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The Design of a Combination Cooker

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ABSTRACT: *Cooking apparatus in Nigeria today comprises of both the locally fabricated cookers and the imported cookers. The locally fabricated cookers include the locally fabricated hot plate, Kerosene stoves, gas cookers, briquette stoves, fire wood tripod stove, and locally fabricated electric cookers, charcoal stove and so on. Most of these cookers can only use or take advantage of one heat source at a time and hence most Nigerians need up having more than one cooker with different heat source in their homes at a time. This is due to the non-stable heat sources for cooking in Nigeria; irregular power supply, scarcity of cooking fuels like kerosene and gas at one time or the other. These challenges have led to the design of a combination cooker with oven. The cooking apparatus will take advantage of electricity, kerosene, gas and charcoal hence eliminating the possession of more than one cooking apparatus at a time. It is right to say the combination cooker is four cookers built into one. The apparatus will perform all domestic cooking, baking and so on. The estimated price is sixty thousand naira only (₦ 60, 000: 00). The surface of cooker houses two hotplates, two medium gas burners, two pressurized kerosene burners and a charcoal cooking surface.*
KEYWORDS: *Cooking, Apparatus, Heat source, Combination cooker, Domestic, Fuel Analysis*

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I. INTRODUCTION

1.1 Background of Study

Cooker and oven are cooking devices use for producing an appreciable quantity of heat to a food cooking or processing. They are use for heating substances in order to undergo phase transformation or changes as might be required. Cooker and oven have many advantages on the standard of living of the entire human race, with the advancement and systematic approach of cooking for domestic and commercial consumption; they can be used for softening, melting, drying, roasting, digesting, steaming and many more transformation to enhance palatability and edibility of foods. Cooking is integral and vital parts of life that cannot be overlooked since most foods only become edible after they must have been cooked to improve taste, texture, digestion and their nutritional values. (Johnson, Kreid, and Hanson. 1983)

In view of this, cooking technology is an essential human activity; it is the application of mechanical, chemical, electrical and applied science to generate heat energy for processing and preparation of foods for consumptions. Oven is an enclosed metallic or ceramic box that is heated from a source, flame or electric filament, for the purpose of drying, baking, preserving and sometimes cooking. Cooker on the other hand, is an open heat source that gives direct flame or heat energy on to the surface of the container containing the food substances. Oven is used in the laboratories as an indirect heat source for removing moisture from materials to improve their properties such as hardness, ductility, brittleness, etc. Cooker serves as a direct source of heat in the laboratories for softening and melting to beat or bend materials to desire shape and for heat-treating. (Tezuka, Takada, and Kasai, 1976)

There are different types of cooker and oven depending on their energy sources, which include, gas, electricity, solar, kerosene, charcoal, etc. (Roger,1992). Cooker and oven could comprise of one, two or more sources of fuel incorporated into a single device depending on the environmental requirement and individual choices. The numbers of incorporated sources of heat on a single device have a tremendous benefit on the design of both cooker and oven for effective operation especially in the third world countries where electricity and fuel availability have been a great challenge. Nigeria for instance, always witness scarcity of domestic hydrocarbon fuel and electricity, and most homes employ the use of charcoal, wood and other farmer wastes as an alternative energy source creating untidiness, stress and sometimes aches when situation of such arise because of the exorbitant charges mostly placed on fuel during scarcity.

This design will put into consideration three different sources of fuel and an electric source incorporated into a single cooker and oven. The energy sources are charcoal, gas, pressurized kerosene and electricity.

II. AIM AND OBJECTIVE

The aim of the paper is to design a multipurpose cooker and oven with four different sources of heat and the specific objectives are:

i. To create two additional stove to the existing cooker and oven.
ii. To incorporate pressurized kerosene stove facility into the design of the cooker and oven.
iii. To incorporate charcoal stove facility into the design of the cooker and oven.

2.2. Scope and Limitation

This design will only consider four sources of heat energy as stated above, that is, the incorporation of pressurized kerosene and charcoal burners to the existing electric gas cooker and oven. Solar or any other apart from the above stated energy source would not be considered.

