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DESIGN AND CONSTRUCTION OF A MINI OVEN WITH DIFFERENT HEATING MODES

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Abstract

An oven is a thermally insulated chamber used for the heating, baking or drying of a substance and most commonly used for cooking. This study utilizes as many theoretical and practical concept to build an intellectual ability in the interpretation of working drawing in designing and development of an electric cooker.

1. INTRODUCTION AND LITERATURE

Electrical cooker is an appliance that works basically by the heating effect of electric current on conductors. Sometime, this heating effect is an inevitable waste of power for instance, in transmission of electricity on power lines in which the voltages at the terminals is evolved due to the heating of electric current. However, the heat produced by the flow of electricity is utilized by many equipment used at home and industries [1]. Some of which are found in electric cooker, electric oven, and electric space heater inexhaustible.

Heat which is a form of energy is transferred across a boundary of a system and given to another system or surrounding at a lower temperature by virtue of temperature difference between them. The heat is only identified across the system boundary [1]. Heat is of great importance to man on earth for their daily needs. It is with that electricity is generated, food is cooked and houses are warmed. Heat, by which electric oven operates on is generated by electricity of which materials used for the construction must have thermal capabilities and suitability to serve as heating element.

In actual analytical enunciation an oven is an enclosed chamber in which things are heated or cooked with various sources of power. Its importance borders around its function, which are as follows;

(i) It is used to meet the everyday basic need of cooking for human consumption.
(ii) Ovens are used for heat treatment of substance in laboratories and industries.
(iii) Also as a means of preservation by heat application to perishable materials.
(iv) Used for sterilization of instruments and equipment for industrial use
(v) Used for expelling of moisture content to a required measure in some substance

Other importance boarding around its energy source is that the use an alternative source of energy when either fossil fuel or electricity is not available. This can relatively save cost when necessitated.

The aim of this study is to construct an electric oven used in baking and the objectives are;

(1) Compare the various ways used in the production of an electric and gas oven.
(2) Disclose the process in the manufacturing of an electric oven
(3) Exploit the local facilities available in the construction of the oven as against imported ovens.
(4) To know the convenience in the use of alternate power source for operation of ovens.
(5) Discover the basic principle involved in the design and maintenance of an oven.

An Oven is a thermally insulated chamber use for the heating, baking or drying of a substance [2]. 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 and were used to cook for mammoth [3]. In Ukraine from 20,000 BC they used pit with hot covered in ashes. The food was wrapped in leaves and set on top then covered with earth [4]. In camps found in Mezhirich, each mammoth bone house had a hearth used for heating and cooking [2]. 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 [4]. Hence, before the intervention of modern baking oven, people have alternative means of cooking and baking but the alternative they have chosen led to loss of lives and properties. The different types of baking oven are Earth oven, Ceramic oven, Gas oven, Mansonry oven and Electric oven. An electric baking oven is a heating chamber or an enclosed box- like space which is meant for baking foods. In science and Engineering laboratories, it is in form of a small furnace which is

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used in the removal of moisture from some Engineering materials in order to improve their physical properties such as ductility and hardness. It can also be used for the purpose of heat treatment of engineering materials such as steel and it's alloy. An Electric baking oven has several advantages over other baking ovens. It is easy to install, moreso relatively damp, portable and has a very easy mode of operation. It is also easy to maintain and has high durability. It is highly preferred to all other types of oven due to the availability of electricity over a wide range of places throughout the countries. Having considered the advantages that can be derived from the use of electric oven, it is relatively cheap when compared with other means of baking.

As a result of vast advancement in technology, the invention of an electric baking over was brought about by an American self- taught engineer called Dr. Percy Spancer [5]. In the spring of 1946, Percy Spencer and an associate P.R. Hauson (RolyHauson), were working on a secret they called "The Speedy Weenie" which means 'a quick hot dog'. Engineers went to work on Spencer's hot new idea, developing and refining it for practical use. By late 1946, the Ray theon [6] company had filed a patent proposing that baking ovens are used to cook food, baked bread and pre heat food. In 1947, Ray them demonstrated the world's first baking oven and called it a "Rad arange" the winning name in an employee contest Housed in refrigerator sized cabinets. These primitive units were gigantic and enormously expensive, standing 5 ½ feet tall, weighting over 750 pounds and costing about 5000 pounds each. The Margie iron tube had to be water-cooled, so plumbing installations were also required. In 1965, Ray theon acquire Amana Refrigeration two year later, the first counter top, domestic oven was introduced. It was a 100-volt baking oven which cost just under 500 pounds and was smaller, safer and more reliable than previous models this introduced the first popular home model.

