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DEVELOPMENT OF A RENEWABLE ENERGY BARBECUE GRILLING MACHINE

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Abstract: This paper presents the development of a renewable energy barbecue grill. The grill produces the heating effect required for grilling meat/fish by using a clean and renewable energy source (solar energy) for the electricity supplied. The portable grill was developed to replace fossil fuel burning grills. Burning of fossil fuel is usually associated with high energy cost, emission of greenhouse gases and choking effect felt by the grill operator as a result of smoke inhalation from the grill. The renewable energy barbecue grill is made with 12 volts dc heating element, a temperature sensor, an Arduino Uno module, 30 A, 12/24 V solar charge controller, 120 AH 12 V battery and two 160 W solar panel modules. Analysis and sizing of the grilling machine heating element, battery and the solar panel are presented in this paper. Solar energy incidents on the solar panel which produces direct current that flows from the Solar PV panels through the wiring systems into the battery through a charge controller. The charge controller prevents over charging/discharging of the battery and also prevents current in the battery from flowing back to the solar panel at night or when there is no charging from the Solar Panels. The current then flows into the heating element from the battery through connecting wires and it generates the heat required for grilling of the food item. An experiment was performed to observe the grilling of the food item. It was observed that the grilling operation was carried out in about fifty minutes which makes this device to be highly efficient. It is concluded that this device can replace the conventional fossil fuel barbecue grills especially in regions of high solar insolation
Keywords: Arduino Uno, Barbecue, Heating Element, Grilling, Renewable Energy, Solar PV Panel

INTRODUCTION

Grilling involves applying significant amount of direct and radiant heat to the surface of the food in order to roast it. The device that is used for grilling is called a grill or a grill pan. Grilling is a type of cooking method that has existed in many parts of the world in the pre-colonial era. For over 500,000 years, mankind has been making use of fire to roast food. The early men roasted their meat on a wooden structure before consumption (Green, 2012). Direct heat grilling can subject the food to a temperature mostly above 250°C. Grilled meats also acquire a distinctive aroma because of chemical reaction known as maillard reaction in which the amino acids and sugars react together in the presence of heat (Schroder, 2003). Foods are grilled for their numerous advantages which include less fat than the conventionally cooked food which retains the fat which could be health hazard upon consumption. Also, the grilled food retains nutrient according to Wiggins, 2018 unlike being washed away in cooking. However, grilling has its own disadvantages as well. It can be affected by rain and dust if exposed. Also, cooking beef and some other food at very high temperatures can lead to formation of heterocyclic amines and some other compounds which are carcinogens (Williams, 2019). Various methods of grilling include the grid ironing which involves grilling of food using grill suspended above the heat surface; Charcoal kettle-grilling which uses charcoal fire as the source of heat; solar grilling; gas powered grills and so on. Renewable energy is energy that is obtained from renewable sources that can be replenished constantly. Examples of renewable energy sources are sunlight, wind, rain, tides, waves and geothermal. These sources can be harnessed and used in some engineering sectors such as electricity generation, cooling and heating of air and water, off-grid and transportation energy services (Sawin & Martinot, 2010). The use of renewable energy started about a million years ago before the development of coal in the 19th century. In those days, biomass was used to fuel fires, wind was harnessed to drive ships over water, etc. In 2017, renewable energy contributed 19.3% to human global energy consumption and 24.5% to the generation of electricity (United Nations, 2018). Lately, solar energy has been used more because of the recent increase in the cost of energy (Lynch, 2008). Photovoltaic cells were used to convert solar energy into electrical energy which is then used to power many electrical appliances. The type of current produced from the solar panel (photovoltaic cell) is a direct current and most appliances operate on alternating currents hence an inverter can be used to convert the current from DC to AC (Dave, 2019). A renewable powered barbecue grill is a device that harnesses solar energy to grill food. There are few methods in which this can be done. One method includes using solar collector and reflectors to focus beams of light on the focal point where the food to be grilled must have been positioned. This is a direct use of sunlight to grill. Another method is to use photovoltaic cells to power heating coils over the range of high temperature, the heating coils then radiate heat unto the food to be cooked which is an indirect use of sunlight. Advantage of the solar powered barbecue grill is that it integrates clean energy and reduce pollution that can be caused by coal fired grills, it is cheap, efficient and easy to use in the rural areas where other forms of energies especially grid lines are not readily available. Various grilling machines have been created in the past. They include the Gas grill, Charcoal grill, electric grills. The gas grilling machine is usually associated with high running cost in terms of energy source cost, high energy cost is associated with high running cost which could mean reduced profit for a businessman. According to

