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DESIGN, CONSTRUCTION AND PERFORMANCE EVALUATION OF LOW COST ELECTRIC BAKING OVEN

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ABSTRACT

The paper reports on the design and construction of a domestic electric basic oven. The aim of this research work is to improve on the already existing electric baking oven through the incorporation of a blower and interlock switch. The joining techniques and handling of the equipment for optimum usage was explained in details. The AUTOCAD design shows the pictorial views, lines and dimensions for its mass production purposes. The electric baking oven was put to test in order to determine its functionability and effectiveness through some food items. When the elecrtric baking oven was tested, higher efficiency is obtained when compared with the already existing one. Therefore, it can be deduced that the designed project is faster and thus baked effectively when compared with existing one.

Keywords: Electric baking oven, blower, interlock switch, joining techniques, equipment, functionality, effectiveness.

INTRODUCTION

An Oven is a thermally insulated chamber use for the heating, baking or drying of a substance (www.Oven.Merriam-webster.com) 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. They were used to cook mammoth (Jennifer, 2009) 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 (Peter et al) In camps found in Mezhirich, each mammoth bone house had a hearth used for heating and cooking. (www.Mezhirich. Donsmaps.com) 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 (Dales and George, 1974) 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 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. In the spring of 1946, Percy Spencer and an associate P.R. Hauson (Roly Hauson), 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 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 theom 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. However, there were many myths and fears surrounding these mysterious new electronic "radar ranges" By the seventies, more and more people were finding the benefits of baking oven to outweigh the possible risks and none of the them were dying of radiation poisoning, going blind, sterile or becoming impotent. As fears faded, a swelling wave of acceptance began filtering into the kitchens of American and other countries. Myths were melting away and doubt was turning into demand. By 1975, sales of baking ovens would for the first live exceed that of Gas ranges.

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 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.

The purpose of this research work is to design and construct an electric baking oven which is portable, efficient and cheaper than the modern means of baking.

The research work is justified for the following reasons:

(i) It has simple operational method and serves as a medium of exposure to the intricacies of design and fabrication.

(ii) It could be designed and fabricated locally, instead of waiting and longing for it's importation.

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;

$Q = LA\ [T_2 - T_1]$ where ---------- (2)

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.

METHODS AND MATERIALS

Improved Electric baking oven was designed and constructed. It consists of housing unit, blower, rotor, thermostat, Interlock switches, light indicator, timer and heating element. The housing units represent the entire outlook of the baking oven. It was divided into two units, namely Mechanical unit and Electrical Unit. The Mechanical Unit or bigger unit is meant for the food baking and food preservation. The dimension of the unit is 410mm by 540mm rectangular in shape (i.e. length x breadth). The Electrical Unit is the source through which electric power is supplied. This unit makes the mechanical unit perform it function of foods baking. The unit comprises of the interlock switch, thermostat, timer, light indicator and blower. The electrical unit was dimensioned as 270mm x 120mm x 85mm rectangular in shape. The rotor, element and blower which are parts of the electrical component are not installed into the smaller unit but to the rear view (back view) and to the interior part of the baking oven.

The blower is made up of electric rotor attached with blade, which rotates and function as a heat extractor that draws heat from the surrounding through the vent of the outer casing and directs it to the already excited electron. The rotor is a small type, placed at the bottom of the cooking chamber. It rotates a flat dish inside the cooking chamber and this rotation is needed to achieve maximum distribution of heat on the food. Thermostat is a device used for regulating the heat intensity. The element is very essential in an oven system but can be dangerous if not properly controlled. The thermostat, therefore control and regulate the amount of heat produced. The thermostat is connected to the food chamber through a thermocouple arrangement. The thermocouple senses the temperature of the chamber convert it to electrical voltage and feeds it into the thermostat which is then supply through a circuit-breaker system to the heaters as the temperature changes intermittently. It can be preset as required. The interlock switches in baking oven ensure safety operation. All ovens are equipped with safety interlock switch. The door interlock system is one of the most significant safeguards in baking oven. The purpose of interlock system is to interrupt the production of wave energy when the oven door is opened and similar to prevent any microwave output until the door is firmly and safely closed. A principal component of the interlock switches is the interlock monitor switch.

