Journal of Scientific Research & Reports

27(8): 65-85, 2021; Article no.JSRR.72595
ISSN: 2320-0227

Design, Construction and Performance Evaluation of a Dual-Powered Cooker

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JSRR/2021/v27i830427
Editor(s):
(1) Dr. José Alberto Duarte Moller, Universidad de LaSalle Bajio, Mexico.
Reviewers:
(1) Soma Ghosh, India.
(2) Ahmad Zaidi Abdullah, Malaysia.
(3) Yanawati Binti Yahya, University Kuala Lumpur (UniKL), Malaysia.
Complete Peer review History: https://www.sdiarticle4.com/review-history/72595

Original Research Article

Received 05 June 2021
Accepted 18 August 2021
Published 18 September 2021

ABSTRACT

A dual-powered cooker is a combination of components that makes possible the use of alternative heat sources. Due to the irregular power supply common in developing countries, as well as the growing high cost of hydrocarbon fuel sources, the need arises for the development of a dual energy source that uses both electricity and gas for heating and cooking. The aim of this research work is to design, construct and carry out a performance evaluation of a dual-powered cooker.
The materials for the research work were locally sourced and selected based on suitability in reference to the design requirement of the cooker. The cooker consists of two divisions, each fitted with a burner operating on distinct energy sources, electricity and gas. Within the electric burner is a heating element that generates and dissipates heat across a hotplate. On the other hand, cooking gas is supplied to the burner located at the other segment of the cooker via a threaded pipe connection to a gas cylinder, secured unto a control mechanism that allows the burning rate to be varied progressively and continuously. The temperature of the water was allowed to synergize with the ambient temperature of the room before testing.
Several important findings can be drawn from this assessment. The gas cooker has a higher overall thermal efficiency between (57.50% [without lid] - 62.84% [with lid]) as opposed to

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the efficiency of its electric counterpart, which falls between (29.78% [without lid] - 39.12% [with lid]).
The dual-powered cooker was successfully designed, constructed and evaluated. The gas cooker has a higher efficiency than the electric cooker. Primarily, the gas cooker is at an advantage as it does not need to preheat or rely on power from an electric source subject to fluctuation in voltage before cooking, unlike the electric cooker; therefore, making it better at a wider range of cooking operations.It combines the best of gas and electric cookers. Gas hobs that are quick to heat up and easy to control, plus electric ovens with more accurate heat settings and multiple features.

Keywords: Performance evaluation; dual-powered cooker; electricity; gas; electric burner; cooking gas; temperature.

1. INTRODUCTION

Cooking or cookery is the art, technology, science and craft of preparing food for consumption [1]. Cooking requires various techniques depending on the heating energy commodities and sources, which include the use of solid fuels, electricity, liquid fuels, Liquefied Petroleum Gas (LPG) and so on. In order to achieve the effective use of any of these sources in the production of edible food, a sort of cooker or oven is required. About 40% of the world's population still uses solid fuels and kerosene, the burning of which has deleterious health, economic and environmental consequences [2-4]. Every year, up to four million people die prematurely from the effects of household air pollution caused by cooking with solid fuels—almost all of them in low- and middle-income countries [5].

A cooker is an appliance used for cooking food, typically consisting of an oven, hob and grill, powered by gas or electricity. There are essentially two types of cookers: the free-standing cooker, and the "separate hob and oven" cooker [6-9]. A free-standing cooker is one with the oven and hob together in one unit. It is the de-facto standard in most modern kitchens, while the "separate hob and oven" cooker is a configuration setting where the hob upon which consists of burners, either all electric; all gas; or a combination of both, is separated from the oven. Cookers can be broadly classified into three groups, fuel–based (solid or fluid), solar, and electric cookers [10-13].

Nowadays, environmental deterioration and global warming effects have drawn pressing concerns around the world. Actions for reducing the carbon footprint in people's daily life are highly advocated. The need to promote the use of clean cooking energy source as well as propagating safe and sustainable environment to cut down the number of human lives lost to the use of unsafe, inefficient and unhealthy cooking energy sources should be of utmost concern in the industries of today. Furthermore, the cooking process inevitably produces carbon dioxide (CO_2) and other chemical by-products that are unfriendly to the environment. This cooking mechanism is classified as an unsustainable energy processing and would, therefore, reduce greenhouse effects resulting from cooking.

The electrical cooker is an electric powered cooking device for heating, drying, cooking, baking and roasting. It works basically by the heating effect of electric current on conductors. Sometimes, this heating effect is an inevitable waste of power for instance, in the transmission of electricity on power lines in which the voltages at the terminals is evolved due to the heating of electric current [14,15]. Electric resistance heating, which is the principle of operation behind electric cookers, has various advantages over systems based on fuel combustion, such as better control accuracy, increased heating rate, and constant heat distribution over aperture surface. Thus, electrical heating constitutes a suitable choice for developing laboratory instruments, especially those demanding small heating volumes and precise temperature control. When combined with a stove employing another means of heat production (for example, LPG stove), an improved, more efficient system of cooking is introduced [16-18]. Such a combination of two or more energy sources is referred to as a combination stove, range or a dual-powered cooker. Electric Cooker provides better cooking and permits efficient use of electricity. It is quick to use, relatively quiet and devoid of any pollutant to the environment. Although, the electric cooker is both relatively cheap to purchase and maintain; its major advantage lies in cost effectiveness, as opposed to the gas cooker, which requires the replenishment of its fuel Its only major limitation is that it cannot be used where there is no electricity since it makes use of electrical energy.

A gas cooker is a stove which uses natural gas, propane, butane, liquefied petroleum gas (LPG) or other flammable gas as a fuel source. LPG is the most convenient and clean fuel for domestic use and is very popular these days [19,20]. The LPG stove industry is about 36 years old and is mainly concentrated in the small-scale sector. LPG is an exceptional energy source due to its origin, relative advantages and applications [21]. In theory, gas cookers do not have to heat a coil before cooking the contents within pot, which in turn makes it faster and most efficient than any electric resistance cooker for quick cooking tasks. However, electric cookers are slightly as efficient as gas cookers for long cooking tasks with higher power inputs (at a steady temperature rise). In those cases, the electric cooker has enough time to catch up without any fuel consumption.

Gas cookers provide quicker responses, faster heating for short tasks, easier cleanup, and better durability/ruggedness; while electric cooker guarantees a more accurate temperature target, temperature control, and better safety. Employing a dual-powered combustion cooker equipped with two distinct fuel sources can commendably constitute the following advantages: cost-effective, reliability, low-emitters, versatility and space-saving 26-28].

Researchers have worked extensively on the dual-powered cooker, improving upon the previous works of others and creating a more distinct blend of energy sources [22,23].

As a result, the aim of embarking upon this research work is to explore the possibility of creating an effective, yet, portable dual-powered cooker, constructed by making use of locally available materials, as well as evaluating its performance in relation to both environmental and systematic factors. Undoubtedly, this will go a long way in influencing the decisions behind cooker production quality control and usage.