As the food industry of electric baking oven began to recognize the potential and versatility of the baking oven, its usefulness was put to new tests. Technology advanced and further developments led to a baking oven that was polished and priced for the consumer kitchen.

An expanding market has produced a style to suit every taste; a size, shape and colour to fit any kitchen and a price to please almost every pocket book. Options and features, such as the addition of convention heat, probe and sensor cooking meet the needs of virtually every cooking, heating or drying application. Over the years, improvements have been made in electric baking ovens and this trend still continues. This has led to the incorporation of features like a thermostat which turns the oven on and off and also helps in regulating the temperature of the electric baking Oven, insulator or lagging materials e.g. thermoses thing plastic which help in preventing heat loss from the oven and timber may allow the baking oven to be turned ON and OFF automatically at Pre-set times and it can also be used to shut the baking oven off when the food is completely cooked or when the bread is completely baked to the desired degree. Some ovens provide various ands to cleaning. Continuous clearing ovens have the oven chamber coated with a catalytic surface that helps break down (oxidize) food splatters and spills overtime.

Gas oven is one which works by the liquefied petroleum gas for the baking of the bread, cake and biscuit. The major operational principle of the 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. 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 [7]. The baking process usually requires significant energy consumption as relatively high temperature is applied in order to remove moisture in bakery products and create desired texture. Analysis and optimization of baking process and equipment have been conducted for minimizing energy consumption [8].

Induction Cooker

Induction heating is widely used in today's industry, such as melting, hardening and brazing etc. It is also getting popularity in cooking ranges due to good heating efficiency, clean working environment and low cost advanced power semiconductor devices. When an AC current flows in a coil in close proximity to a conducting surface the magnetic field of the coil will induce circulating currents (eddy) in that surface as shown in Figure 1.

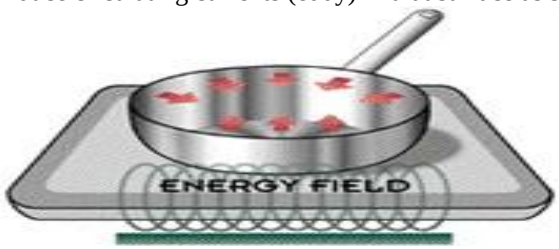

Fig. 1. Induction Cooker.

Advantages of induction cooker:

i. Only radiation that comes from an induction cooker is heat radiation.

ii. The coil stays cool, and is therefore safer, giving higher efficiency.
iii. Constant output power.
iv. Absence of shock hazard in the cooking pan.
v. Flexible temperature control.
vi. Cheaper than readily available microwave-oven.
vii. Common kitchen-purpose steel utensils are sufficient for cooking.

Disadvantages of induction cooker:

i. Costlier than common electric hot plate.
ii. Only heating vessels with high resistivity and relative permeability can be used.

Working principle of induction cooker:

In an induction cooker, initially an AC supply of 50 Hz is applied, and then rectified to DC and subsequently back to a high frequency AC source through an inverter. This high frequency current produces a high frequency alternating magnetic field through an induction coil. Therefore, placing a cooking pan / utensil close to the induction coil will induce eddy current in the pan [9]. As a result of which, heat energy will be produced on the surface of the pan. The internal resistance of the pan causes heat to be dissipated according to *Joules effect*. The basic components of an induction cooker is given in Fig. 2, along with its basic circuit structure.