Harris (1999), the flavor is not as good as that of the charcoal due to the chemical composition of the gas, they also dry out the food which makes it tough as a result of the direct exposure of the food to extended application of flames. Also, when the piece of food falls on the fire from burner, flare-ups occur. These flare-ups are major source of fire accident and can be fatal, it can also cause overcooking of food or burning of food, hence there is need for constant monitoring of the grilling process. The smoke caused by the flare-ups also create harmful emissions and also make the food carcinogenic. (World Health Organization, 2015). The charcoal grill takes a long time before proper grilling, the temperature is harder to control, the ash is hard to deal with which makes it takes longer time to clean. and the costs of charcoal is high and it burns rapidly (Slater 2016). Burning of charcoal causes air pollution and causes emissions of some gases like CO_2 which are not environmentally friendly (Chafe, et al., 2016). Also, when oil from the food drops on the fire, flare - ups occur which have the same effects as that in gas grilling machine accidents can occur (World Health Organization, 2015). Electric grills mostly use ac electric current which can shock the operator and they consume very high amount of energy. Giguere & Thibodeau (1974) discovered that the electric heater generates too much heat when used indoor and they can cause fire accident when they come in contact with combustible materials. The aim of this paper is to present the development of a renewable energy barbecue grilling machine for grilling food items. The objectives of this paper include the design of a renewable energy powered barbecue grill and fabrication of the solar powered barbecue grill and testing of the barbecue grilling machine. The importance of this study includes: (1) It helps to reduce air pollution that can be caused by the use of fossil fuel fire, (2) It also reduces the financial cost of energy because the sunlight is available at a cheaper cost and (3) It helps to eliminate dangers of electric shock, flare ups and (4) It helps to eliminate dangers of toxic smokes during use.

MATERIALS AND METHODS

The materials and methodology for the design and development of Renewable Energy Grilling Machine (REGM) are discussed below. Although, the REGM is going to be used at Abule Okuta (Bariga) Bus Stop, Lagos, it can be deployed in any area as long as there will be daily sunshine. It is intended to replace gas fired grilling machine already in use there.

— Design Analysis and Consideration

Various factors were considered in order to develop an efficient solar PV powered barbecue grilling machine. The considerations are: heat energy required to grill food items, the temperature of the air at the point of contact with the food, the size of Solar PV panels required to provide the required power and the battery storage capacity to store and release the power when needed. The thermal conductivity of the materials to be used.

— Heat energy required for grilling

The food to be grilled is model as a homogeneous wall that is conductive and being heated on one side while other side is in free air as shown in Figure 1 below. Newton's law of cooling states that the heat transfer from a solid surface of area, A, at a temperature t_w, to a fluid of temperature t, is given by equation (1) below in (1)

$$Q = hA(t_w - t) \quad (1)$$

where Q = heat transfer (W), h = heat transfer coefficient (W/m^2. K) and it depends on the properties of the fluid and the fluid velocity. t_w = temperature of the wall and t = temperature of the free space.