2. RESEARCH METHODOLOGY

The importance emphasized in the design of the combined cooker is to accomplish a synergy between gas and electric energy sources without causing interference or heating of the carrier frame and damaging of the individual components attached herewith. The design intention was based on reduced cost and weight, compactness, durability, ease of mobility in transporting, and effective heating balance. Despite this, it was taking into consideration the material availability and suitability, strength of materials, reduced Green House Gas (GHG) emissions from the cooking mechanisms, as well as, possibility of promoting marketability.

2.1 Design Description

The cooker was designed such that the electrical source (heating element) and the gas source (gas burner) were incorporated into one frame to minimize wastage of material which would have been used to construct two different chambers for the two sources. Notable from the front, the gas burner is located to the left of the entire assembly while the electric cooker is placed to the right of the assembly, equipped with two heating elements, which are situated just beneath the metal spiral groove banded by a protective metal sheet covering the groove and heating element [24,25].

The frame of the cooker (Plate 1) is made up of mild-steel metal, which is coated to prevent corrosive substances from attacking the surface and to protect the metal from rusting. Within the compartment is sufficient space for aeration and heat dissipation within, serving as a means for electrical insulation away from the gas. The cooker design has a general outlook dimension of 460 mm x 250 mm x 220 mm (length × width × height). A gas port of radial diameter 20 mm is provided at the bottom of the cooker, connected to a pipeline through which Liquid Petroleum Gas (LPG) flows to the burner, lined along the frame of the burner to the gas cylinder. As shown in (Plate 1), the cooker frame is built high, extended above the ground such that the cooker compartment can be easily positioned firmly on any flat surface. The extension is kept at a height of 20 inches from the ground level to aid ease of use during cooking; allow the burner to receive enough oxygen from below; and give the pipe, linked to the gas tank, sufficient area of placemen.

2.2 Material Selection

A variety of factors were put into consideration in the design of the dual-powered cooker. The factors considered include ease of assembly of the parts; the size of the cooker; size and geometry of cooking container; heating temperature; space between each individual burner; time needed to cook; and cooking effect on the environment. The criterion for material selection (Table 1) was based on the distinct characteristics found in different types of iron accessible within the locality. Some of the characteristics considered include: durability, workability, high thermal resistivity, corrosion resistance, high creep resistance and malleability.

Plate 1, Working Assembly of the Dual-Powered Cooker

Table 1. Components used in the fabrication

S/N	Oven Component	Functions	Reason for Selection
1	Low-Carbon Steel(Gauge 16)	For the outer frame construction of the cooker	Availability and low cost
2	Rheostat	For the regulation of current inflow to the heating element	Availability
3	Three-pin plug	For the completion of the electrical circuit to a socket	Availability
4	Heating element	Converts electrical energy to heat energy needed for cooking	Availability suitability
5	Gas burner	For burning the hydrocarbon gas in heating the cooking container	Suitability
6	Gas hose	Connects the gas burner to the external gas cylinder	Resistivity to breakage and leakage
7	Stand (20inches angular steel iron)	For rigid support and suspension of the cooker for allowance of gas pipe.	Durability and High strength
8	Indicator light	It indicates when the electric portion of the cooker is in operation	Suitability
9	Gas valve control	Attached to the gas burner for adjustment of gas flow rate	Ease of handling
10	Spiral Groove	To serve as a protective metal sheet for the electric heating element	Consistent heat distribution
11	Camping gas pressure regulator	Serves as a link regulating the pressure of gas from the tank to the burner	Pressure control and Safety

2.3 Description of the Dual-Powered Cooker

The dual-powered cooker has heating units that use both gas and electric current to produce heat. The electric heating unit has an exterior shell in the form of a metal tube in two parts. Each section is shaped like a spiral and encases a coil of wire. Electricity travels through the coil, thereby heating the coil and the metal tube. The heat generated by the electric cook top unit is regulated by means of a rheostat to determine the amount of electric voltage that passes through the coil; in which case, the higher the voltage, the hotter the coil and the faster the rate of heating.

The gas unit comes fitted with a gas burner for maintaining a correct gas and air mixture for low-flame ignition. The gas burner includes a burner cap having a gas inlet and a plurality of gas outlets each having a predetermined diameter. The plurality of gas outlets is circumferentially spaced about a periphery of the cap and communicates with the gas inlet. The gas burner is further positioned at the centre of cooking grate, constituted of four angled metals, welded to the assembly frame spaced away from the burner; allowing the flame to spread out progressively across the utensil surface, heated by the gas flames emanating from the burner.

2.4 Principle of Operation

The electric cooker works on the principle of electric resistance. The resistance to current flow causes the heating element to be heated up. As soon as the switch is turned on, the indicator for the electric unit turns orange confirming the presence of current and indicating that the cooker is in operation. The heat generated by the heating element is dissipated over the surface of the utensil by means of conduction since it is in contact with the electric burner and by free convection, is transferred throughout the fluid content within the utensil. The rheostat attached to the electric cooker can be used to regulate current flow to the heating element in order to prevent excess heat and avoid burning.

In case of power failure, the cooker is disconnected from the power source and the gas can be used as an alternative heat source. The gas cooker works on a similar principle but uses a burner in place of an electric coil to heat the utensil. The utensil is, however, unable to establish a direct contact with the gas burner, rather it is placed resting on a grate. The gas burner is activated by the turning of a mechanical knob. Gas flows to the gas burner and is ignited manually by a lighter or matchstick. Heat energy is caused to escape around the spaces created just above the burner and circulates about the bottom of the cooking utensil. The mode of heat transfer is by radiation, rather than conductor; and convection. A pressure regulator is also incorporated to control the heat generation by regulating gas flow.

2.5 Heat Transfer Consideration

The major operational principle of the dual-powered (gas/electric) cooker is the process of heat transfer. Heat transfer tends to occur whenever there is a temperature difference. It is the movement of heat from hot surfaces to cooler surfaces.

Fig. 1. The Three Modes of Heat Transfer.

Taken from: Kosky, P., Balmer, R., Keat, W., and Wise, G. [26]. Mechanical Engineering. In P. Kosky, R. Balmer, W. Keat, and G. Wise, *Exploring Engineering* (3rd ed., pp. 259-281). Elsevier B. V. doi:10.1016/B978-0-12-415891-7.00012-1.

