Indus Valley had an oven within each mud-brick house by 3200 BC. Thus, before the intervention of modern baking oven, people have alternative means of baking [15]. However, this method practice in the past is not safe; as a result, loss of lives and properties cannot be rule out. Various types of baking oven are in existence and they include; earth oven, ceramic oven, gas oven, mansonry oven and electric oven.

Electric ovens are the direct fired oven, which effectively distribute heat while being powered by electricity, although this can often result in a higher heating cost for the consumer. Many prefer this type of oven because they tend to use dry heat, which helps to prevent the buildup of rust. Electric ovens also feature a thermostat that controls the oven temperature electronically, and many have top, bottom, or rear grill elements. Electric ovens can take longer to heat, but they are relatively inexpensive in cost compared to other types of ovens.

2. Materials and Methods

The design of the domestic electric oven was done by using solid works modeling which shows the isometric views of the fabricated prototype. It consists of housing unit, thermometer, outlet nozzle, heating gas burner. The housing unit represents the entire out look of the oven. The housing unit of the oven was made up of three layers. The dimension of the oven is 430mm×330mm×220mm. The outer layer was fabricated from mild steel. Mild steel was selected due to cost and workability. The inner layer was made out of aluminum sheet with the dimension of 380×280×190mm, and the middle layer of the oven consist of thermal insulating material such has silicone rubber. Asbestos sheet was used in the four sides of the oven. Both the asbestos sheet and silicone rubber serve as insulator, and this help to reduce heat lost from the system. The door of the oven was made up of the stainless steel and the asbestos sheet of thickness 10mm was placed in between the steel plate to avoid the loss of heat through the door.

The oven makes use of a single burner which was attached to the stand so that pot can be easily placed on the stand. A bimetallic thermometer ranging the temperature from 0 to 300˚C was placed in the side wall of the stove. The thermometer sensor was placed in the center portion of the oven chamber to ensure that the thermometer should detect the temperature of both the lower and the upper layer of the stove. The oven is provided with the handles in both sides to remove or/and to place the stove above the burner stand. The two trays were provided in the stove, lower tray was made of the perforated aluminium mesh of thickness 4mm.

2.1. Design Consideration

During the development stage of the electric oven, a lot of design consideration was put in check to balance the design and economical value of the product. I considered cost, performance and design of other authors and tried to come out with the most effective and economical viable design of the electric oven. Mild steel was chosen for the design of the housing unit because it has the capacity to withstand the heat required for the drying process. Also the choice of abestors as insulation material was also deemed fit as suits our output requirements. Other factors considered include;

i. Its capacity per unit volume
ii. The temperature range over which it operates
iii. The means of addition and removal of heat and the temperature differences associated with it.
iv. Temperature stratification in the storage
v. The power requirements for additional or removal of heat
vi. The means of controlling thermal losses from the storage system, and
vii. Its cost

2.2. Sensible Heat Storage

In sensible heat storage (SHS), thermal energy is stored by raising the temperature of a solid or a liquid. SHS system utilizes the heat capacity and the change in temperature of the material during the process of charging and discharging.

$$Q = V\rho C_p dt \quad (1)$$

$$Q = MC_p dt \quad (2)$$

where;
Q = Sensible heat stored in the material
V = Volume of the substance (m^3)
ρ = Density of the substance (kgm^{-3})
M = Mass of substance (kg)
Cp = Specific heat capacity of the substance (Jkg-1 $°C^{-1}$)
dt = Temperature change (°C)

2.3. Latent Heat Energy Storage

Latent heat Storage (LHS) is based on the heat absorption or release when the storage material undergoes a phase change from solid to liquid or liquid to gas or vice versa. In the latent heat storage, the storage medium undergoes a phase change by absorbing and releasing heat in an approximately isothermal process.

2.4. Design of the Housing Unit

The housing unit represents the entire outlook of the electric oven. The housing unit of the electric oven was made up of three layers that was outer mild steel of thickness 26 gauge with the dimension 450×350×380 (Length × Width × Height) mm, inner layer was made out of aluminum sheet of thickness 24 gauge with the dimension of 380×310×340 mm (Length × width × height) and the middle layer of the electric oven consist thermal insulating material such has silicone rubber and the asbestos sheet all covering the four sides of the oven.

2.5. Design of the Thermometer Ranger

The bimetallic thermometer ranging the temperature from 0 to 300 ºC was placed in the side wall of the oven. The thermometer sensor was placed in the center portion of the heating chamber to ensure that the thermometer should detect the temperature of the both the lower and the upper layer of the electric oven.

2.6. Design of the Oven Tray

Two trays were provided in the oven; lower tray that was made of the perforated aluminum mesh of thickness 3mm to place the small baking tins and the oven works by the natural convection that enhances the movement of the hot air to the upper tray of the oven. The upper tray was equally made up of the aluminum mesh. The distance of upper tray from the top of the oven was kept at 120 mm distance and the distance from upper tray to the lower tray was kept at 120 mm and the distance from the lower tray to the base of oven was 100 mm.

2.7. Design of the Heating Chamber

The heating chamber is made of stainless steel. This unit consist of the following; blower, heater, temperature, sensor and temperature regulator.

3. Results and Discussion

Figure 1 shows the skeletal isometric view of the electric domestic oven.

