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Design, Construction and Thermal Performance of Solar Box Cooker

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Abstract: *Solar box cooker was designed constructed and tested under yola climatic condition. The objective of the research was to determine the thermal performance of the constructed solar box cooker. The test was carried out on the constructed box cooker on 5th February, 2021, using 0.3kg of cooking pot contained 2litres of water was placed at the focus of the cooker which was already oriented in the direction of the sun. The result of the thermal performance of the cooker attained a maximum temperature at 121°c with a cooking power at 21.19w. The average solar radiation and ambient temperature observed during the period of test were 508.5w/m² and 31°c respectively.*

Keywords: *solar energy, solar box cooker, thermometer, pyrometer, cooking power, thermal performance.*

INTRODUCTION

Background of the Study

A significant proportion of the Nigeria's population as in many other developing countries in Africa, Asia and Latin America depends on fossil fuels, biomass and fire wood for coking and domestic heating, this is because; it is the source of almost all renewable and non-renewable energy. Also, it is the cleanest, it is free from environmental hazards and it is readily available and inexhaustible. This account for more than 70% of the energy needs for most household. There is no gain saying the fact that conventional sources of energy for domestic cooking like liquefied petroleum gas otherwise called natural gas, kerosene and electricity are characterized by irregular availability, increasing costs and some are mostly not environmentally friendly.

Solar energy is one of the main alternative renewable sources of energy crucial to our search for domestic fuel replacement. However, like the development of all other energy sources, the breakthrough of solar energy into technological world will involve a lot of planning, organization, generation and enhance information as well as the provision of

infrastructure or devices to harness it for efficient and various effective uses. Solar cooker is a way of harnessing the sun power to bake as well as to cook food. An aluminum box forms the simple cooker. A set of aluminum foils or a large Fresnel lens to focus sunlight to a single point may also be added. However, although a workable solar cookers and cookers had been developed, many have serious limitation for example except for the indirect cookers, most can only be used outdoors and during day and most often when the sun is high.

From this point of view, it can be easily said that solar cookers have a big potential in these countries in order to meet the energy demand especially in the domestic sector. In addition, utilization of solar cookers provides potential in order to narrow the gap between renewable and conventional power resources. These solar devices are based on the simple principles of reflection, concentration, glazing, absorption and the greenhouse effect to store energy in order to increase the temperature. Various types of solar cooker exist, harnessing one or more of these principles (Jaramillo, 2007). The vast majorities of the solar cooker presently in use are relatively cheap and used low technology devices. Solar cooker cost nothing to operate and use no fuel, and because of that many nonprofits organizations are promoting their use worldwide to help reduce fuel costs for low income people, reduce air pollution and slow deforestation and desertification that caused by the use of firewood for cooking. Solar cooker radically decreases the world's dependence on fuel wood and dung as the primary cooking fuels while benefiting the environment, raising the standard of living, and improving the health of the poor worldwide. Energy consumption for cooking in developing countries is a major component of the total energy consumption, including commercial and non-commercial energy sources (Sharma, 2009). The exploding population throughout the developing world has hastened the ever increasing need for firewood, severely enhancing the degradation of land and creating massive deforestation which often leads to desertification. Solar cooker is the innovative methodologies which harness the power of free sunlight to decrease a family's use of fuel wood and charcoal by up to 70%, while improving their quality of life.

1.1 REVIEW OF SOLAR COOKERS

The sun's structure and characteristics determine the nature of the energy it radiates into space. As seen from the earth, the sun rotates on its axis about once every four weeks. However, it was not rotate as solid body, the equator takes about 27 days and Polar Regions take about 30 days for each rotation. The sun, in effects, a continuous fusion reactor with it constitute gases as the containing vessels retained by gravitational force (Aliyu, 2012).

The first scientist who designed a solar box cooker was a German physicist named Tschiruhausen. He used a large lens to focus the sun's rays and boiled water in a clay pot. Horace De Saussure who also improved on the clay pot, he designed and built solar cookers out of Mahogany wood which produced enough heat to cook food (Raja Mohan, et al, 2009). French scientist, Mouchot improved on the wooden hot box designed by adding transparent glass (glaze) to reduce heat loses. Ducurlna also improved on the cooker by adding mirror to reflect more sunlight and insolating the box.