2.6 Conduction

Conduction transfers the heat using direct contact; food is heated directly in a metal pan, in a liquid, or surrounded by air. For steady conduction heat transfer through a flat plate or a plane wall, Fourier's law, according to [26], is given by:

$$Q_{cond} = -\frac{k_t A \Delta T}{\Delta x} = \frac{k_t A(T_{hot} - T_{cold})}{(X_{cold} - X_{hot})} \quad (1)$$

Where:

k_t = thermal conductivity of the material (W/mK)
ΔT = temperature difference between the metal surface
Δx = thickness of the plate or wall (m)
A= cross-sectional area perpendicular to the direction of heat transfer

2.6.1 Convection

Convection is the transfer of energy from one place to another by the motion of a mass of materials between the two points. The basic equation for the rate of convection heat transfer is known as Newton's Law of Cooling and for a flat plate, is given by:

$$Q_{conv} = hA(T_\infty - T_s) \quad (2)$$

Where:

T_∞ = bulk temperature of the surrounding fluid
T_∞ = surface temperature of the container
h = convective heat transfer coefficient in (W/m^2K)
A = surface area of the heated container

2.7 Design Calculation

The formulae that will be considered in the evaluation of the performance of the cooker include:

1. the quantity of heat required
2. the cooking power
3. the thermal efficiency
4. the heat intensity

2.7.1 Quantity of heat required to cook

This is defined as the energy required to raise the container medium from ambient to cooking temperature [27]. It is calculated using the following equation:

$$Q = m * C * (T - T_0) \quad (3)$$

Where:

T = average cooking temperature
m = mass of a cooking medium (1 kg | 1ltr)
C = specific heat capacity of the fluid (4.168 kJ/kgK)
T_0 = initial fluid temperature

2.7.2 The cooking power

The cooking power of the cooker can be calculated using the equation given by [28] as follows:

$$P = \frac{Tw_2 - Tw_1}{t} m_w C_{pw} \quad (4)$$

Where:

P = cooking power (Watt | J/s)
t = time taken (s)
m_w= mass of water (kg)
Tw_2= final water temperature (^oC)
Tw_1= initial water temperature (^oC)
C_{pw} = water heat capacity (4.168 kJ/kgK)

2.7.3 Thermal efficiency

The thermal efficiency of a burner is defined as the ratio of heat actually utilized to the heat theoretically produced by complete combustion of a given quantity of fuel (which is based on the net calorific value of the fuel). According to [29], the efficiency for a LPG stove can be calculated using the following equations:

$$\eta = 100 \times \frac{(m_w C_w + m_p C_p)}{m_f \times CV} \times (Tw_2 - Tw_1) \quad (5)$$

With regards the electric cooker, the thermal efficiency of a boiling-plate is defined by the ratio of the heat absorbed by the liquid heated, to the heat equivalent of the energy dissipated in the boiling plate, multiplied by 100. The energy analysis is however based on the principle of conservation of energy. In this regard, the input energy (E_{in}) to the surface heating element and the energy output (E_{out}) of the cooker to the container has to be determined. The thermal efficiency of the electric cooker would then result in:

$$\eta = \frac{E_{out}}{E_{in}} = \frac{m_f C_f \Delta T_f}{IV\Delta t} \quad (6)$$

Where:

P = the cooking power
η = thermal efficiency of a cooker (%)
m_w= mass of cooking fluid (1 kg)
m_p= mass of cooking pot with lid (kg)
CV = calorific value (45780 kJ/kg)
I = current flowing through the coil (9 A)
V = electric potential difference (220 v)
C_p=specific heat of CO_2 gas at constant pressure (0.8956 kJ/kgK)
C_f = specific heat capacity of cooking fluid (4.168 kJ/kgK)
G = maximum heat intensity of the burner surface (W/m^2)
ΔT_f= difference between the final and initial water temperature.
Δt = period of time required to achieve the desired temperature

2.7.4 The Heat Intensity

The heat intensity of the cooker can be calculated using the equation:

LPG Stove: $I = \frac{P}{\pi(R_1^2 - R_2^2)} = \frac{p}{8.168 \times 10^{-3}}$ (7)

Electric Cooker: $I = \frac{P}{\pi R^2}$ (8)

Where:

I = heat intensity (kW/m^2)
P = cooking power (Watt | J/s)
πr^2 = surface area of electric cooker (r: 0.085 m | Area = $8.168 \times 10^{-3} m^2$)
R_1 = outer radius of gas burner (0.075 m)
R_2= outer radius of gas burner (0.055 m)

2.8 Experimental Procedure

The performance evaluation of the cookers was carried out using a typical water boiling test (WBT). At room condition, maintained at between 30°C from 35°C, the test was carried out by boiling a liter of water in a pot covered with a lid. The procedure was replicated thrice and the time taken for the completion of the process was determined with the aid of a stop watch. The effect of boiling was determined by observing bubbling and steam rising from the boiling water. The pot was placed in direct contact with the electric stove (with a power rating of 2000 W) and a working condition of 900W, while the gas cooker shot beneath the pan, jets flames emanating from 75 (15 x 5) distinct ports. A pressure regulator was placed between the gas tank and the gas valve to maintain the pressure at which gas entered into the stove.

3. RESULTS AND DISCUSSION

For this study, three separate observations were taken for the two distinct burners, gas and electric, employing two different kinds of reading modes. The first reading mode involved each burner type heating the pot with its lid removed (Open System Condition) and the other reading mode was carried out with the lid intact (Closed System Condition). This was carried out in this manner to observe the difference in the time taken to boil the specified amount of water and the effect it has on the efficiency of the individual burners. The following results were obtained from the experimental approach.

3.1 Evaluation of the Gas Cooker

From Table 1 above, Observation A has a cooking power of 601.49W, heat intensity of $73.64 kW/m^2$, and an efficiency of 63.19%; Observation B has a cooking power of 605.61W, heat intensity of $74.14 kW/m^2$ and an efficiency of 62.57%; and to Observation C has a cooking power of 601.81W, heat intensity of $73.68 kW/m^2$ and an efficiency of 62.77%. The results reveal that as the cooking power increases, so does the intensity of the heat produced. It also indicates that a higher cooking power, would result in lesser efficiency of the cooker.

Table 1. Gas burner (Observation sheet A) – with lid

Observation	Value	SI Unit
Experiment time	03:43	p.m.
Quantity of heat required	253.83	kJ
Ambient Air Temperature (Final)	45	^oC
Volume of Water	1	Litre
Weight of Pot (with lid)	0.65	kg
Initial Temperature of Water	30.6	^oC
Boiling Temperature of Water	91.5	^oC
Time taken to boil	422	s

Table 2. Gas burner (Observation sheet B) – with lid

Observation	Value	SI Unit
Experiment time	03:51	p.m.
Quantity of heat required	251.33	kJ
Ambient Air Temperature (Final)	43	^oC
Volume of Water	1	Litre
Weight of Pot (with lid)	0.65	kg
Initial Temperature of Water	30.9	^oC
Boiling Temperature of Water	91.2	^oC
Time taken to boil	415	s

Table 3. Gas burner (Observation sheet C) – with lid

Observation	Value	SI Unit
Experiment time	04:00	p.m.
Quantity of heat required	252.16	kJ
Ambient Air Temperature (Final)	44.5	^oC
Volume of Water	1	Litre
Weight of Pot (with lid)	0.65	kg
Initial Temperature of Water	30.4	^oC
Boiling Temperature of Water	90.9	^oC
Time taken to boil	419	s

Table 4. Gas burner (Observation sheet G) – without lid

Observation	Value	SI Unit
Experiment time	04:45	p.m.
Quantity of heat required	247.16	kJ
Ambient Air Temperature (Final)	49	^oC
Volume of Water	1	Litre
Weight of Pot (without lid)	0.30	kg
Initial Temperature of Water	30.4	^oC
Boiling Temperature of Water	89.7	^oC
Time taken to boil	568	s