Light Indicator is fixed to the oven so as to know the working condition of the oven that is, when the oven is ON, the light glows, and when it is not working, it does not glow. Thus, for this oven the light indicator is green colour. Timer is an electronic device that controls the time duration of the oven. It will automatically shut down the oven at the required time set on it.

Material Selection

The table 1 shows the material required for the design and fabrication of an electric

baking oven. Thus, the materials selected for this project was mild steel. The reasons considered in the selection of this material are it's resistance to rusting, affordability, durability, insulating properties and availability in large quantities.

Table 1: Part Names, Selection of Materials and Quantity

S/N	Part Names	Materials	Quantity
1	Top cover	Mild steel	1
2	Oven Door	Mild steel	1
3	Door Handle	Iron Rod	1
4	Insulator	Robber	1
5	Nut	Iron	1
6	Insulator	Plastic	1
7	Oven Lock	Mild Steel	1
8	Air Hole		1
9	Plug	Plastic	1
10	Oven wall	Mild Steel α Fibre	4
11	Oven Stand	Pipes (Mild Steel)	4
12	Electrical Housing	Mild Steel	1
13	Thermostat	Bi-Metal	1
14	Interlock Switch	Plastic	1
15	Indicator Light	Plastic	1
16	Electrical Wire	Cable	4
17	Rotor Housing	Mild Steel	1
18	Blower	Galvanized Steel	1
19	Layer Net	Iron rod	1
20	Layer Net	Galvanized Steel	1
21	Element	Bimetallic	1

Table 2: Procedures for Assembling and Installing of the Parts

Procedures	Operation	Descriptions	Tools
1.		Collection of the materials for the constitution and installation of the parts	Free hand
2.	Measurement	Making out the measured points on the mild steel	Scriber meter rule
3.	1. Drilling (Hand drilling) 2. Clamping 3. Welding Operation	Hole drilled on the front view i.e. facade view at the lower part of the oven. Another hole was made on the rear side (back view) at the upper part.	Bench vice drill bit and electrical welding machine
4.	Cutting Riveting	Cutting of the same material to the electrical compound, to dimension and rivet the pins to the joints.	Plate cutting machine, riveting machine, hammer and rivet pin.
5.	Bending	Bend some of the parts cut to 30mm as shown in the AutoCAD design	Plate bending machine
6.	Installation	The installation of the electrical component to it unit orderly (whichever come first)	Screw driver and tester.
7.		Placing of the parts cut to their appropriate shape and sizes.	Free hand
8.	Insulation	Putting fibers into the oven walls as shown in the AutoCAD design before welding operation	Free hand
9.	Welding Riveting	Welding of the mechanical unit to food chamber and joining the electrical unit to the mechanical unit by riveting the pins	Electrical welding machine.
10.	Welding Electrical connection	Fixing of the element to the interior part of the oven and fixing of the blower, rotor to it housing as shown in the AutoCAD design.	i. Electric welding machine ii. Free hand for the connection
11.	Grinding machine	Grind all the welded parts on the oven.	Plate grinding machine
12.	Electrical Connectivity	Connection of the electrical wire from the electrical component to the heating place at the interior side and to the motor at the back view of the oven. (rotor housing).	Free hand
13.	Painting	Paint the entire interior and exterior views of the baking oven as shown when seen.	Painting brush
14.	Electrical connectivity	Insert the plug into the socket	Free hand

The bill of Engineering Measurement and Evaluation and total Engineering Evaluation for the electric baking oven was as shown in the table 3 and table 4 respectively.