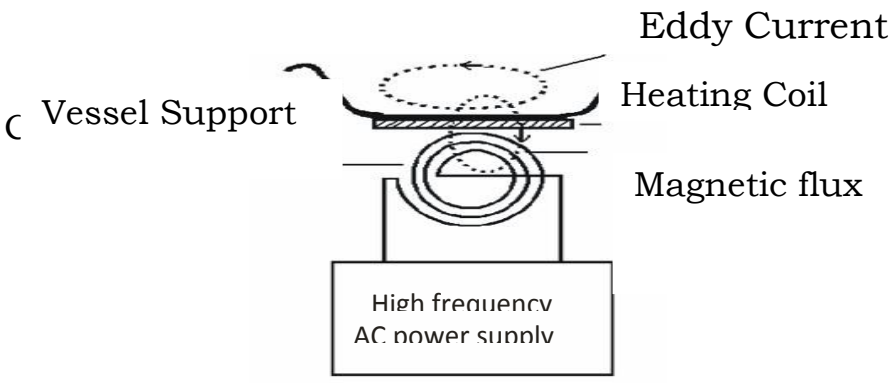

Fig. 2: Principle of Induction cooking.

Physical Structure of an Induction cooker

Fig. 3, shows a real model of an Induction cooker. A flat planner heating coil is used for induction cooking. A thermal insulator is placed between the cooking vessel and the heating coil to protect the coil from overheating and to support the vessel. Forced air cooling of the coil is usually necessary. A ferrite disc is used to enhance the coupling. The spacing (X_{cw}) between vessel and coil should be small for maximum flux but large enough for sufficient support, insulation and airflow as shown in Fig. 4. The ferrite disc reduces the overall reluctance of the conductor.

The heating coil is made up of multi stranded litz wire to eradicate skin and proximity effect. The strands of the litz wire are twisted or woven together that causes the total current to be distributed equally among them. This construction reduces external proximity effect and internal skin effect of litz wire. The number of twist per unit length plays a great impact at the calculation of AC resistance. Three or more such litz wires are twisted to form a composite litz wire. The composite litz wires are suitable for the coil, which uses in a high-frequency [10].

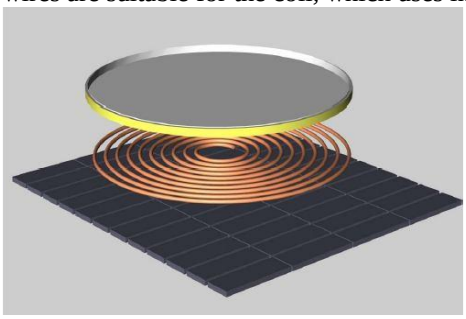

Fig. 3: Typical arrangement of Induction cooker [7].

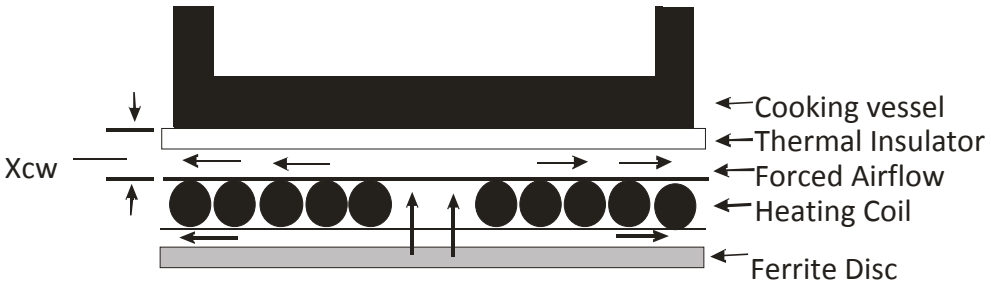

Fig.4: Cross-section of Induction cooker.

The rate of heat flow in induction cooking depends on the following factors:

i. Permeability of the disc material.
ii. Resistivity of the disc material.
iii. Spacing between the coil and the material to be heated.
iv. Spacing between the coil and the ferromagnetic disc placed beneath the heating coil.

1. METHODOLOGY

The material selected for this project is mild steel, based on its properties such as resistance to rusting, affordability, durability, insulating properties and availability in large quantities.

Operational Principle of Electric Baking Oven

The major operational principle of the electric oven is the process of heat transfer. Heat transfer tends to occur whenever there is a temperature difference, and the three ways in which heat may be transferred are conduction, convection and radiation.