Table 5. Gas burner (Observation sheet H) – without lid

Observation	Value	SI Unit
Experiment time	04:56	p.m.
Quantity of heat required	246.33	kJ
Ambient Air Temperature (Final)	48.7	^oC
Volume of Water	1	Litre
Weight of Pot (without lid)	0.30	kg
Initial Temperature of Water	30.5	^oC
Boiling Temperature of Water	89.6	^oC
Time taken to boil	565	s

Table 6. Gas burner (Observation sheet I) – without lid

Observation	Value	SI Unit
Experiment time	05:08	p.m.
Quantity of heat required	248.41	kJ
Ambient Air Temperature (Final)	49.1	^oC
Volume of Water	1	Litre
Weight of Pot (without lid)	0.30	kg
Initial Temperature of Water	30.3	^oC
Boiling Temperature of Water	89.9	^oC
Time taken to boil	572	s

Table 7. Gas burner performance (with lid)

Quantity	Parameter		
Cooking power (J/s | W)	601.49	605.61	601.81
Heat Intensity (kW/m2)	73.64	74.14	73.68
Efficiency (%)	63.19	62.57	62.77
Area of Gas Burner (m2)	8.168 x 10-3		

Table 8. Gas burner performance (without lid)

Quantity	Parameter		
Cooking power (J/s | W)	435.14	435.98	434.28
Heat Intensity (kW/m^2)	53.27	53.38	53.17
Efficiency (%)	57.47	57.28	57.76
Area of Gas Burner (m^2)	8.168 x 10^{-3}		

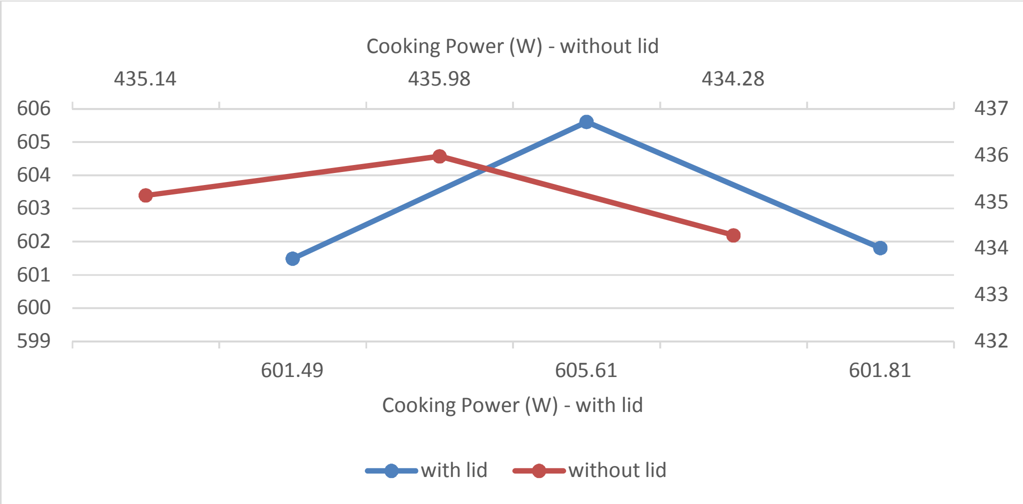

Fig. 1. Cooking power of the gas burner

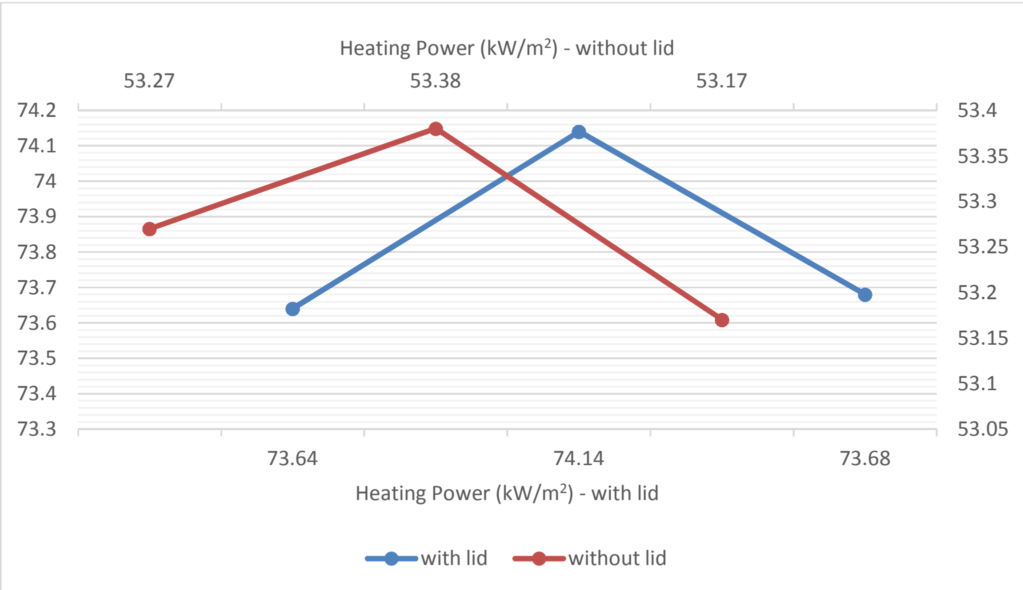

Fig. 2. Heat intensity of the gas burner

From Table 2 above, Observation G has a cooking power of 435.14W, heat intensity of 53.27kW/m^2, and an efficiency of 57.47%; Observation H has a cooking power of 435.98W, heat intensity of 53.38kW/m^2 and an efficiency of 57.28%; and to Observation I has a cooking power of 434.28W, heat intensity of 53.17kW/m^2 and an efficiency of 57.76%. The results support the earlier stated note, that the higher the cooking power, the higher the heat intensity and the lower the efficiency of the gas burner in use.

From the Figs. 1, 2 and 3 above, it can be observed that letting the cooking process to run in the form of a closed system, wherein the pot is covered with a lid, as opposed to an open system, wherein the pot is placed without a lid, has a significant influence in both the cooking power, heat intensity and the efficiency of the stove, in relation to the time used in achieving the required temperature.