III. MATERIALS AND METHOD

3.1 Improvement on Design

The following are the improvement on the existing designs

i. Location of pressurized kerosene tank in a conspicuous place and comfort ability in pumping.
ii. Provision of charcoal cooker and oven in addition to other source of energy.
iii. Redesign and restructuring to reduce the size of the project.

3.2 Materials and Parts

The study is design of a multipurpose cooker with oven. The cooking device operates with the principle of heat transfer and combustion of gases. The cooker is a rectangular like box (1250mm x 550mm x 850mm) on which all the sources such as charcoal, electric, gas and pressurized kerosene are incorporated. The cooker comprises the following parts.

3.2.1 The Frame

The frame is made up of ¾ square pipes of 850 mm x 5mm x 5mm for the four vertical frames and 1250mm x 5mm x 5mm for four horizontal frames at end view. Each member of the frames is held together by welding process.

3.2.2 The Walls

The walls are composite with an insulator placed in between the outer and inner walls.

i. Inner walls: The inner walls are of 1240 x 540 x 850mm dimensions and gauge 22 mild steel.
ii. Outer walls: The outer walls are of 1250 x 550 x 850mm dimensions of gauge 18 mild steel.

3.2.3 The Doors

Electric oven door is of 300mm x 450mm. Gas and pressurized kerosene doors are to 650mm x 740mm and charcoal oven door is 300mm x 400mm.

The insulator (fiber glass) is installed inside the cooker to prevent heat lost by mostly conduction and radiation. The door handle (oven door) mounted on the door for opening and closing of the oven. Hinges are used to hold the oven's doors.

Figure 3.1 show the isometric projection the multipurpose cooker indicating other important parts.

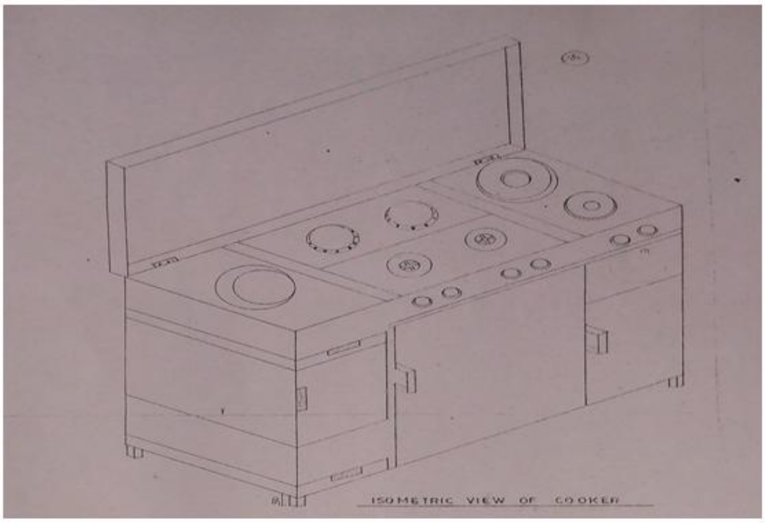

Fig. 3.1 Isometric projection of multipurpose cooker

IV. DISCUSSION

4.1 Operational Principle

The operational principle(s) of the multipurpose cooker with oven is the process of combustion of gases in the case of gas and pressurized kerosene and charcoal by releasing energy which serve as the heat required for cooking and in the oven for baking. This heat transfer occurs within the composite walls of the cooker, the sources operate separately or independently on one another.

4.1.1 Electric Cooker/Oven

Heat is generated in the electric burner by the principle of electric heating device. Each burner comprises a solid burner packed between heat resistant steel plates. Thus electrical energy is converted into heat energy as the burner is heated to the operative temperature, according to Ohms law in relation with heat transfer of conductive materials.

$V = IR$ and $Q = KA/L$ (Tezuka, Takada, and Kasai, 1976)

Where
- V = potential difference
- I = current
- R = resistance of the element
- Q = heat passing through the walls
- K = thermal conductivity
- A = area
- L = thickness

The electric cable supplies the required voltage to the cooker, after which it is converted to the heat for cooking and baking in case of oven. The heat supply is regulated by thermostat and the control knobs.