Conduction

Conduction of heat in solid is partly due to impact of adjacent molecules that vibrate internal radiation. The heat will now flow from hotter end to the coldest end. The greater the temperature difference, the faster the heat will flow. There is a law governing the heat transfer by conduction based on the observation of one dimensional steady heat flow through a solid. Fourier's law of conduction in one dimensional state that the rate of flow of heat through a single homogenous solid is directly proportional to the area A of the section at right angle to the direction of heat flow and to change of angle to the direction of heat flow and to the change of temperature with respect to the length of the path of the heat flow dt/dx.

Mathematically expressed as:

$Q = KAD\ T / DX$ ---------- (1)

Q = the rate of heat flows in Kw (kj/secs)

K = Thermal conductivity of the material (W/mk)

DT = Temperature difference between the surfaces of metal

DX = Thickness of the material (m)

A = Area of the section at right angle.

Convection

This is the transfer of energy from one place to another by the motion of a mass of materials between the two points. In a natural convection, the motion of the fluid is entirely as a result of differences in density resulting from temperature differences. Naturally, convection occurs when a solid surface is in contact with a fluid of different temperature from a surface. Density differences provided the body force required to move the fluid. Mathematically, it can be expressed as;

$Q = LA [T_2 – T_1]$ ---------- (2)

Where L = Coefficient of corrective heat transfer

A = Area of surfaces not perpendicular to direction of heat flow

$T_2 – T_1$ = thermal temperature

In the oven, the fluid involved is the enclosed air and the burner surface or heating element, which provides the sold surface, while the oven walls serve as the solid surfaces. The rate at which heat is transferred across an enclosed space (oven) is calculated from a coefficient based upon the temperature differences of the surfaces.

Radiation

This type of heat transfer requires no materials medium. It is accomplished by means of wave motion through space. All objects can emit and absorb radiation, and radiation carries energy. When an object emits radiation, it gives of energy, and

when it absorbs radiation, it takes in energy. Sometimes, the emission or absorption will take place only in certain parts of the spectrum and sometimes they are distributed all across the spectrum. When an object gives off some radiation, then the energy stored in the object must decrease by the amount of energy given off in the radiation. The total radioactive flux throughout the hemisphere from black surface of area "A" and absolute temperature T is given by the Stefan- Boltzman law, which state that:

Mathematically, it can be expressed as;

$Q = A\sigma T^4$ ---------- (3)

Where;

Q =Heat flux, energy per Time.

A =Area of heat flux intensity. σ =Stefan Boltzman constant (5.67×10^{-8}) $10/m^2$ (K^4)T=Absolute Temperature.

These three (3) phenomena may take place in a given system one at a time or may occur simultaneously. The design of the electric/gas/coal oven was done by using the software 3D solid works which shows the pictorial views, lines and dimensions for the fabrication as shown in diagram.