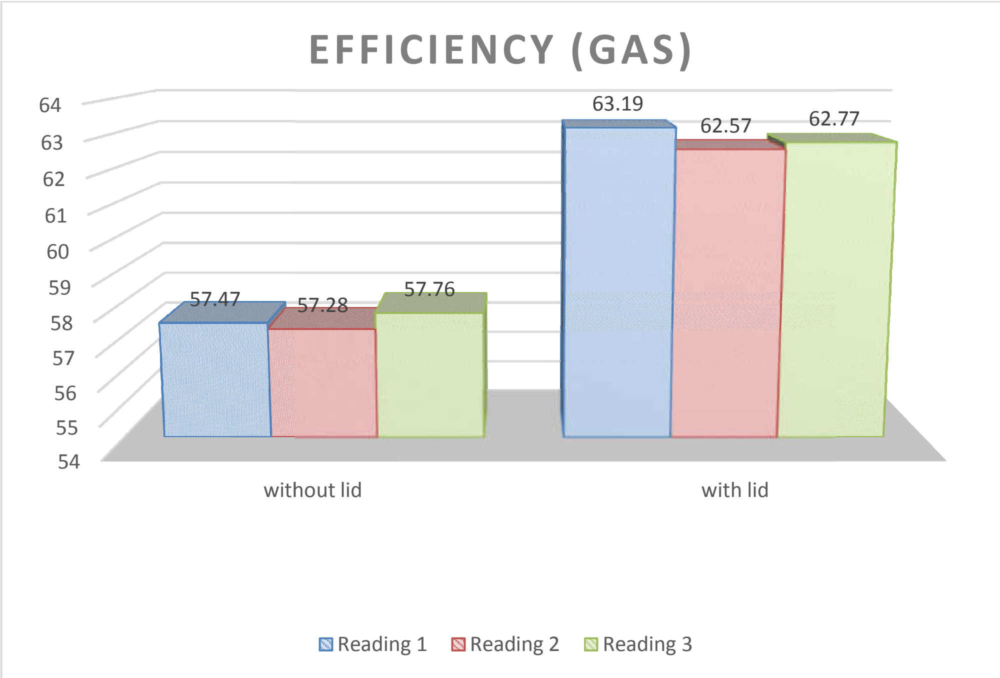

Fig. 3. Efficiency of the gas burner

Table 9. Electric cooker face I (Observation Sheet D) – with lid

Observation	Value	SI Unit
Experiment time	04:09	p.m.
Quantity of heat required	248.83	kJ
Ambient Air Temperature (Final)	40	°C
Volume of Water	1	Litre
Weight of Pot (with lid)	0.65	kg
Initial Temperature of Water	30.6	°C
Boiling Temperature of Water	90.3	°C
Time taken to boil	714	s

Table 10. Electric cooker face II (Observation sheet E) – with lid

Observation	Value	SI Unit
Experiment time	04:21	p.m.
Quantity of heat required	246.33	kJ
Ambient Temperature (Final)	39	°C
Volume of Water	1	Litre
Weight of Pot (with lid)	0.65	kg
Initial Temperature of Water	31	°C
Boiling Temperature of Water	90.1	°C
Time taken to boil	703	s

Table 11. Electric cooker face I (Observation sheet F) – with lid

Observation	Value	SI Unit
Experiment time	04:25	p.m.
Quantity of heat required	245.08	kJ
Ambient Air Temperature (Final)	37	^oC
Volume of Water	1	Litre
Weight of Pot (with lid)	0.65	kg
Initial Temperature of Water	30.8	^oC
Boiling Temperature of Water	89.6	^oC
Time taken to boil	686	s

Table 12. Electric cooker face II (Observation Sheet J) – without lid

Observation	Value	SI Unit
Experiment time	05:20	p.m.
Quantity of heat required	234.66	kJ
Ambient Air Temperature (Final)	43	^oC
Volume of Water	1	Litre
Weight of Pot (without lid)	0.30	kg
Initial Temperature of Water	30.6	^oC
Boiling Temperature of Water	86.9	^oC
Time taken to boil	884	s

Table 13. Electric cooker face I (Observation sheet K) – without lid

Observation	Value	SI Unit
Experiment time	05:36	p.m.
Quantity of heat required	233.41	kJ
Ambient Temperature (Final)	42.6	^oC
Volume of Water	1	Litre
Weight of Pot (without lid)	0.30	kg
Initial Temperature of Water	30.5	^oC
Boiling Temperature of Water	86.5	^oC
Time taken to boil	861	s

Table 14. Electric cooker face II (Observation sheet L) – without lid

Observation	Value	SI Unit
Experiment time	05:50	p.m.
Quantity of heat required	234.24	kJ
Ambient Air Temperature (Final)	42.9	^oC
Volume of Water	1	Litre
Weight of Pot (without lid)	0.30	kg
Initial Temperature of Water	30.2	^oC
Boiling Temperature of Water	86.4	^oC
Time taken to boil	875	s

Table 15. Electric cooker performance (with lid)

Quantity	Parameter		
Cooking power (J/s | W)	348.50	350.39	357.26
Heat Intensity (kW/m^2)	15.35	15.44	15.74
Efficiency (%)	38.72	38.93	39.70
Area of Gas Burner (m^2)	0.0227		

Table 16. Electric cooker performance (without lid)

Quantity	Parameter		
Cooking power (J/s | W)	265.45	271.09	267.70
Heat Intensity (kW/m^2)	11.69	11.94	11.79
Efficiency (%)	29.49	30.12	29.74
Area of Gas Burner (m^2)	0.0227		