According to Fourier's law of conduction, the rate of flow of heat through a single homogenous solid is directly proportional to the area, A, of the section at right angles to the direction of heat flow, and to the change of temperature with respect to the length of the path of the flow $\frac{dT}{dx}$. The thermal resistance concepts is given in the heat conduction through a solid and it is given in equation (2) below

$$Q = \frac{T_1 - T_2}{R_{solid}} \quad (2)$$

where Rsolid = thermal resistance of the solid (k/W)

The various expressions for Rs are given in equation (3a) and equation (3b) below

$$R(solid) = \frac{L}{KA} \quad (3a)$$

$$R(conv) = \frac{1}{hA} \quad (3b)$$

Consider a steady state one-dimensional heat flow through a plane wall of thickness x, area A, and thermal conductivity k that is exposed to heat convection on both sides at temperatures $T_{(\infty1)}$ and $T_{(\infty2)}$ with heat transfer coefficients h_1 and h_2 respectively, as shown in Figure 1 below. Assuming $T_{(\infty2)} < T_{(\infty1)}$, the variation of temperature will be as shown in Figure 1 below. Note that the temperature is assumed to vary linearly in the wall (the material to be grilled food since we assumed an homogeneous material), and asymptotically approaches $T_{(\infty1)}$ and $T_{(\infty2)}$ in the fluids as we move away from the wall.

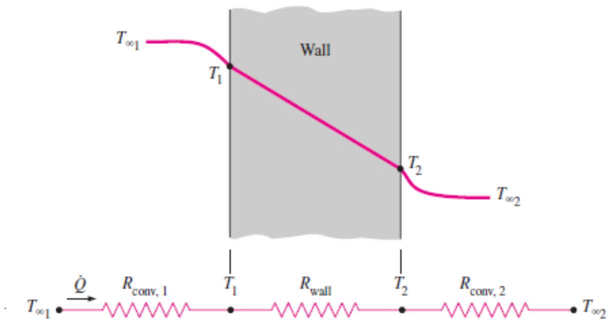

Figure 1: Conductive wall and Electrical resistance models of the Grilled materials

In a steady state heat flow, the rate of heat convection into the fish (wall) = rate of heat conduction through the fish (wall) = rate of heat convection from the fish (wall).

Therefore,

$$Q = h_1A[T_{(\infty,1)} - T_{(\infty,2)}] = h_2A[T_{(1)} - T_{(\infty,2)}] = kA\frac{T_1 - T_2}{x} \quad (4a)$$

$$Q = \frac{[T_{(\infty,1)} - T_{(1)}]}{h_1 A} = \frac{[T_{(1)} - T_{(\infty,2)}]}{h_2 A} = \frac{T_1 - T_2}{x/kA} \quad (4b)$$

Adding up the numerators, we get

$$T_{(\infty,1)} - T_{(\infty,2)} = Q\left[\frac{1}{h_1} + \frac{1}{h_2} + \frac{L}{kA}\right] \quad (5)$$

Therefore,

$$R(\text{total}) = \left[\frac{1}{h_1} + \frac{1}{h_2} + \frac{x}{kA}\right] \quad (6)$$

$$Q = \frac{T_{(\infty,1)} - T_{(\infty,2)}}{\left[\frac{1}{h_1} + \frac{1}{h_2} + \frac{L}{kA}\right]} \quad (7)$$

To determine the heat energy required to grill a mass of food item, the relationship shown in equation (8) below is employed:

$$Q = m \times C_P \times \Delta T \quad (8)$$

where Q = heat energy required (J), m = mass of food item (kg), C_P = specific heat capacity (KJ/Kg°C) and ΔT = temperature change (°C)

It is assumed that the food to be grilled; fish, meat and chicken were defrosted already at 20°C and will be heated to 250°C for it to be properly grilled. The specific heat capacities for fish (fresh Crocker), beef and chicken are 3.6 KJ/Kg°C, 2.85 KJ/Kg°C, 3.1 KJ/Kg°C respectively (The Engineering Toolbox, 2003). Therefore, the heat required to grill the fish, beef and chicken are given below in equations (9a), (9b), and (9c) respectively

For fish, $q = 0.5 \times 3.6 \times (250 - 20) = 414\text{kJ}$ (9a)