4.1.2 Gas Cooker/Oven

The operational principle of gas cooker/oven is a process of heat transfer (conduction, convention and radiation) and combustion of gases. The heat transfer can take place through occurrence such as conduction and radiation. This two heat transfer takes place simultaneously. During combustion, fuel (butane) react with air (oxygen) to liberate energy, and this librated heat energy is used in cooker for cooking and oven for baking.

The chemical equation for the burning of the gas is given as

$$C_4H_{10}(g) + 6\frac{1}{2}O_2(g) \quad 5H_2O(g) + 4CO_2(g)$$

4.1.3 Pressurized Kerosine Cooker/Oven

Pressurize kerosene cooker obtain heat from complete combustion of kerosene to produce heat, carbon dioxide and water vapour as by product. Air is available for complete combustion. The pressure is exerted on kerosene of liquid state to form vapor this is facilitated by a pump. The operation of this pumping device vapourises the kerosene by increasing the pressure. The pressurize kerosene gas flows through the pipe to the burner. The kerosene vapour reacts with air which is igniting in this same way as gas cooker. Kerosene is a hydrocarbon fuel which contain C_{12} to C_{18} and reacts completely with oxygen. The chemical equation is given as

$$C_{14}H_{30} + 43\tfrac{1}{2}\ (O_2 + 79/21\ N_2) \qquad 14CO_2 + 15H_2O + 50.55N_2$$

4.1.3 Charcoal Cooker/Oven

Charcoal is a domestic fuel contains mainly carbon. Charcoal granules are poured inside a conical perforated container. The charcoals are carefully packed in the container before the burning, the charcoal react completely with air. The combustion process of charcoal comprises three phases. These are:

i. $2CO + O_2 \qquad 2CO_2$ (Phase 1)
ii. $CO_2 + C \qquad 2CO$ (Phase 2)
iii. $C + O_2 \qquad CO_2$ (Phase 3)

In phase 1: The carbon monoxide produces at center react totally with the oxygen to form carbon (IV) oxide. The heat energy produced is use for cooking.

In phase 2: Carbon monoxide is a product of incomplete combustion while carbon dioxide is found on the surface that is exposed to air while

In Phase 3: The carbon monoxide found at the centre of the loaded cone rises up and react completely with oxygen to form carbon dioxide.

4.2 Design Theory and Specification

The design of the multipurpose cooker covers both the oven shape and the shape of the burners.

4.2.1 Oven Shape

The shape of the oven is convectional rectangular shape which gives the enclosed space. The charcoal oven roof by 550mm by 400mm. Electric oven roof is 500mm by 300mm and the roof for pressurized kerosene and gas oven is 650mm by 600mm. This gives room for conservation of the heat at the top part of the oven while the rectangular shape of dimension 1250mm by 550mm account for uniform heat transfer from source to all parts of the oven.

The front part of the oven is where the door to the oven compartments is situated. It is made to be a composite wall of fibre glass in between the walls. The dimension of the charcoal door is 400mm by 300mm, gas and pressurized kerosene oven is 650mm by 600mm, electric oven is 500mm by 300mm, and jointed to the oven body by two hinges.

The oven base or floor is provided with burners such as electric, charcoal, gas and pressurized kerosene. The heat distribution analysis is an advance heat transfer, analysis which could be analyzed by finite element method. The compact size of the oven also ensures that heat is uniformly distributed to all parts at a short interval of time.

4.2.2 The Burners

The burners are of pre-mix that mixes air and fuel in mixing chamber before the combustion takes place. The burner admit air through a small opening in which fuel coming from the gas cylinder via the control knob is passing through the hose to the “burner head” at which the mixture of air fuel burnt to release energy in form of heat. The burner is in circular form and centrally placed at the bottom floor of the oven to ensure uniform heating of the oven.

The diameter of the oven’s burner is 65mm which is sufficient enough for uniform heat distribution when considering the oven size and volume.