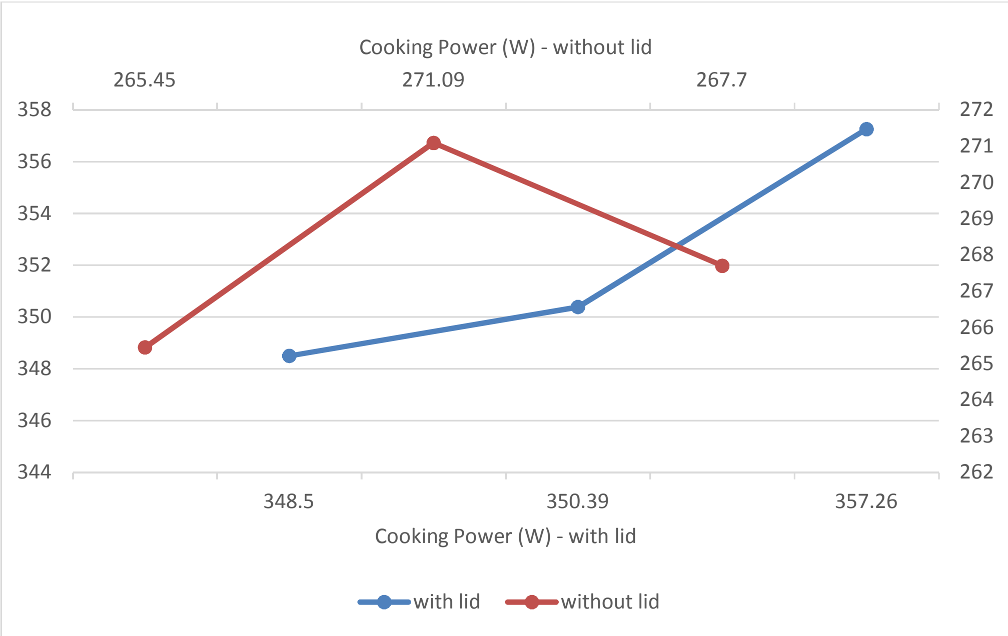

Fig. 4. Cooking power of the electric cooker

Fig. 5. Heat intensity of the electric cooker

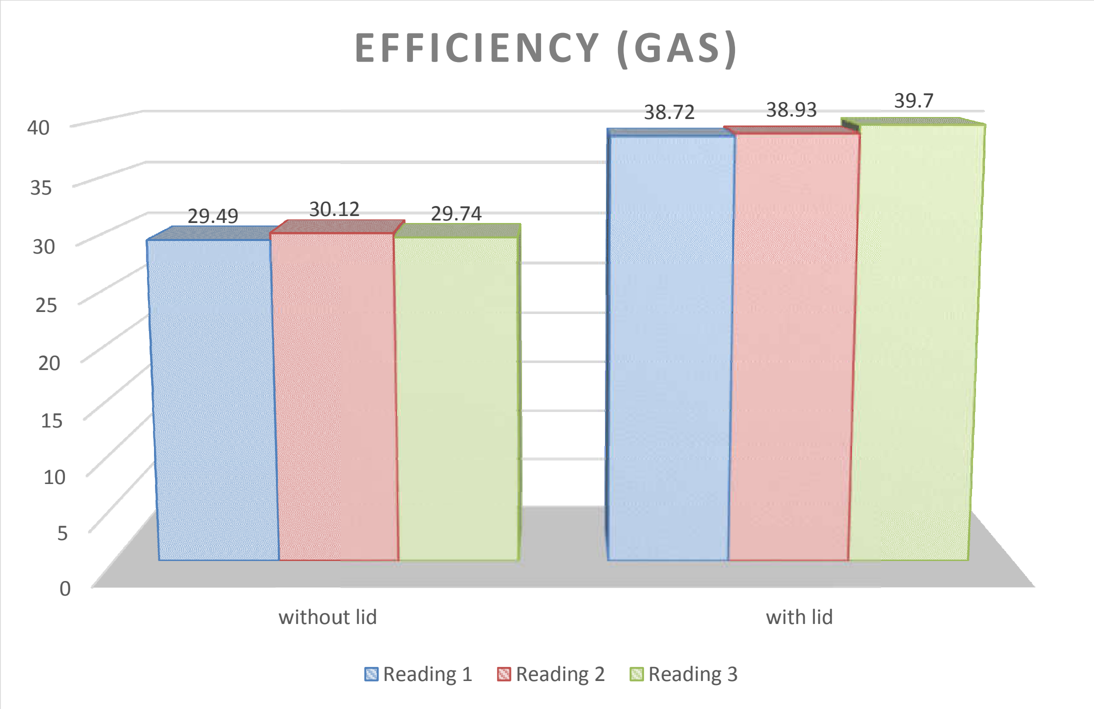

Fig. 6. Efficiency of the Gas Burner

3.2 Evaluation of the Electric Cooker

From Table 1 above, Observation D has a cooking power of 348.50W, heat intensity of 15.35kW/m^2, and an efficiency of 38.72%; Observation E has a cooking power of 350.39W, heat intensity of 15.44kW/m^2 and an efficiency of 38.93%; and to Observation F has a cooking power of 357.26W, heat intensity of 15.74kW/m^2 and an efficiency of 39.70%. The results reveal that the higher cooking power, the greater the intensity of the heat produced. It also indicates that the higher the cooking power, the lesser the efficiency of the cooker.

From Table 2 above, Observation J has a cooking power of 265.45W, heat intensity of 11.69kW/m^2, and an efficiency of 29.49%; Observation K has a cooking power of 271.09W, heat intensity of 11.94kW/m^2 and an efficiency of 30.12%; and to Observation L has a cooking power of 267.20W, heat intensity of 11.79kW/m^2 and an efficiency of 29.74%. The results support the earlier stated note, that the higher the cooking power, the higher the heat intensity and the lower the efficiency of the electric cooker in use.

From the Figs. 4, 5 and 6 above, it can be observed that letting the cooking process to run in the form of a closed system, wherein the pot is covered with a lid, as opposed to an open system, wherein the pot is placed without a lid, has a significant influence in both the cooking power, heat intensity and the efficiency of the stove, in relation to the time used in achieving the required temperature.

Table 17, Efficiency of the gas burner

Condition	With lid		Without lid	
	Efficiency	Time taken	Efficiency	Time taken
Reading 1	63.19	422s	57.47	568s
Reading 2	62.57	415s	57.28	565s
Reading 3	62.77	419s	57.76	572s
Average	62.84	418.67s	57.50	568.33s

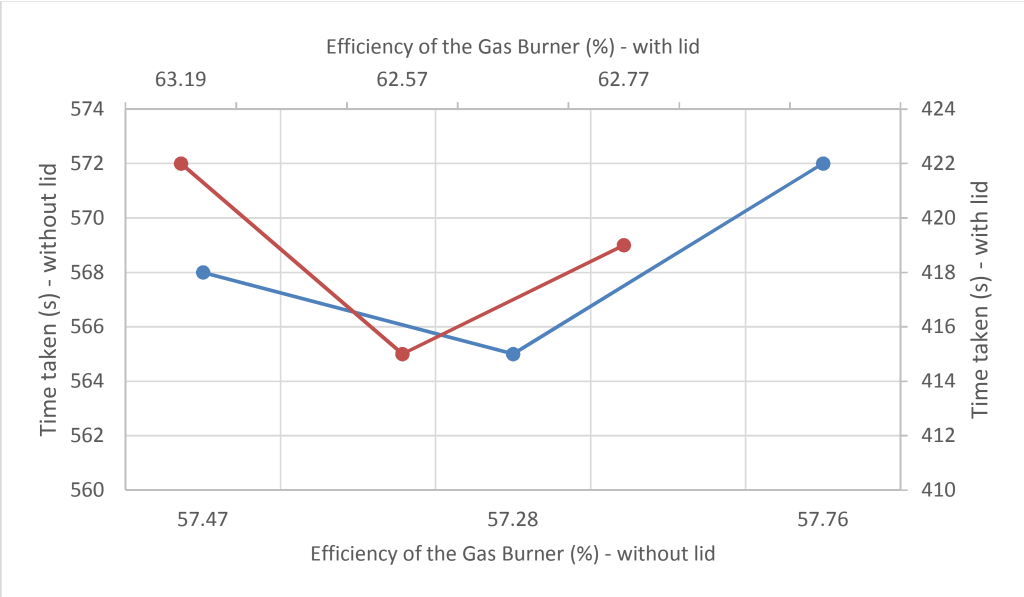

Fig. 7. Efficiency of the gas burner against time

Table 18. Efficiency of the electric cooker

Condition	With lid		Without lid	
	Efficiency	**Time taken**	**Efficiency**	**Time taken**
Reading 1	38.72	714s	29.49	884s
Reading 2	38.93	703s	30.12	861s
Reading 3	39.70	686s	29.74	875s
Average	39.12	701s	29.78	873.33s