Table 3: Bill of Engineering Measurement and Evaluation (BEME)

S/N	Construction	Amount (N)	AUTOCAD	AMOUNT (N)	Typing & Binding	Amount (N)
1.	Mild steel	7,000	AutoCAD	3,500	Typing six copies	5,000
2.	Iron rod	5,000	Drawing		Spiral binding Six copies	1,500
3.	Thermostat	1,000				
4.	Blower	500	Total	3,500		
5.	Element	2,500			Total	6,500
6.	Rotor	1,500				
7.	Interlock switch	150				
8.	Light indicator	150				
9.	Insulation materials	200				
10.	Galvanized steel	200				
11.	Transport (for the oven carriage	250				
12.	Paints	250				
13.	Hiring of generator and fueling (2days)	1,800				
	TOTAL	N17,000				

Table 4: Total Engineering Evaluation of the Electric Baking Oven

S/N	DESCRIPTIONS	AMOUNT IN NAIRA (N)
1.	Construction	17,500
2.	AutoCAD	3,500
3.	Typing and Binding	6,500
	TOTAL	N 27,000

Result 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 5: Time-taken and temperature attained by the electric baking oven for Egg.

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

Table 6: Time-taken and temperature attained by the electric baking oven for Fish.

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

Table 7: Time-taken and temperature attained by the electric baking oven for 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.

(ii) Graph of Time against Temperature.

(iii) Graph of Temperature against Calibrated Mark.