For beef, $q = 0.5 \times 2.85 \times (250 - 20) = 327.75\text{kJ}$ (9b)

For chicken, $q = 0.5 \times 3.1 \times (250 - 20) = 356.5\text{kJ}$ (9c)

The power required is given by the expression in equation (10) below:

$$\text{The power required} = \frac{\text{heat energy required}}{\text{total time required}}. \quad (10)$$

The power required to grill the fish, beef and chicken are given below in equations (11a), (11b), and (11c) respectively

$$\text{For fish, power} = \frac{414000}{1800} = 230 \text{ watts} \quad (11a)$$

$$\text{For beef, power} = \frac{327750}{1800} = 182 \text{ watts} \quad (11b)$$

$$\text{For chicken, power} = \frac{356500}{1800} = 198 \text{ watts} \quad (11c)$$

The heating energy, E, in the heating element is given by the expression in equation (12),

$$E = I^2 \times R \times t \quad (12)$$

where I = current that flows through the heating element, R = resistance of the heating element, t = time,

Power of the heating element, P = 250 W. The margin of safety of 20 percent assumed will give: 250 W x 1.2 = 300 W.

Voltage of the heating element, V = 12 V

$$I = \frac{300}{12} = 25 \text{ A} \quad (13)$$

Also, the resistance of the coil is obtained from:

$$P = \frac{V^2}{R} \quad (14)$$

R= 0.48 ohms

The grilling machine will be operated between the hour of 1800 hours and 2300 hours. Therefore, the total energy requirement is = 300 W x 5 hours = 1, 500 Wh/day = 1.5 kWh/day.

— Temperature of the air at the point of contact with the food

The grilling machine is modelled as two materials in series with an air gap between them as shown in Figure 2 and the heat source from the heating element. We can now determine the temperature of the air that grills the food item.

Given:

Thermal conductivity of fish = 0.534 W/m K, Thermal conductivity of chicken = 0.503 W/m K, Thermal conductivity of beef = 0.506 W/m K, Initial temperature of food = 20 °C, Temperature of the air = 25 °C, thickness of food to be grilled = 0.02 m. temperature of the grill = 500 °C, the length of the airgap is = 0.06 m

Assumptions made:

- R (air gap) = 0.16 k/W
- area = 1 m^2
- thickness of food to be grilled = 0.02 m
- the heat transfer coefficient of the outside air=17 W/m^2 K
- heat transfer through the wall is steady since the surface temperatures remain constant at the specified values
- thermal conductivity is constant
- heat energy is considered to flow at a uniform rate
- heat transfer by radiation is negligible
- area of the solid is constant
- assume Newton's law of cooling for heat transfer at the fluid and solid interface

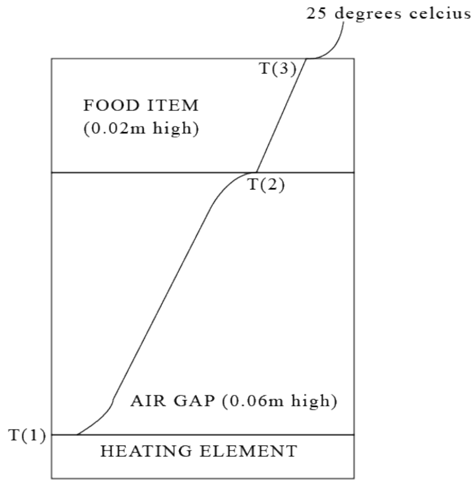

Figure 2: Schematics of the heat transfer from the heating element to the food item