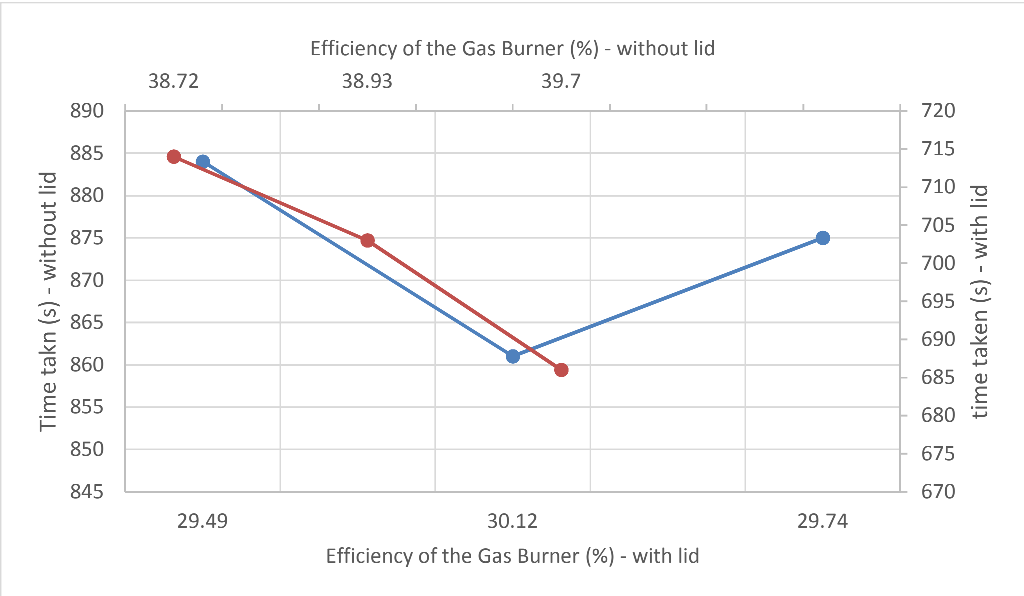

Fig. 8. Efficiency of the electric cooker against time

3.3 Efficiency of the Dual-Powered Cooker

From Table 17 above, the average efficiency of the gas cooker is 62.84% at an average time of 418.67s when the pot is closed, and 57.50% at an average time period of 568.33s when the water in the pot is cooked without a lid. Furthermore, Table 18 above gives the average efficiency of the electric cooker to be 39.12% at an average time of 712s when the lid of the pot is intact, and an efficiency of 29.78% at an average time period of 873.33s. From the two results, we can deduce that a pot lid plays an active role in both the efficiency of a cooking stove, as well as, the time it would take to have the contents of the pot arrive at the required temperature. Additionally, this results shows that the gas cooker is more efficient than the electric cooker, with or without a lid, especially when the power input into the electric cooker is a factor under consideration.

Table 19. Dual-powered cooker performance summary

	Gas Burner			Electric Cooker		
Parameter	**Water Boiling Test (with lid)**					
Qty of water (l)	1.0	1.0	1.0	1.0	1.0	1.0
Wind effect	**Stable heating rate throughout the evaluation period**					
Heating Temp.	738°C – 855°C			347°C – 404°C		
Efficiency with lid (%)	63.19	62.57	62.77	38.72	38.93	39.70
Efficiency without lid (%)	57.47	57.28	57.76	29.49	30.12	29.74
Method of observation	Water bubbling and steaming indicates boiling					

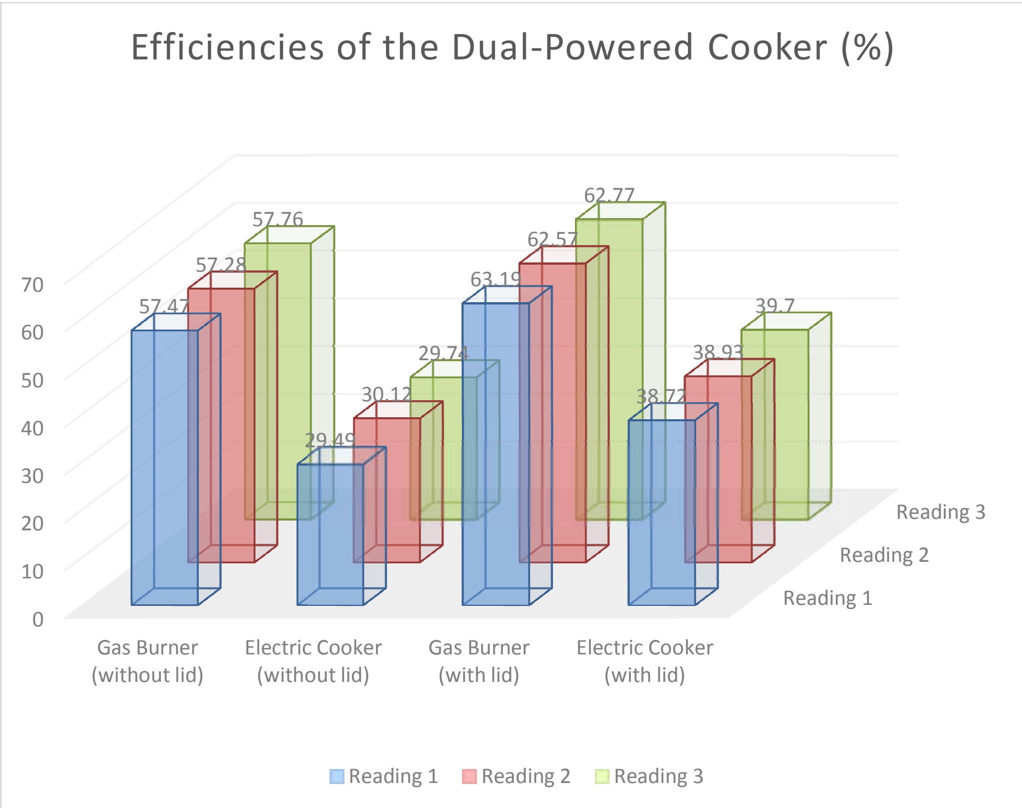

Fig. 9. Various efficiencies of the dual-powered cooker

4. CONCLUSION

The dual-powered cooker was successfully designed, constructed and evaluated. According to the obtained results from its performance evaluation, the gas cooker has a higher efficiency than the electric cooker. In this case, it is understood that several factors could constitute such results. Among these factors include:

i. The power input and output of the cooker
ii. The temperature at which the heat produced
iii. The intensity of heat towards the pot
iv. The time required for the element to heat up before dissipating the heat produced to the body of the pot and its content