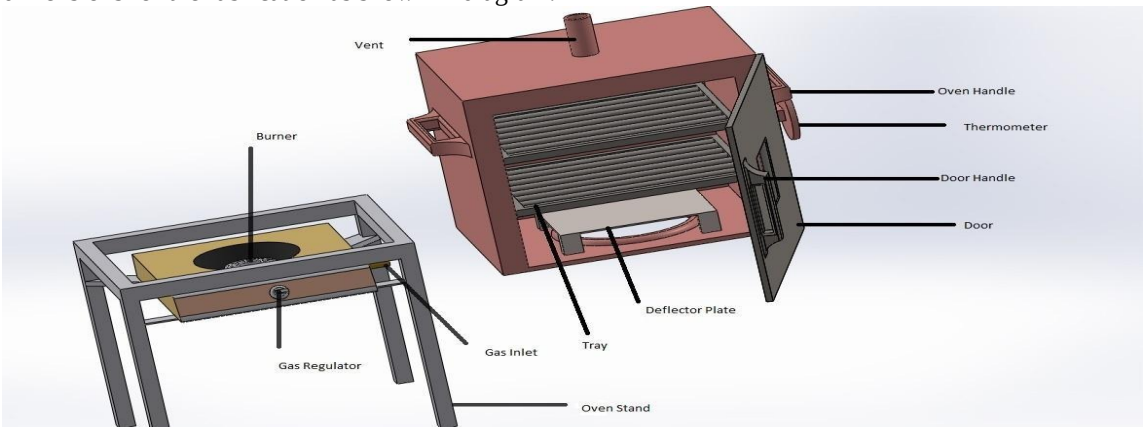

Fig 5. Design of the Electric/Coal/Gas Oven

A new design of the baking gas oven has been fabricated according to the design with the use of indigenous material. The oven consist of housing unit, thermometer, outlet nozzle, heating gas burner. The housing unit represents the entire out look of the baking oven. The housing unit of the gas oven was made up of three layers that was outer stainless 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 gas oven consist thermal insulating material such has silicone rubber and the asbestos sheet all four sides of the oven. These two material acts as an insulator to avoid the loss of the heat from the inner baking chamber to the outside ensures for the even baking of the product in the baking chamber. The door of the gas oven was made up of the stainless steel and the asbestos sheet of thickness 5 mm was placed in between the steel plate to avoid the loss of heat through the door and in the front of the door provided with the toughened glass to monitor the inside baking product without opening the door.

The single stove burner was attached to the stand so that the baking oven chamber can be easily placed on the stand. The stand kept at a height of 300 mm from the ground level so that the burner receives the enough oxygen for the burning of the gas and the flame coming from the burner directly enters the baking chamber for baking and there was less loss of the heat and the flame controlling knob was provided to control the flame in turn controls the temperature in inside baking chamber. The base of the inner baking chamber was provided with the deflector plate of the thickness of 3mm with dimension of 240×200 (length × width) mm placed at a height of 40 mm from the base of the oven to avoid the direct flame from the burner to the baking chamber and to the even distribution of the heat throughout the baking chamber as shown in the diagram.

The two trays was provided in the oven, lower tray was made of the perforated aluminium mesh of thickness 3mm to place the small baking tins and the oven works by the natural convection it helps for the movement of the hot air to the upper tray of the oven and the upper tray was also made up of the aluminium 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.

Fig 6. Fabricated Electric/Coal/Gas Oven

Design Analysis of the Oven
Oven Dimension
Height of Oven = 920 mm
Length of Oven = 480 mm
Breath of oven = 450mm

Oven tray Dimensions
Length of tray = 450 mm
Breadth of tray = 400 mm

Hashe Tray Dimension
Length of hashe tray = 35 mm
Breadth of hashe tray = 35 mm

In the construction of this baking oven equipment, emphasis was laid on its functional aspects as well as on the structural appearance of the formal design and construction work.
The functional aspects of the construction include the capability of the equipment to perform reliably most in the combustion of the gas and quantity of heat produced. Such a combustion is required to produce smokeless bluish flame which is effective, much better and non- luminous. The flame is obtained by creating an air space or air hole to allow a limit amount of air to mix with the burning gas.
The capacity of the gas baking oven is expressed in terms of the number of loaves of bread the oven can process per batch.
Average mass of a loaf of bread = 0.5kg (4)
Size of tray = $l_t \times b_t$ (5)
Size of loaf of bread considered = $l_b \times b_b$ (6)
where: l_t is the length of tray; b_t is the breadth of tray; l_b is the length of bread; b_b is the breadth of bread
Size of tray = 450 mm (length) x 400 nm (breadth)
=180,000 mm^2 (7)
Size of loaf of bread = 280 mm (length) x
130mm (breadth) =36,400mm^2 (8)
Capacity of Oven = Size of tray / Size of bread
= 180,000 / 36,400 = 5 Loaves of bread per tray (batch). (9)
However the capacity of the oven might vary for other food items such as fish, meat, plantain, etc.

2. RESULTS AND DISCUSSION

The electric baking oven was put to test in order to determine its functionability and effectiveness through some food items like egg, fish and meat. The experiment was performed for each of them while measurement were taken with respect to

corresponding temperature and time-taken for particular turning level of the thermostat knob or timer and the temperature control switch that is graduated between low, medium and high is constantly maintained at HIGH throughout the experiment. The timer was set at 1500C and the food item was put into the food chamber. The machine was put on while the timer was set to the expected marked point gradually. At interval of 10 minutes, the food item was check and tested. The following results were obtained during the various experiment conducted.