Kahcsay, (2014), proposed the improvement of the box cooker by designed the cooker with an aluminum sheet which discovered that aluminum box cooker will receive more heat than the wooden box cooker. He also improved the box type cooker, using internal reflector. He discovered that a cooker with internal reflector has a higher performance of heat than the same cooker without reflector. W. Adams developed an octagonal cooker equipped with eight mirrors and he reported that the cooker cooked rations for seven people in two hours. This was due to equipped with eight reflected mirrors which increased the maximum heat of the cooker.

2.0 THEORY AND METHODs

2.1 THEORY OF SOLAR BOX COOKER

Solar collector is a types of solar collector that use direct solar radiation incident on the reflector to a black absorber for heating at its focus. Is made up of two parts that shave single casing. A collector for collection of heat and a cooking pot which serve as the absorber.

2.2 THE CONSTRUCTION OF SOLAR BOX COOKER

A typical box cooker consist of the following major component, octagonal collector made of aluminum sheet, absorber plate, glass cover, wooden stand and glazing reflector as shown in plate 1.

Plate; 1

A solar box container 23cm top and 11.5cm base with front height of 25cm was constructed. Absorber plate with 10cm×10cm made of aluminum sheet, painted black absorb the sun radiation. The inner sides of the octagonal collector was glued with mirrors as a reflector materials. The absorber pot which suspended on the stainless steel pipe was hang on the middle of one of the side of the collector. A transparent glass sheet 4mm thick cut into octagonal shape serve as a cover of the constructed box cooker. The whole constructed cooker was placed on a wooden stand with adjustable lever used for tracking sun.

2.4 cooking power.

The cooking power at the constructed solar box cooker was calculated using equation by Kundapur (2009).

$$P = \frac{Tw2 - Tw1}{t} \times M_W C_{Pw} \quad \text{..... 3.13}$$

(Kundapur, 2009)

Where,

P = Cooking Power (w)

T_{W1} = Initial Water Temperature

T_{W2} = Final Water Temperature

M_W = Mass of Water

C_P = Water Heat Capacity (4.168kj/kgk)

2.5 thermal performance of the solar cooker.

The solar cooker can be obtained by the following

1. Time require to obtained the maximum temperature, boiling point temperature of the water. The major variables obtained are: ambient temperature, the initial temperature final temperature and the maximum temperature obtained. A test was conducted on the constructed solar cooker to obtain the thermal performance of the box cooker. The maximum thermal performance at the cooker was calculate as 121°c.

2.6 solar cooking power.

The calculated result of the cooking power of the constructed solar cooker was found to be p=21.19w

2.7 testing of the constructed box cooker.

The test was carried out on 5th February, 2021, at 10:00am to 3:00pm. The whole set was place in an open space under the sun, a 0.3kg of cooking pot contained 2litres of water was placed at the focus of cooker which was already placed under the direction of the sun. The temperature was measured with a thermometer until boiling started taking place. The average solar radiation and ambient temperature observed during the period of test were 508.5w/m^2 and 31c° respectively. The pot water temperature at 100c° boiling point of water was observed and the highest absorber temperature attained was 121c°.

Conclusion

Based on the findings from the study, the following conclusion has been reached:

The study revealed that solar cooker was designed, constructed and tested as presented in this research. The performance of the cooker was higher than expected. To achieve this, readily available materials and sample devices for its mode of operation were used. The collector heats the water to a temperature of 100^0c by focusing the sun's radiation unto the receiver placed at the focal point containing the water.

Based on the finding from the study.

Discussion

The broad aim of this research was to determine the thermal performance of the constructed cooker to harness energy by solar means. From the result of this experiment, it was evident that the thermal performance of the cooker was achieved which attained a maximum absorber temperature of 121c° which is sufficient to boil water, cook and boil egg.

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