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Thermal performance of box solar cookers

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Abstract

The aims of this research are to identify the future of the use of solar energy in the field of cooking. This supports Vision 2030 in developing solar energy in the Kingdom of Saudi Arabia.The location and climate of the Kingdom of Saudi Arabia make it one of the most suitable countries for the application of energy exploitation.In this research, several experiments were done with different types of box cookers at different times of the year. In order to test the performance of the solar cooker. The cookers were made of locally available materials (shoe boxes, pizza boxes). The experiments and results were evaluated at a maximum insulation of 7300Wh/m2 at 1:00 pm and a minimum insulation of 4400 Wh/m2.The cooker gives pad performance as the experiments were conducted in the winter season.

Keywords: Solar cooker box- type, Thermal Efficiency , Power for Cooking , Performance , Kingdom of Saudi Arabia Article

1. Introduction

Cooking is one of all the daily activities for people. In many developing countries, people. In rural areas, people use wood, kerosene, and alternative petroleum bi-products for cooking. Solar energy is available at no cost and is environmentally clean, so it is known as one of the most promising alternative energy resource options. Moreover, solar cooking is the simplest and most attractive method for solar energy utilization. (Kassem. et al.2011).

In 69 countries, solar cooking was used. The largest number of cookers is in India. The highest numbers of cookers are in India and China, with approximately 34,000 in India and 140,000 in China (G. A. Alozie. et al.2010). To evaluate solar cookers, many parameters are contemplated to establish their output. One of those parameters, geometry, and materials, are evaluated. Many experiments were carried out to find the effects of geometrical and location on the performance of the solar cooker (Funk P.200). One of these experiments was carried out to test the solar cooker box type. Their findings in the experiment allowed them to determine the cooker power in relation to temperature and solar radiation (El-Sebaii. et al.20050) (Sethi V Pal D. et al.2014). another hand, the author developed a mathematical model to evaluate the performance of the cooker-type. This model is useful for estimating certain parameters. standardized cooking power and thermal efficiency, allowing comparison of solar cooker performance (Harmim . et al.2013),(Esteves et al.2008]. the study was considering qualitative and quantitative parameters for the box type. They studied if the use time could have an impact on the solar cooker (Servín. et al.2012). Saudi Arabia is the largest country in the Arabian Peninsula. It is located in southwest Asia and extends from the Red Sea in the west to the

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Arabian Gulf in the east. The area of the Saudi government estimate is 2,217,949 km2. More than half of this area is desert.
(A.H.AlmasoudHatim. et al.2015). Desert camping is one of the important experiences for people in Saudi Arabia. Applications of solar energy in Saudi Arabia began in 1960(William L. et al.2020). A solar cooker is a device that traps solar energy and uses this energy for heating and preparing food. Cooking comprises 90% of energy consumption in households in developing countries. (B. Z. Adewole. et al, 2015),
(Mullick. et al,1996). Most of the energy requirements for cooking come from firewood and agricultural waste in a rural areas. Saudi Arabia lies within a high sunshine belt, and the country's solar radiation is fairly distributed as well. The annual average of total solar radiation is 5700 Wh/m2 to 6700 Wh/m2. (Adewole Bamiji. et al,2015). Our designs of solar cookers have become acceptable because they are relatively cheap, low-tech devices, and their handling is easy.

2. Materials and Methods

2.1Materials

shoebox, pizza box, black tape, aluminium foil, transparent sheet, silicon to prevent leakage, thermometer. The dimensions of the shoebox (40cm x 35cm x 20cm) were used. The aperture is surrounded by transparent material. Aluminium foil has been used to cover the entire interior of the shoebox. Figure 1. The dimensions The pizza box has a transparent aperture.
area of 37.5cm x 37.5cm x 5cm Figure 2. Aluminum foil has been used to cover the entire interior of the shoebox.
The use of these types (shoebox, pizza box) is because of:
1-shoebox, pizza box, available to all Saudi people.
2-Easley handling epically for students camping.
3: safe to use
Solar cookers are not acceptable to Saudi people because of:
1-using gas cookers is popular for Saudi people.
2-solar cookers give poor performance, especially in winter and cold weather.
3-Solar cookers are not used at night.

Fig. 1 Shoebox solar cooker

Fig. 2 Pizza box cooker

2.2Methods

The experiment was conducted at Qassim University, College of Science and Arts, Uyun Al-Jawa, to design a solar cooker, and evaluate the performance of each of the taste, color and smell on separate days in the month of February, March and April of the year 2020 AD.

3.Result and Discussion

3.1Experiment (1): (2/2/2020) Shoebox solar cooker

Without load) (

The experiment conducted from 1:50 pm and 3:00pm . the cooker's temperature T_{co} and ambient temperature T_{am} were measured . Figure 3.

The experiment conducted from 1:35 pm and 2:05pm . the cooker's temperature T_{co} and ambient temperature T_{am} were measured plate temperature . Figure 4.

Experiment (3):(Pizza box)The experiment was conducted on Saturday, 7/8/2020 in Buraidah city. The highest degree of heating of the pot is 334°K. Figure No. (5).