At T_1 = 500°C, and T_{air} = 25°C,

$$Q = \frac{T_1 - T_{\text{air outside}}}{R_{\text{Total}}}$$

$$R_{(\text{Total})} = R_{(\text{air gap})} + R_{(\text{fish})} + R_{(\text{air outside})}$$

$$R_{(\text{fish})} = \frac{L}{K*A} = 0.037 \text{ k/W}$$

$$R_{(\text{outside})} = \frac{1}{h*A} = 0.057 \text{ k/W}$$

$$R_{(\text{Total})} = 0.16 + 0.037 + 0.059 = 0.256 \text{ k/W}$$

$$Q = \frac{500-25}{0.256} = 1855.4 \text{ W}$$

Since the setup is in series, the same heat energy flows through them

To obtain the temperature at the interface of the air gap and the fish, $T_{(2)}$:

$$\frac{500-T_2}{0.16} = 1855.4\ W$$

$$T_{(2)} = 205°C$$

To obtain the temperature at the interface of the fish and the surrounding air, $T_{(3)}$:

$$\frac{205-T_{(3)}}{0.037} = 1855.4\ W$$

$$T_{(3)} = 136.4°C$$

— Solar PV panel

A solar PV panel as shown in Figure 3 is a device that is made up of many photovoltaic cells linked up together. A photovoltaic cell is a cell that mainly converts sunlight into electricity. When photons incident upon an atom, an electron is released from the outer shell of the atom. This flow of electron generates a flow of electricity. This device is the only source of energy in this work. It supplies DC current to the heating element through the charge controller and battery. It is usually tilted at an angle from the ground to improve the efficiency. The tilting depends on the latitude of the location which is 3.3^0. The power generated by one solar power depends on many factors which are related by Eq. 16

$$P_{PV} = R_{PV} \times D_{PV} \times \left(\frac{S_i}{I_{sc}}\right) \qquad (15)$$

Where R_{PV} = Rated power capacity of the needed PV, D_{PV} = Derating of the PV (%), S_i = Global solar irradiation (kW/m^2), I_{SC} = Incident amount of solar irradiation at standard condition. The derating factor accounts for the solar PV panel power losses which can be due to dust cover on the surfaces of the panels and elevated temperature during exposure. Derating factor (D_{PV}) is taken to be 0.9 as reported in F. Rinaldi et. al (2020)

Figure 3: Solar PV panels exposed to the sunlight

— Sizing of the solar panel

Solar PV panels sizing always depend on the load and average daily sun hours in the locality. The power generation rating of a solar panel is watts. In reality, the energy generated by solar PV panels is obtained by multiplying solar capacity by average daily sunlight. This is what will be supplied to the battery for storage. The grilling machine will be deployed at Bariga Market (6.537406, 3.391975) Lagos. According to NREL, the average daily solar radiation in this area is 5.12 kWh/m^2/day (NREL, 2021)

The load required is = 1, 500 Wh = 1.5 kWh/day

The solar power requirement is 1.5 kWh ÷ 5.12 kWh/m^2/day = 0.293 m^2 at standard condition of 1000W/m^2 and T_c of 25°C

The wattage of the solar panel = 0.293 m^2 x 1000 W/m^2 = 293 W

Two 160 W Monocrystalline solar panels with the following specification: Peak power (PMP) – 160 Wp, Open circuit voltage of 21.84 V and Maximum Power Current (IMP) 8.80 A, Maximum Power Voltage 18.20 V, Short Circuit current of 9.33 A were selected and connected in parallel giving maximum power voltage of 18.20 V output and maximum short circuit current of 18.66 A. Photovoltaic rated at 1000 W/m^2, solar irradiation AM = 1.5 at 25^{0}C cell temperature.

— Charge Controller

This is a device that controls the amount of energy that is supplied to and drawn from the battery. The charge controller, shown in Figure 4, is placed between the solar panel and the battery. The solar charge controller controls the way the battery works that is charging and discharging operations. It also prevents the battery from overcharging thereby extending the service life of the battery. Overcharging the battery will reduce its service life. The charge controller stops the battery from discharging through the solar panel when there is no insolation especially at night. The charge controller has six terminals, two for the solar PV panels, two for the battery connections and the remaining two for the load hook up.

