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Design and construction of a solar powered grill using a wooden box

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Abstract

A solar powered grill using wooden box cooker was successfully constructed with cheap and locally available material with efficiency from the various experiments that were carried out, the highest temperature gotten both on the ground floor and at the top of the roof was 72ºC both on the days with air temperature of 38ºC and 35ºC respectively. Efficiency was found to increase with decreasing temperature difference between collector temperature and ambient temperature. Increase in temperature does not necessarily lead to increase in efficiency. Efficiency decreased with decreasing solar radiation. Now a day non-renewable energy available less percentage, that's why we have to use renewable energy i.e. solar energy, wind energy etc. Nothing is cheaper than free of cost .But solar energy is available in abundant amount in nature at free of cost so that we can use solar energy as option for non-renewable energy source. Hence to replace traditional cooking method by solar energy can be considered. Solar cooker is one of the best appliances to utilize solar energy for cooking. Solar cooking is a form of outdoor cooking and is often used in situation where minimum fuel consumption is important or the danger of accidental fire is high and the health and environmental consequences of alternative are severe.

Keywords: Solar powered grill; Renewable energy; Ambient temperature

1. Introduction

According to World Bank statistics, 94 % of the African rural population and 73 % of the urban population use fuel wood as their primary energy source. Unfortunately supplies of fuel wood are diminishing throughout the world. As the cost and collection time for fuel wood increases, people seek for alternative sources. In many sunny parts of the world, solar cooking is a viable option [1,2, 3]. The need to to cook food for nourishment is fundamental to every society and this requires the use of energy in some form. The use of solar energy to meet this important need apart from being a viable alternative is also accomplished without the environmental and health problem associated with most other fuels.

Solar cooker technology is not conceptually new. Many efforts have taken place over the years [4, 5]. Different solar cookers have been tested by researchers at specific geographical locations and under unique climate and physical conditions. One of the most solar cooker types is the box solar cooker in different versions [6, 7, 8,]. Another solar cooker type is the concentration type where the solar radiation is directed to convey at a point called the focal point where the cooking pot is placed [9, 10].

A promising idea for solar cooker was introduced by Bernard of France in 1994 and Barbara Kerr a few years ago [11]. Its development is unique in terms of its simplicity and very light weight. A search through literature revealed that only a limited amount of data existed on quantitative performance evaluation of the panel cooker especially in this country.

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It is as a result of this the research was carried out by designing and constructing solar cooker using locally available material at Federal polytechnic Ado-Ekiti.

In building a solar cooker, the heat principles considered are heat gain, heat storage and heat loss. Solar cooking is simple, safe and it is convenient to cook food without consuming fuel or heating up the kitchen and cooks at moderate temperature and this helps to preserve nutrients. Depending on the latitude and weather, food can be cooked either early or later in the day. A solar box cooker is smoke free unlike other forms of cookers which uses smoky cooking fires which results in eye and lung diseases. Solar cooking helps to reduce the demand for wood and to prevent deforestation, saving fossil fuel and lowering utility bills. In studying the difference in air temperature at high elevations and close to the sea level, it was realized that the earth's atmosphere served as a heat trap for solar energy, causing high temperature at lower elevation instead of the other way round as was first expected. Coincidentally, it was discovered that the wooden "hot boxes" built for that purpose got hot enough to cook. [12, 13, 14].

2. Material and methods

The study was conducted at Federal polytechnic situated in Ado-Ekiti. Ado Ekiti is a city in southwest Nigeria, the state capital and headquarters of the Ekiti State. The wet season is warm, oppressive, and overcast and the dry season is hot, muggy, and partly cloudy. Over the course of the year, the temperature typically varies from 64°F to 90°F and is rarely below 58°F or above 95°F.

2.1. Materials Used for the Construction:

MDF Plywood, Glass plate, Aluminum foil, Adhesive bond, Foam, Spray Paint (Black), Screw bolt, Thermometer, Hot dog (Food to be cooked), Hammer, Screw driver.

The materials and other items were purchased in the city of Ado-Ekiti, and then it was then transported to the Science technical laboratory, Department of Science and laboratory Technology, Federal polytechnic, Ado-Ekiti

2.2. Design Framework/Principle:

There are hundreds of different designs of solar box cookers in use. These vary in size, material, insulation and components used. The general methodology used for the research work is as shown below:

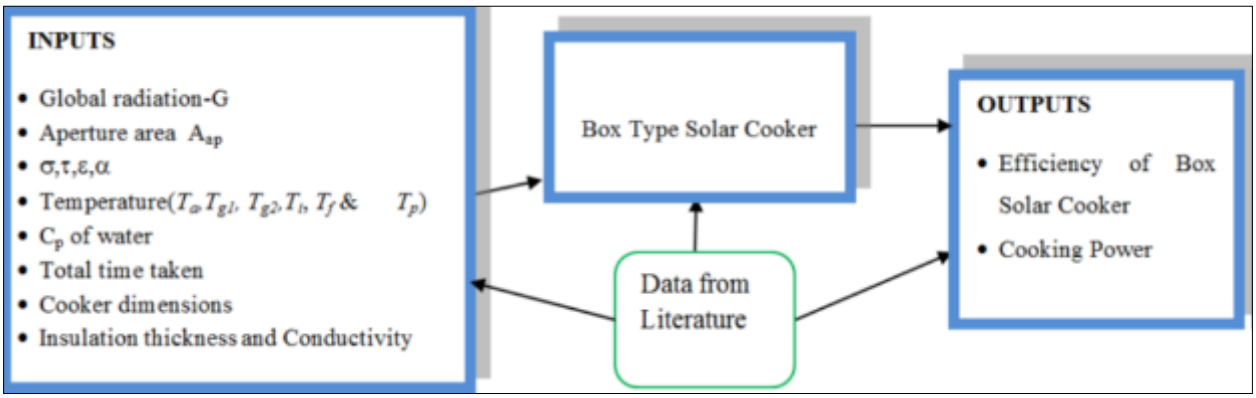

Figure 1 Flowchart for Working Principle of Solar Grill [14]

2.3. Methodology for Construction:

Plywood was used since it is very cheap and locally available. It is an opaque substance and does not allow light to pass through it. It contains a natural polymer based on the cellulose molecules. It has strength and stiffness parallel to the grain but is weak across the grain. It is a much weaker material in compression than in tension. The plywood is strong in the two directions and it is easily warped than the single wood with grains in one direction. (Nelkon and Parker, 1995).

The thickness of the plywood used to construct the box was 2.1 cm and the inner plywood thickness used as lining of the box was 1.27 cm. These thicknesses are used so that the box will not be too heavy. Each side of the box is lagged using a baton and saw dust to prevent heat loss due to convection. When the wood is lagged, heat escaping from its sides

is negligible and the flow per second is now constant along the length of the wood. The plywood was cut and joined together using hammer, screw bolt and screwdriver as there is no drilling machine.

The dimension of the box used was 7 cm x 17 cm x 13.8 cm, while the dimension of the absorber plate was 31 cm by 23 cm. as shown in figures 1, 2, and 3 there are grooves made around the top of the box to serve as a slot for the mirrors. The inner part of the box is painted black to absorb the heat and trap the heat needed for cooking. A black surface is a good emitter and absorber of radiation. A black surface absorbs all the radiation that falls on it, but reflects, and transmits none.

The radiation that was refracted by the glass is absorbed by the black plate and converted to heat. Food cooks best in dark, shallow, light-weight, thin metal pots with tight fitting to hold heat and moisture which works best in solar cooker. For this project, a shallow pot that is slightly larger than the food to be cooked is used. The mirrors serve as reflectors. Inside the box is a mechanism which makes the mirror slant at an angle as soon as it is slotted into the groove made for it. When radiation from the sun is incident on the mirror, it is reflected in the opposite direction in such a way that it is absorbed by the glass on top of the box which serves as the lid. For this project, a mirror with thickness of 3mm was used.

The dimension of the mirror used for the sides of the box was 46 cm by 30.5 cm. Glass provides about 10% better performance than plastic. And there is reason to believe that under windy conditions, glass is preferred since it doesn't flap in the wind and pump heat out of the cooker. For this project, the thickness of the glass used is 4mm. The glass dimension was 33cm x 26 cm. The top cover was made at an angle of 135° in order to tap the sun very well. A thermometer was used to measure the temperatures of the absorber plate in the box cooker and the ambient at different time intervals.

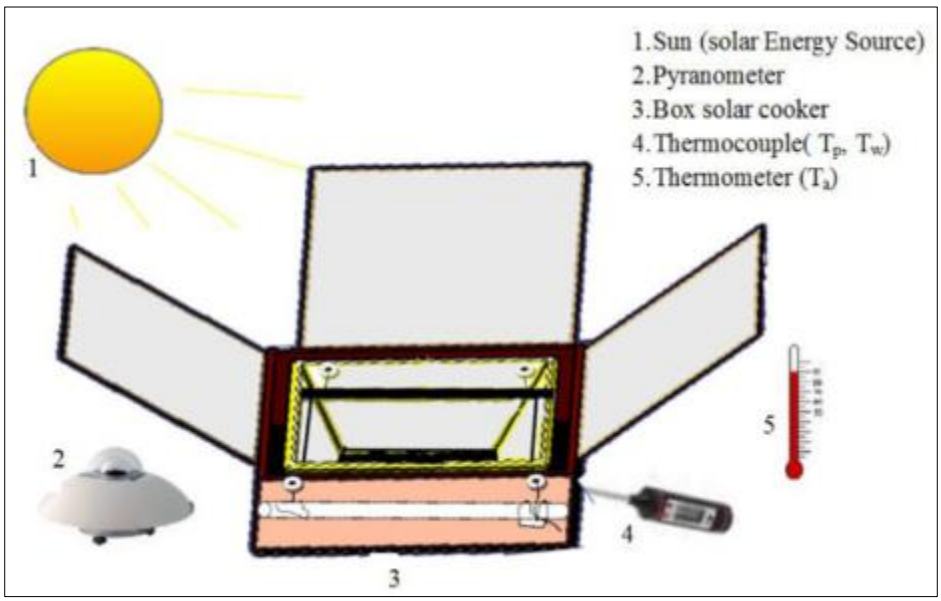

Figure 2 Prototype used for the Design and Construction

The construction process is shown below:

Figure 3 Construction process

Figure 4 Process of painting black

Figure 5 Picture showing the side view of the box

3. Results and discussion

3.1. Stagnation temperature test

The result of stagnation temperature under no load condition is shown in Figure 6. The graph reveals the variation in the solar radiation and ambient temperature and their effects on the stagnation temperature observed in the absorber plate of the solar cooker. The average ambient temperature for the test was 31.2 °C. The maximum absorber plate temperature of 161.7 °C was obtained after 3 hours 30 minutes at 13:30. The corresponding insolation value was 1,083 W/m2. In the report discussed with a truncated pyramid solar thermal cooker, a maximum plate temperature of 131 °C was attained after 2 hours and 20 minutes. The thermal performance of a reflector based solar box cooker implemented in Ado Ekiti Federal Polytechnic, Nigeria reported a temperature of 76 °C and 100 °C was attained for a finned absorber plate box cooker as discussed in. The result shows that the absorber plate temperature was retained for a longtime. This is desirable for heating water since the major mode of heat transfer to the cooking vessels is by conduction from the absorber plate. The plate temperature, ambient temperature and insolation versus time are plotted in Figure 6.

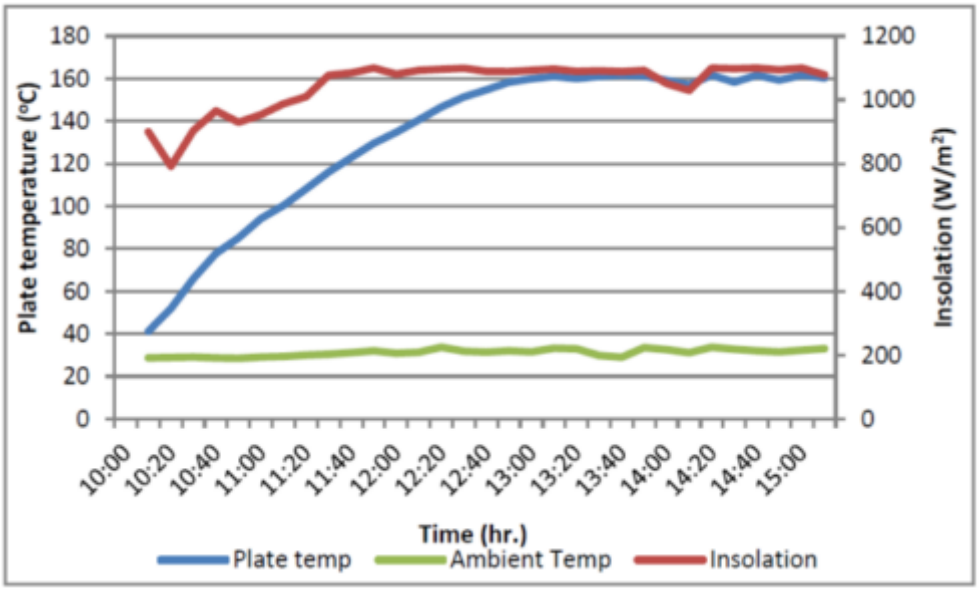

Figure 6 Thermal performance under stagnation test condition

4. Conclusion

A wooden solar box cooker was successfully constructed with cheap and locally available material. From the various experiments that were carried out, the highest temperature gotten both on the ground floor and at the top of the roof was 72°C both on the days with air temperature of 38°C and 35°C respectively. Efficiency was found to increase with decreasing temperature difference between collector temperature and ambient temperature. Increase in temperature does not necessarily lead to increase in efficiency. Efficiency decreased with decreasing solar radiation and meanwhile, our hypothesis was right, the hotdog grill made of wood can really cooked delicious hotdogs which is acceptable in the real world, the cooker is cheap if built because the materials are not expensive. Produced hotdog is the same as it is cooked in the grill, We think that if a reflective hotdog cooker can be built from a wooden box, cardboard box, tin foil and poster board is feasible that hotdog can be cooked there just like mama used to cook, We think that is cheaper and economical since we live in a tropical country.

Compliance with ethical standards

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Disclosure of conflict of interest

There is no conflict of interest between the two authors.

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