4.2.3 Size Specification

The overall length of the oven is 1250mm and breadth is 550mm. Electric oven is made up of top part of 500mm by 300mm, charcoal oven is 400mm by 550mm, gas and pressurized is 650mm by 600mm dimension and the body of 1250 by 850mm dimension.

The dimension of the doors are as follow; electric oven is 500mm by 300mm, charcoal oven is 400mm by 300mm, gas pressurized kerosene is 650mm by 600mm. the oven compartment for electric oven is located 350mm from the surface burner plate. The gas and pressurized kerosene is 150mm from the surface plate and charcoal oven is 200mm from the surface plate.

The measured sizes of each part were done accurately to ensure uniform heat distribution in the oven and the compact size of the oven also ensures that heat is distributed to all parts at a short interval of time.

4.2.4 Design Calculation

Oven capacity

The capacity of the oven (in m^3) is calculated independently by considering each oven capacity.

i. Charcoal oven

Volume of charcoal oven = Length x breadth x height

V = L x B x H (m^3)
V = 0.4 x 0.55 x 0.4
V = $0.888m^3$

ii. Gas Oven

Volume of Gas oven = Length x breadth x height
V = L x B x H (m3)
V = 0.325 x 0.55 x 0.6
V = 0.10725m3

iii. Electric oven

Volume of the electric oven = Length x breadth x height
V = L x B x H (m^3)
V = 0.3 x 0.55 x 0.5
V = $0.0825m^3$

iv. Pressurized kerosene oven

Volume of pressurized kerosene oven = Length x breadth x height
V = L x B x H (m^3)
V = 0.325 x 0.55 x 0.6
V = $0.10725m^3$

iv. Electronic Oven

Electric current is the source of energy. The flow of heat can be thought of as analogous to an electric current. The heat flow is caused by a temperature difference whereas the current flow is caused by potential difference; hence it is possible to postulate a thermal resistance analogous to an electric resistance.

From ohm's law

$$V = IR \quad \text{or} \quad I = V/R$$

V = Potential difference (volts
I = current (ampere)
R = resistance (ohms)
L = thickness (mm)
A = area (mm^2)
K = thermal conductivity (W/mk)
T = temperature
Q = heat flow

Comparing

$$Q = [KA\ (T_1 - T_2)]/L \quad \text{AND} \quad V = IR$$

Q is analogous to I
T_1 - T_2 is analogue to V
Q = [KA ($T_1 - T_2$)]/L AND I = V/R
[KA/L = I/R

ΔT = Temperature change (k)
For the 3 walls
$Q = K1\ A(T_1 - T_2)/\ \Delta X1 = K_2A\ (T_2 - T_3)/\ \Delta X2 = K_3A\ (T_3 - T_4)\ \Delta X_3$
$Q/A = K_1\ (T_1 - T_2)\ DX1 = K_2\ (T_2 - T_3)/DX_2 = K_3\ (T_3 - T_4)/DX_3$

Mathematically,
$T_1 - T_4 = (T_1 - T_2) + (T_2 - T_3) + (T_3 - T_4)$
$T_1 - T_4 = Q\Delta X_1/AK_1 + Q\Delta X_2/AK_2 + Q\Delta X_3/AK_3$
$T_1 - T_4 = Q/A\ [\Delta X1K1 + \Delta X_2/K_2 + \Delta X_3/K_3]$
$Q = A\ [T_1 - T_4]/\ [\Delta X_1/K_1 + \Delta X_2/K_2 + \Delta X_3/K_3]$

Control temperature in any heat transfer system will be the environment or ambient temperature. There must be a temperature difference between the surface and its surroundings if there is to be any heat transfer [second law of thermodynamics] provided heat transfer Q passes through the wall, then Q passes through each layer of the wall.

T_1 = Temperature of the oven (k)
R = L/[KA]
Q = $(T_1 - T_2)/R$

Assuming steady heat flow in the oven with close system using Fourier's law of conduction based on the design temperature considering the composite wall in the figure above, in which there are three layers. If Q (w) passes through these walls then the same quantity to heat Q (w) passes through each layer of the wall.