— Sizing of the charge controller

The maximum current that flows through the charge controller system is 18.66 A

The solar charge controller rating = Total short circuit current rating of PV array × 1.3 = 18.66 × 1.3 = 24.23 A.

Therefore, a 25 A charge controller is selected.

Figure 4: A Solar charge controller

— Battery

A battery is a device made up of one or more electrochemical cell and it is used to store electrical charges. A deep cycle battery, shown in Figure 5, which stores the charges from the Solar panel and supplies the charges to the heating element is used. The battery used for this experiment is of 12V, 120AH. An electric battery.

— Sizing of the battery

Since the system is designed to be used at sun down periods then, there must be deep cycle batteries to store up

the charges during the day so as to power the heating element for about 5 hours needed during off sunlight hours. The sizing of the battery would be done as follows:
Assuming 80% Depth of discharge for the battery
Power rating of the heating element and margin of safety, P = 300 watts and operating voltage, V = 12 V. But the energy generated by the two 160 W solar panels for 5.12 hours will be 1, 638 Wh

$$P = VI$$

≡ Part A:

The current drawn from the heating element, $I = \frac{250}{12} = 20.8A$

Battery capacity (AH) = $\frac{It}{0.8}$

Battery capacity (AH) = $\frac{20.8*5}{0.8}$ = 130 AH

≡ Part B:

Energy to be stored = 1, 638 Wh
The battery is 12 V, : 1, 638 Wh ÷ 12 V = 136.5 Ah
Two 70 Ah, 12 V batteries selected which will give a combined capacity of 140 Ah at 12 V.

Figure 5: A sealed battery

— Heating element

Heating element, Figure 6, is a device that mainly converts electrical current into heat energy by the principle of joule heating. The heating element is made of resistance heating element, electrical insulator and metal casing. The material of the resistance heating element for this experiment is made of stainless steel in order to prevent contamination of the food item. This device is supported by the frame and it grills the food item directly above it. The heating element used in this project is 250 watt, 12 volts direct current.

Figure 6: Heating element

≡ **The Grill Mesh:** Figure 7 below is the picture of the grill mesh. It serves as a means of supporting the food items to be grilled. It is being supported by the frame and it rests above the heating element. It is made of stainless steel as well to prevent corrosion by the hydrated food.

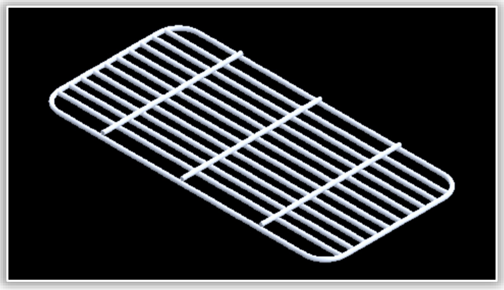

Figure 7: Grill Mesh

≡ **Temperature sensor:** The temperature sensor is shown in Figure 8 below. It is a MAX 6675 K-Type thermocouple temperature sensor. It performs cold-junction compensation and digitizes the signal from a type-K thermocouple. The data is output in a 12-bit resolution, SPI™-compatible, read-only format. MAX6675 converter resolves temperatures to 0.25°C, allows readings as high as +1024°C, and exhibits thermocouple accuracy of 8 LSBs for temperatures ranging from 0°C to +700°C. It is placed just above the heating element to take the instantaneous temperature reading in the grilling machine.

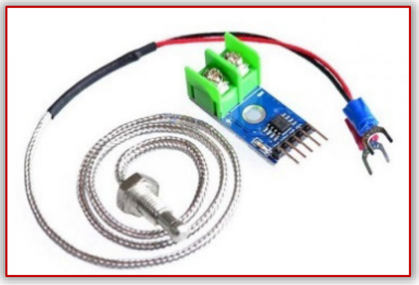

Figure 8: k-type thermocouple and Max 6675 temperature sensor

≡ **Connecting wires:** They are 4mm thick multi strnds wires used to connect the solar PV panels to the battery and the battery to the heating element.