Primarily, the gas cooker is at an advantage as it does not need to preheat or rely on power from an electric source subject to fluctuation in voltage before cooking, unlike the electric cooker; therefore, making it better at a wider range of cooking operations. However, Dual fuel ranges feature a gas cook top and an electric oven, taking advantage of the strengths of both. Gas cook tops offer immediate heat and improved temperature control versus traditional electric cook tops. Electric ovens evenly distribute heat, making them ideal for baking.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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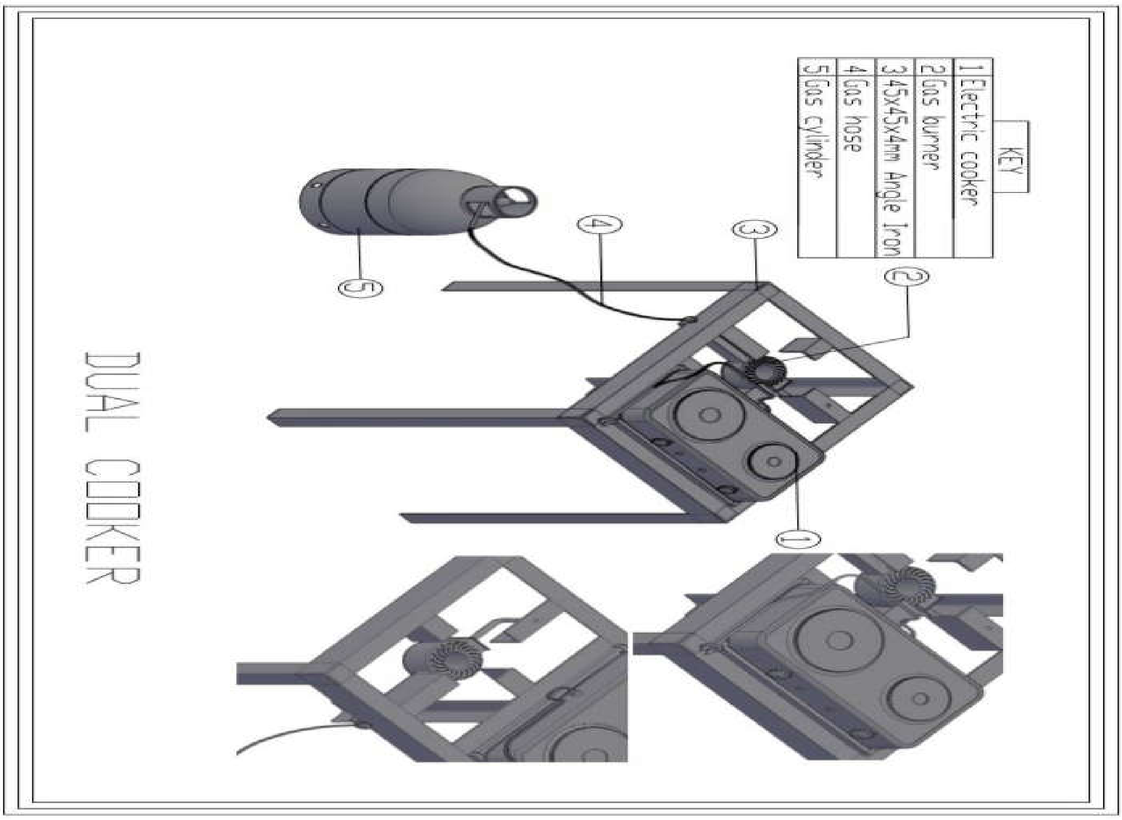
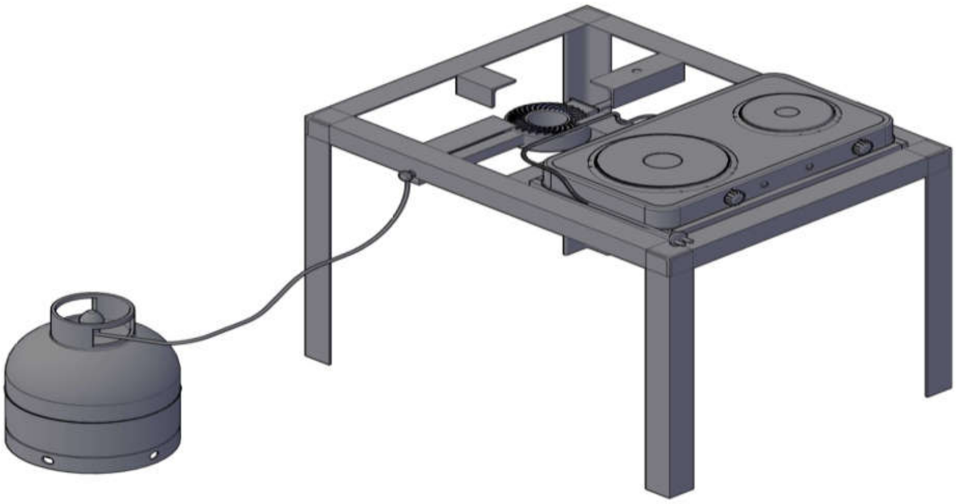
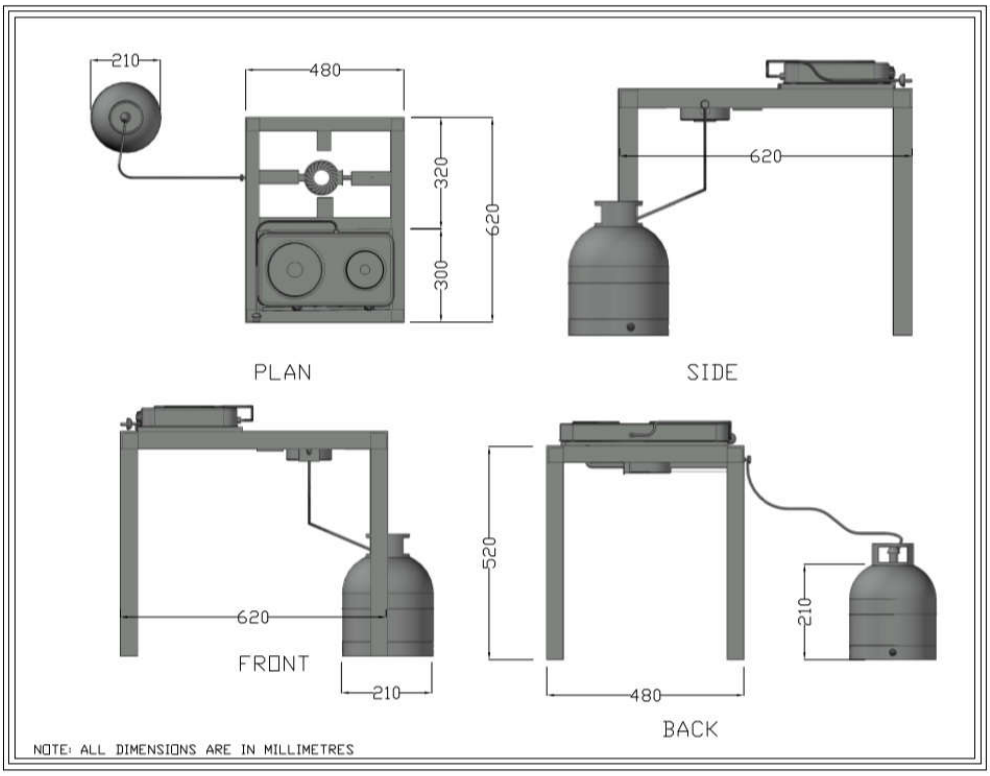
APPENDIX



KEY
1 Electric cooker
2 Gas burner
3 45x45x4mm Angle Iron
4 Gas hose
5 Gas cylinder
DUAL COOKER




210
480
320
620
300
PLAN
620
SIDE
620
FRONT
210
520
210
480
BACK
NOTE: ALL DIMENSIONS ARE IN MILLIMETRES

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Peer-review history:
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