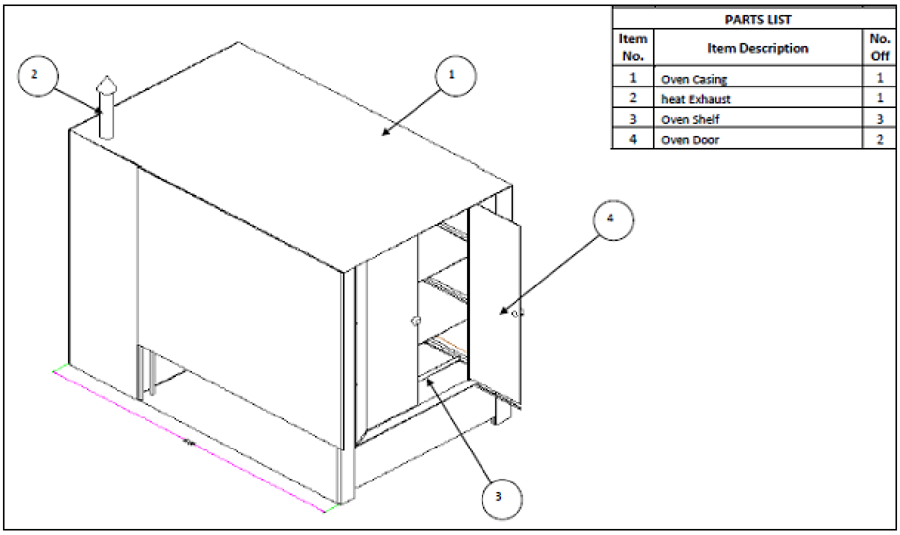

Figure 1: Electric Domestic Oven

Figure 2 shows the isometric view of the electric domestic oven.

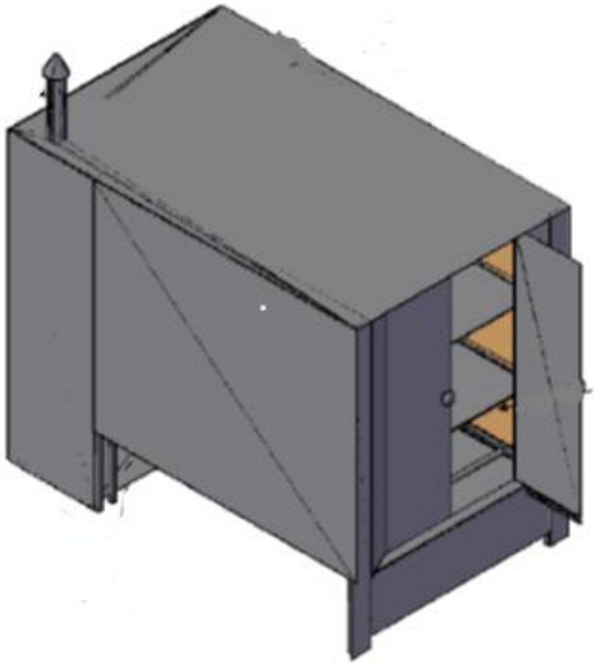

Figure 2: Isometric Model View of Domestic Electric Oven

The electric oven was put to test in order to determine its functionality and the effectiveness through drying of food items like plantain chips, cassava chips and fish. The oven works majorly by conduction and convection mode of heat transfer. The experiment was performed for each item and measurements were taken with respect to the corresponding time taken for the drying of the particular food items. The plantain chips of different size was dried in the electric oven at a temperature range of the 170-180 ºC. The time taken by the electric oven for the drying of the chips is shown in the Table 1. From the results analysis, it was observed that as the size of the chips increases, the time required for proper drying increases as well. The quality of the end product was satisfactory.

Table 1: Drying time for the Plantain Chips

Product	Time Taken to Dry
Plantain Chips (small size)	19mins
Plantain Chips (larger size)	28mins

The cassava was dried in the electric oven; the time taken for the drying of the cassava chips is shown in the Table 2. A heating temperature of 180 ºC was used. However, the heavier cuts of the cassava chips were dried at a higher temperature than the smaller portions. The cassava chips were evenly dried and the texture and the colour of the cassava chips were acceptable.

Table 2: Drying Time for Cassava Chips

Product	Time Taken to Dry
Cassava Chips (small size)	26 mins
Cassava Chips (larger size)	32 mins

Collected fish was dried in the electric oven; the time taken for the drying of the fish is shown in the Table 3. A heating temperature of 210˚ C was used. Just like in the past scenario, the bigger the fish, the higher the temperature required for proper drying. The quality of the dried fish both in term of texture and colour were acceptable. Tables 3 shows the results obtained when fish is used.

Table 3: Drying Time for Fish

Product	Time Taken to Dry
Fish (small size)	36 mins
Fish (larger size)	46 mins

4. Conclusion

From this study, it is clear that the designed and fabrication of electric oven can be better used for the drying of foodstuffs such chips, cookies and all the bakery products with good quality such as colour, texture, taste and good volume in the fermented products. Furthermore, the pre heating time of the electric oven is a function of the foodstuff used. It can deduce that the larger the foodstuffs, the higher the time required for proper drying.

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