≡ **Arduino Uno module:** Arduino Uno, Figure 9 below, is a microcontroller board that is equipped with sets of digital and analog inputs and output pins. The Arduino used for this experiment takes in the temperature and humidity readings from the sensors and displays it on the computer.

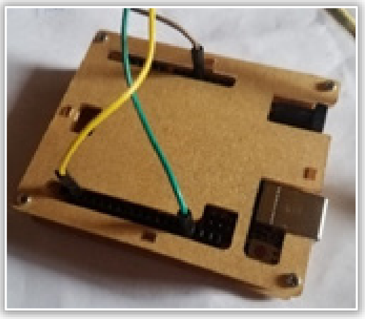

Figure 9: Arduino Uno module

≡ **Jumper wires:** They are used to connect the thermocouple sensor to the Arduino module.

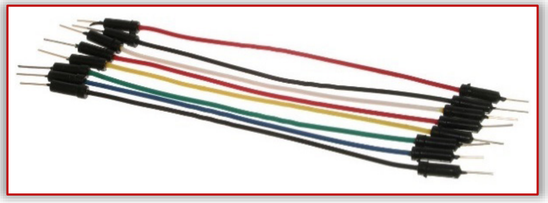

Figure 10: Jumper wires

- **The frame:** This serves as a housing support to the heating element. It has a passage for the drippings from the grilled meat and it also holds the switch and thermostat. It also serves as a support for the grill which is above the heating element.

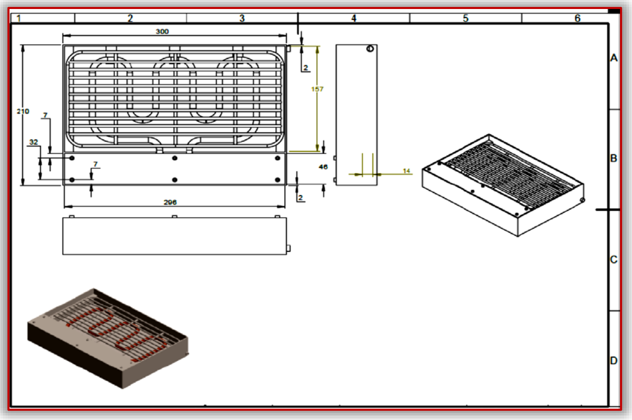

Figure 11: Assembly drawing of the solar grilling machine

- **Experimental setup:** The heating element was placed in the base frame and it is connected to the solar charge controller. The solar charge controller is connected to the battery and the solar panel. The experiment is set up as shown in Figures 12 and 13. Solar energy is the energy from the Sun, like other renewable energies, it is intermittent and not predictable. Hence, there is need for storage of energy generated so it can be used at a later time. The storage makes this energy more reliable. Various energy saving mechanisms exist. The most common one is the battery which saves electric current as charges. Therefore, the energy from the sun is converted to electric current using photovoltaic cells and stored in the battery for later use when there is no supply of energy from the Sun. The temperature and the humidity of the food item being grilled is measured using the K-type thermocouple and recorded, Table 1.

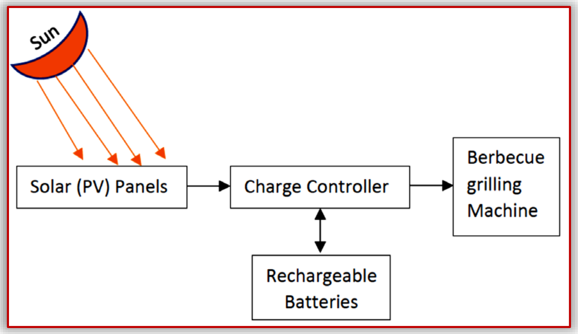

Figure 12: The Renewable Energy Grilling Machine set up

Figure 13: The experimental setup

Table 1: Temperature and relative humidity against time.