Table 1: Time-taken and temperature attained by the electric baking oven for half crate of Egg.

CALIBRATED MARK	1	2	3	4	5
TIME (Min)	50	37	25	20	13
Temp. (^{0}C)	120	150	170	200	230

Table 2: Time-taken and temperature attained by the electric baking oven for 10kg of Fish.

CALIBRATED MARK	1	2	3	4	5
TIME (Min)	35	30	24	18	13
Temp. (^{0}C)	120	150	170	200	230

Table 3: Time-taken and temperature attained by the electric baking oven for 10kg of Meat.

CALIBRATED MARK	1	2	3	4	5
TIME (Min)	50	37	25	20	13
Temp. (^{0}C)	120	150	170	200	230

The following graphical plots for Egg, Fish and Meat were obtained for analysis:

(i) Graph of Time against Calibrated Mark (Fig 7).

(ii) Graph of Time against Temperature (Fig 8).

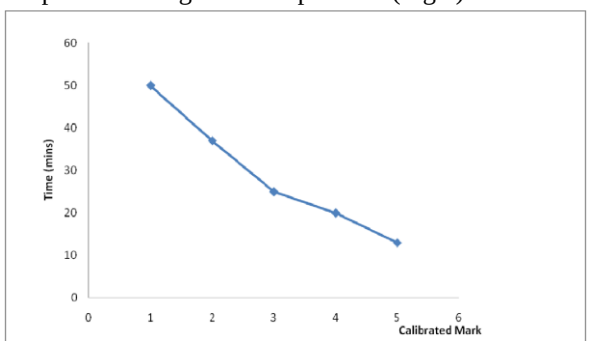

Fig 7: Graph for Temp of Meat and Egg

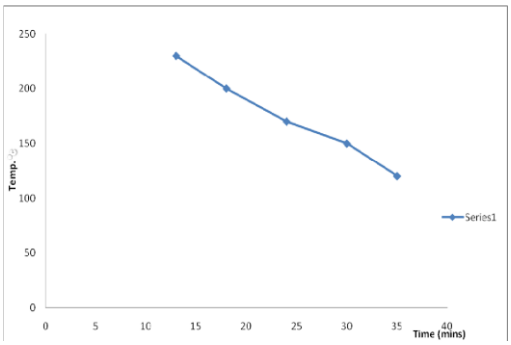

Fig 8: Graph for Temp of Fish and Egg

The graph of calibrated mark against temperature reveals increase in temperature with increase in degrees of turning of the plate or dish, for all food. The graph of time against temperature reveals that foods are bake within shorter time with increase in temperature. The graph also reveal that the higher the degree of rotation of the plate or dish, the lesser the time-taken for food to bake. From the tables, it can be concluded that as the temperature increases, the time required to cook the food reduces. That is, temperature is inversely proportional to time. Also, when compare with the already existing oven using cake, the following result were obtained.

Table 4. Comparing the time taking to bake cake between designed project and already existing baking oven

Size of the Cake	Designed Project	Already existing Oven
Small size Cake	20 minutes	25 minutes
Average size Cake	50 minutes	55 minutes
Large size Cake	1hr 15mins	1hr 30mins

Therefore, it can be deduced that the designed project is faster and thus baked effectively when compared with existing one. Hence after the oven has been tested, it was realized that it is efficient and faster, it does not blacken the baking pan and it is pollution free.

Cookies and Muffins

The cookies was baked in the oven, the time taken for the baking of the cookies was shown in the table at the baking temperature of 150˚ C and the muffins was baked in an gas oven the time taken for baking shown in table 3 at a temperature of 180˚C. Cookies and the muffins are baked evenly and the texture and the color of the cookies was acceptable**.**

Table 5 Baking Time of the Cookies and Muffins

Product	**Time taken for baking**
Cookies	10min
Muffins	13min

3. CONCLUSION

From this study it is evidently clear that the designed gas/electric/wood oven can be better 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. From the tables, it can be concluded that as the temperature increases, the time required to cook the food reduces. That is, temperature is inversely proportional to time. Also, when compare with the already existing oven using cake, it can be deduced that the designed project is faster and thus baked effectively when compared with existing one.

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