Q = KA[AT/AX]

Where
Q = heat transfer (J/S or W)
K = thermal conductivity (W/mk)
A = area of solid material (m^2)
ΔX_1 = thickness of the material (m)

T_2 = Interface temperature (k)
T_3 = Interface temperature (k)
T_4 = exit face temperature (k)
T_5 = ambient temperature (k)

Calculation of the surface is as follows:
$Q = h_0A\ (T_1 - T_2) = haA\ (T_4 - T_5)$ .... (ii)
h_0 = convective heat transfer coefficient of the fluid inside the oven
ha = convective heat transfer coefficient of the atmosphere air
For this walls
Q = $h_0A\ (T_1 - T_2)$ .... (iii)
Q = $K_1A\ (T_2 - T_3)/\ \Delta X_1$ .... (iv)
Q = $K_2A\ (T_3 - T_4)/\ \Delta X_2$ .... (v)
Q = $K_3A\ (T_4 - T_5)\ \ \Delta X_3$ .... (vi)
Q = $haA\ (T_5 - T_6)$ .... (vii)

Transforming these equations we have
$T_1 - T_2 = Q/h_0A$ .... (viii)
$T_2 - T_3 = Q\Delta X_1/K_1A$ .... (ix)
$T_3 - T_4 = Q\Delta X_2/K_2A$ .... (x)
$T_4 - T_5 = Q\Delta_3/K_3A$ .... (xi)
$T_5 - T_6 = Q/ha\ A$ .... (xii)

Adding all equations

$(T_1 - T_6) = (T_1 - T_2) + (T_2 - T_3) + (T_3 - T_4) + (T_4 - T_5) + (T_5 - T_6)$

$(T_1 - T_6) = Q/h_0A + QDX_1/K_1A + ODX_2/K_2A + ODX_3/K_3A\ Qha/A$

$(T_1 - T_6) = Q/A[1/h_0 + \Delta X_1/K_1 + \Delta X_2/K_2 + \Delta X3/k3 + 1ha]$

$A(T_1 - T_6) = Q[1/h_0 + \Delta X_1/k1 + \Delta X_2 + \Delta X_3/k_3 + 1/ha]$

$Q = [A(T_1 - T_6)]/1h_0 + \Delta X_1/K_1 + \Delta X_2/k_2 + \Delta X_3/k_3 + 1/ha]$

But

$1/[1/h0 + +\Delta X_1k_1 + +\Delta X_2/k_2 + +\Delta X_3/k_2 + 1ha] = U$

Therefore,

Q	=	$AU(T_1 - T_6)$
T_1	=	temperature of the oven
T_6	=	ambient temperature

Assuming the maximum temperature for the designed oven = 250^0C

Ambient temperature = 38^0C

Amount of heat retained in the oven = amount of heat generated - total heat lost

Amount of heat generated = total heat lost + amount retained in the oven

Q = $AU(T_1 - T_6)$ (Mizushina, Ito, and Miyashita, 1968)

$1/[1/h0 + \Delta X_1/k_1 + \Delta X_2/k_2 + \Delta X_3/k_3 + 1/ha] = U$

h_0	=	convective heat transfer coefficient of the oven/inside wall
ha	=	convective heat transfer coefficient of the atmosphere air/outside wall
ΔX_1	=	thickness of inner wall
ΔX_2	=	thickness of outside/insulator
ΔX_3	=	thickness of outer wall
K_1	=	thermal conductivity of inner wall
K_2	=	thermal conductivity of outside wall
K_3	=	thermal conductivity of outer wall
T_1	=	temperature of the oven
T_6	=	ambient temperature

h_0	=	2.5W/m2k
ha	=	3.1W/m2k
K_1	=	K_2 = 45W/mk
ΔX_1	=	$\Delta X_3 = 2 \times 10^{-3}$ (mm)
ΔX_2	=	$5 X 10^{-3}$ (mm)