Time	Temperature (°C)	Relative humidity (%)
3.00pm	31.00	65.60
3.10pm	55.80	36.90
3.20pm	82.10	14.70
3.30pm	105.40	10.10
3.40pm	123.40	6.90
3.50pm	140.50	4.70
4.00pm	145.90	3.60

The solar panel converts the energy from the sunlight into electrical energy which flows through a Solar charge controller into a battery. The electrical energy leaves the battery through the same charge controller onto the heating element and it raises the temperature of the heating element. The food to be grilled is placed just above the heating element and it is grilled by natural convection. The grilling machine is covered with an insulating material in order to prevent heat losses.

After the construction of the solar powered barbecue grill, various tests of the components were carried out. The tests include the following:

✓ Determination of the time it takes to attain the various temperature ranges during the grilling operation.
✓ The temperature variation as time increases.
✓ The observation of the test specimen before and after the grilling process.

The experiment was carried out on an evening from 1500 hrs to 1600 hrs to test the performance of barbecue grilling machine.

Specimen = Fish
Weight before grilling = 0.5 kg.
Weight after grilling = 0.41 kg
Weight loss = 0.5 – 0.41 = 0.09 kg

Time taken for proper grilling = 50 minutes for both sides of the fish. Figures 14 and 15 are pictures of the fish before and after grilling respectively. The specimen was turned over manually.

Figure 14: Specimen before grilling

Figure 15: Specimen after grilling

RESULTS AND DISCUSSION

Figure 16 is the graph of temperature and humidity against time. The K-type thermocouple is placed on the furnace side of the fish. The fish (food) was covered to conserve the heat. From Figure 16, the temperature of the fish was rising as the humidity around the fish is reducing. The temperature and humidity began to rise and fall steadily after about 30 minutes.

The grilling actually started at about 20 minutes after the fish has been "de-watered". It is observed that the temperature increases for the first 40 minutes and then becomes steady as it approaches the maximum temperature of the heating element. The relative humidity first decreases sharply initially at the first 20 minutes and then becomes steady after 20 minutes.

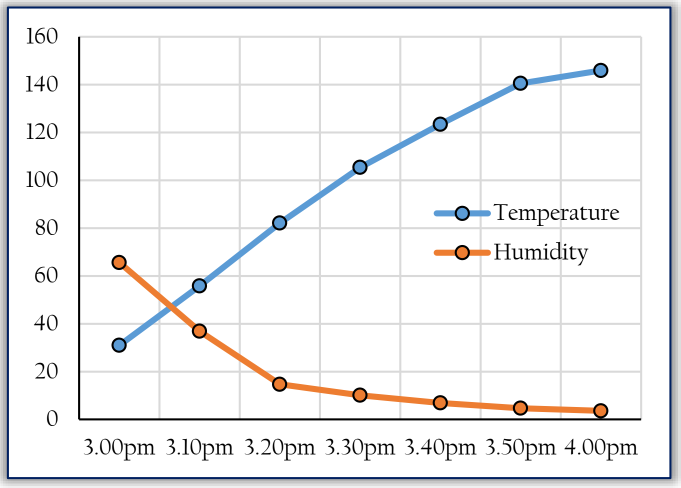

Figure 16: Graph of temperature and relative humidity against time

CONCLUSION

Renewable energy barbecue grilling machine was developed and tested in this article. It took about 50 – 60 minutes to grill 0.5 kg of fish. The machine could grill more food products especially fish, meat and chicken. It is important the top most part of the food is covered with noncombustible aluminum foil to conserve heat and get desired results as quickly as possible.

This project is able to eliminate flare-ups during grilling, reduce running cost, provides stable and evenly distributed flames that. It is fast when compared to the charcoal grilling machine. Since there is no burning of fossil fuels, and emissions, it is environmentally friendly and less harmful to human health. This project will therefore contribute to the reduction of carbon footprint in the environment where it is being operated.

This project is scalable and can be replicated anywhere whether in the rural areas or urban centers. The dwellers of rural areas can conserve the environment by saving the trees.

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