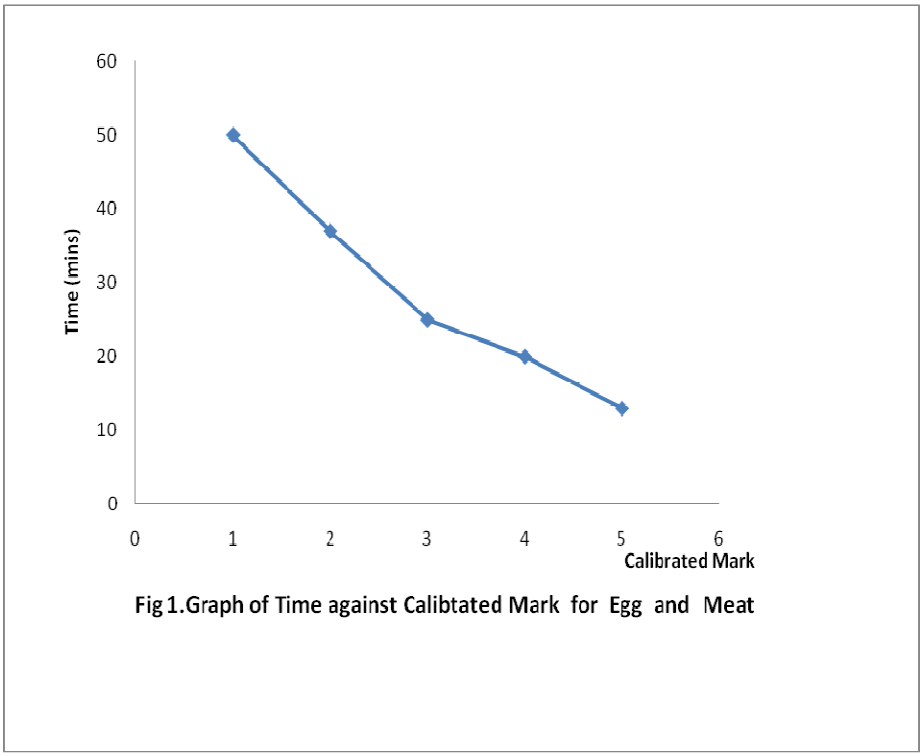

Fig 1.Graph of Time against Calibtated Mark for Egg and Meat

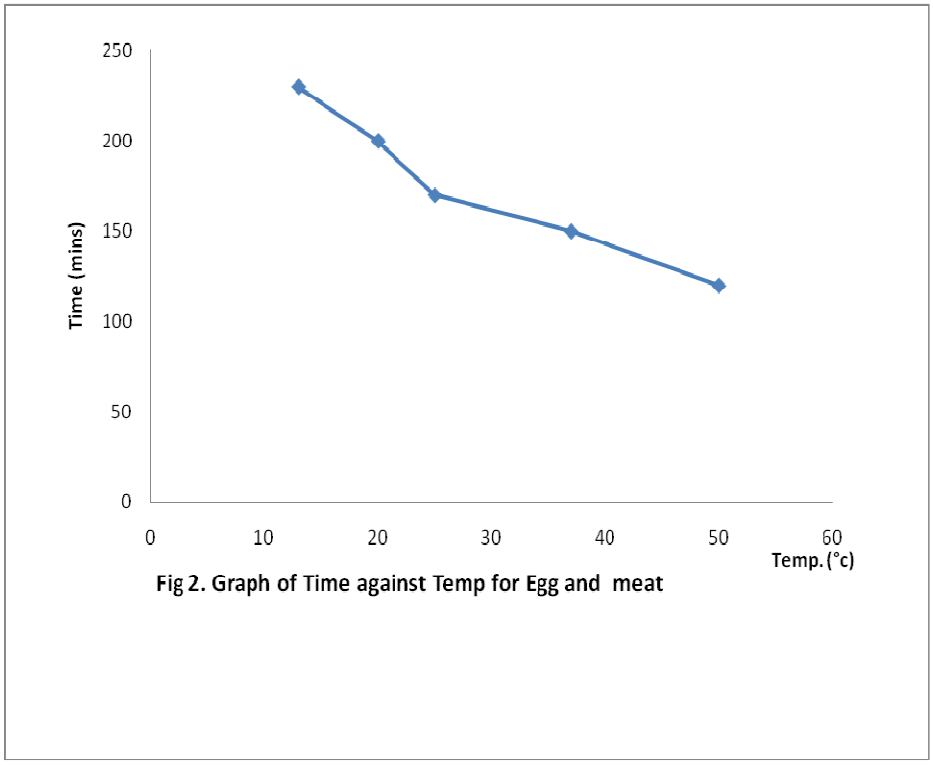

Fig 2. Graph of Time against Temp for Egg and meat

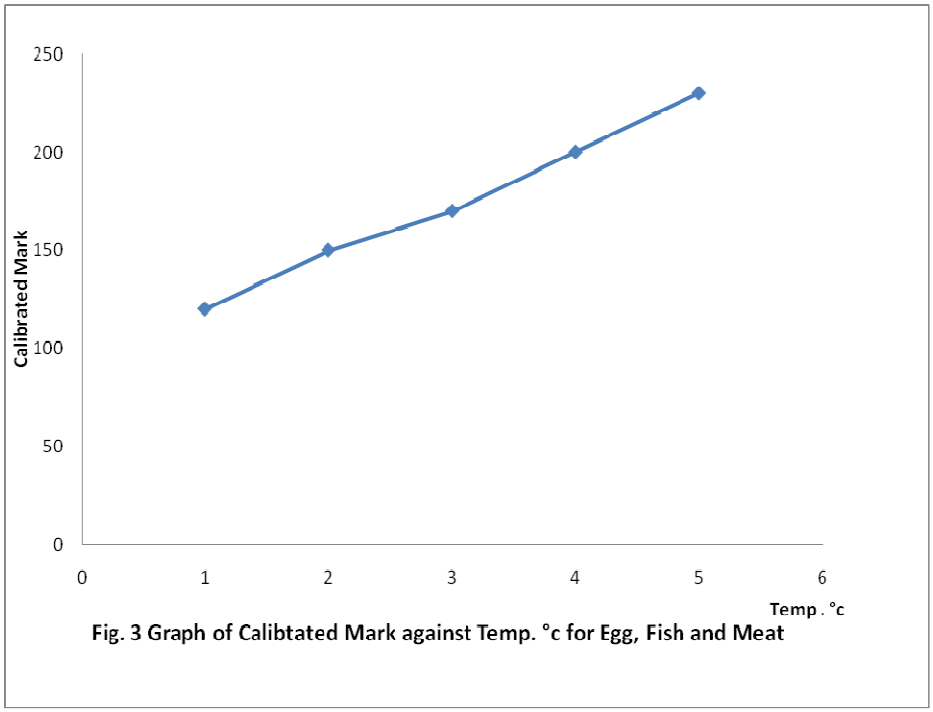

Fig. 3 Graph of Calibtated Mark against Temp. °c for Egg, Fish and Meat

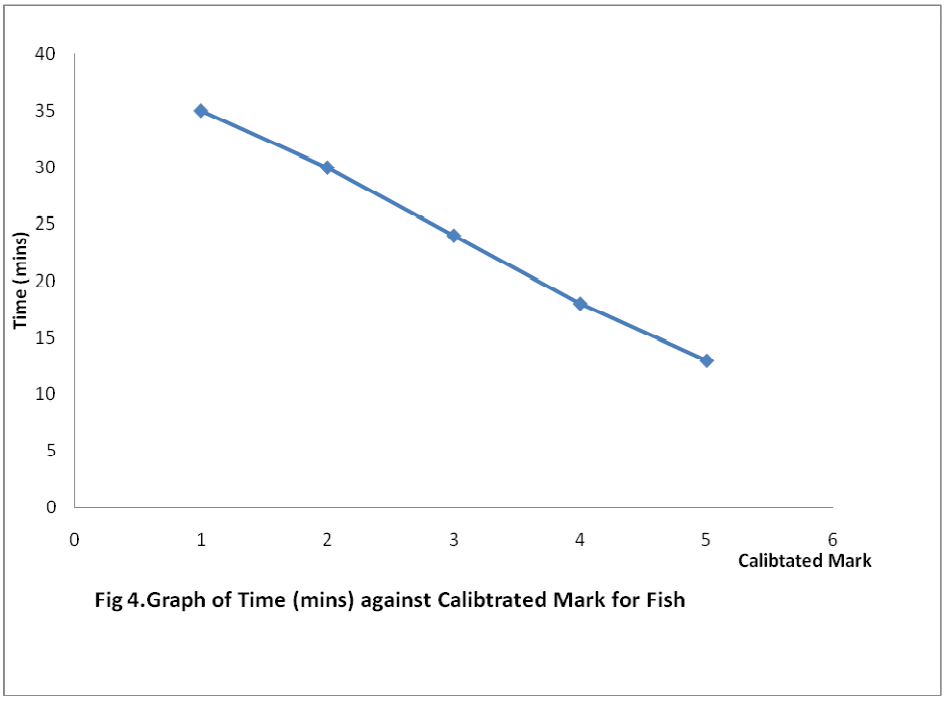