Then

U	=	$1/[1/h_0 + \Delta X_1/k1 + \Delta X_2/k_2 + \Delta X_3/k_3 + 1ha]$
U	=	1/1/(2.5) + (2 x 10-3/45) + (5 x 10-3/0.04) + (2 x 10-3/45) + 1/3.11
U	=	$1/(0.4) + (4.44 \times 10^{-5}) + (0.125) + (4.44 \times 10^{-5}) + (0.322)$
U	=	1/[0.8470888]
U	=	1.1805W/m2 k

Oven walls

A	=	Length x breadth
A	=	L x B
T1	=	2500C = 523K
T6	=	380C = 311K

A = 1.25 X 0.85 = 1.0625m2
QL = AU (T1 - T6)
QL = 1.0625 x 1.1805 x (523 - 311)
QL = 265.908Watts

For two Walls
QL_1 = QL x 2
QL_1 = 265.908 x 2
QL_1 = 531.815Watts
Since,
QL = AU (T1 - T6)
A = (0.85 x 0.55)m2
A = 0.4675m2

QL = 0.4675 x 1.1805 (523 x 311)
QL = QL x 2
$Q_{1,2}$ = 116.999 x 2
QL_2 = 233.999Watt
QLT = Total heat lost in the oven
QLT = QL_1 + QL_2
QLT = 531.815 + 233.999
QLT = 765.814Watts

It shows that 765.814W quantity of heat were lost per second.
Therefore, the quantity of heat lost for 30 x 60 = 1800s

= 765.814 x 1800J/s
= 1378465.2J/s
= 1378.465KJ/s

4.2.5 Cost Analysis
If the multipurpose cooker were to be constructed, Table 4.1 shows its cost analysis

Table 4.1 Cost Analysis

S/N	ITEMS	QUANTITY	UNIT PRICE (₦)	TOTAL PRICE (₦)
1.	Mild steel for outer walls and inner walls (gauge 20)	4sheets	2,500	10,000
2.	Thermostat control	3	1,000	3,000
3.	Surface hot plate for cooking	Medium -800 Large - 600	1,400	1,400
4.	Oven hot element for baking (medium)	1	1,400	1,400
5	Gas burner for cooking	2	400	800
6	Gas burner for Oven	1	400	400
7.	Pressurized kerosene burner for cooking	1	750	750
8.	Pressurized kerosene burner for Oven	1	750	750
9.	Electrode	1packet	1,500	1,500
10.	Pressurized kerosene tank	1	1,500	1,500
11.	Control knob	7	300	2,100
12.	Control valves for Gas cooker	4	300	1,200
13.	Control valves for pressurized kerosene cooker	4	300	1,200
14.	Fibre glass for insulation	3rolls	2,500	7,500
15.	Paint	1 Tin	1,500	1,500
16.	Socket and electric cable	1 and 2 yards	800	800
17.	¾ Rubber hose for gas cooker/oven	2yards	300	600
	TOTAL MATERIAL COST			37,150

Material cost = ₦37,150
Labour cost = 10% of materials cost
= 10/100 x 37,150 = ₦3,715
Overhead cost = 15% of material cost
= 15/100 x 37,150 = ₦ 5,573
Gain = 10% of material cost

	=	10/100	x 37,150	=	₦3,715

Total cost = Labour cost + Overhead cost + Gain + Material cost
Total cost = 37,150 + 3,715 + 5,573 + 3,715
Total cost = ₦ 50,155

V. CONCLUSION

Cooking apparatus in Nigeria today comprises of both the locally fabricated cookers and the imported cookers. Most of the cookers can only use one heat source as such, Nigerians are forced have more than one cooker with different heat sources in their homes. This design do not only put an end to this scenario but also make it possible for homes to save money meant to buy individual cooker of different source of heat. The design combines four heat sources of power to a single cooker. This design takes advantage of electricity, kerosene, gas and charcoal hence eliminating the possession of more than one cooking apparatus at a time. It is also cost effective since it cost cannot exceed sixty thousand naira.

VI. RECOMMENDATION

Since power failure and unavailability of energy source are the leading factor in Nigeria, this project is thereby commended for domestic use and mass production thereby creating employment and solving the problem of dilemma of no fuel for cooking in days of scarcity of any of the four sources.

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