Fig 4.Graph of Time (mins) against Calibtrated Mark for Fish

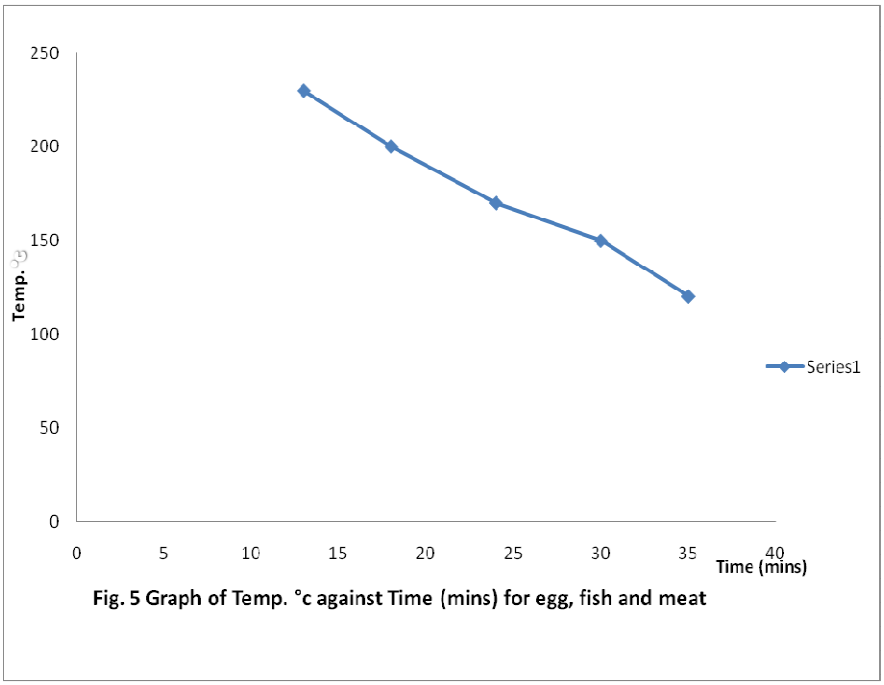

Fig. 5 Graph of Temp. °c against Time (mins) for egg, fish and meat

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 8. 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.

CONCLUSION

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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