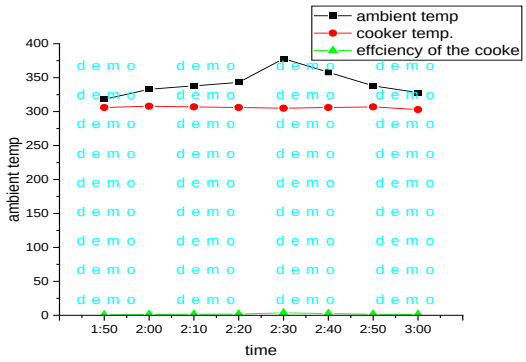

Fig. 6 **The Shoebox solar cooker's temperature ambient temperature, and the efficiency**

3.3.1Performance Testing:

1- The efficiency of box cooker is given byη :

$$\eta = \frac{\eta_0}{U_L} \qquad (1)$$

Where η_0 is optical efficiency and U_L is over loss coefficient [14,15]

Experimentally,

$$\eta = \frac{T_{co} - T_{am}}{H_c} \quad (2)$$

Where T_{co}, T_{am} and H_c are stagnation plate temperature, average ambient temperature and intensity of solar radiation respectively .

Figure (5)From Figure (7) maximum efficiency of the cooker was found at 2:30 pm.

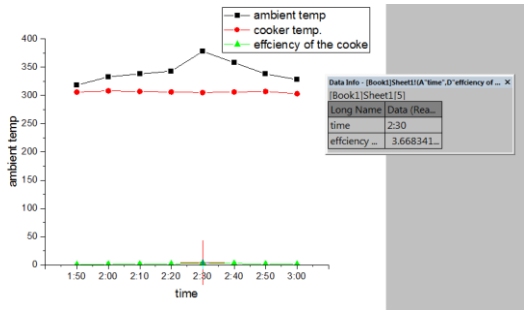

Fig. 7 Maximum efficiency of the shoebox solar cooker was found at 2:30pm.

3.4. Thermal Efficiency

(Pushkaraj D. et al.,2017), (Ashok k. et al.,2009), (Sonage, B ,et al.,2015)

$$P = \frac{T_{co} - T_{am}}{600} m C_p \quad (3)$$

η = overall thermal efficiency (percentage) (%)

C_f = Specific heat of cooking fluid (joules per kilogram per temperature)

I_{av} = average solar intensity (W/m2) over the time interval

A_c = is the aperture area (m2) of cooker

ΔT = time required to achieve the maximum temperature of cooking fluid (s).

2.2.2Power for Cooking

$$P = \frac{T_2 - T_1}{600} m C_p \quad (4)$$

T_2 = final temperature

T_1 = initial temperature

m = mass of egg (kg) =195x10-3Kg

C_p = heat capacity for an egg (3.8 kJ/kgK)(El-Sebaii, A. et al.,2005)

Equation 4 is divided by 600 to account for the number of seconds in each 10-minute.

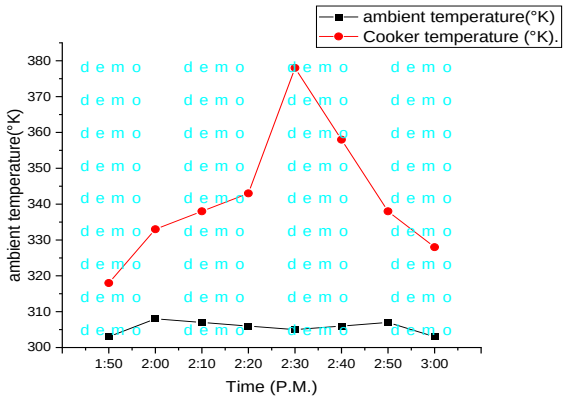

Fig. 3 The Shoebox solar cooker's temperature compared, ambient temperature

3.2Experiment (2): (2/2/2020) Shoebox solar cooker (Load test) :

The experiment conducted from 1:35 pm and 2:05pm . the cooker's temperature $\mathbf{T_{co}}$ and ambient temperature $\mathbf{T_{am}}$ were measured plate temperature . Figure 4

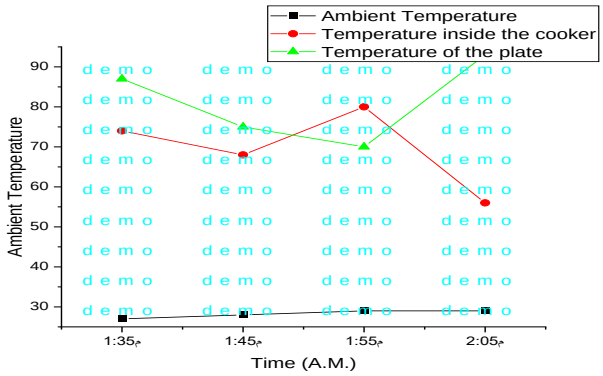

Fig. 4 The Shoebox solar cooker's temperature, ambient temperature, and plate temperature.

3.2Experiment (3):(Pizza box) :The experiment was conducted on Saturday, 7/8/2020 in Buraidah city. The highest degree of heating of the pot is 334°K. Figure No. (5)

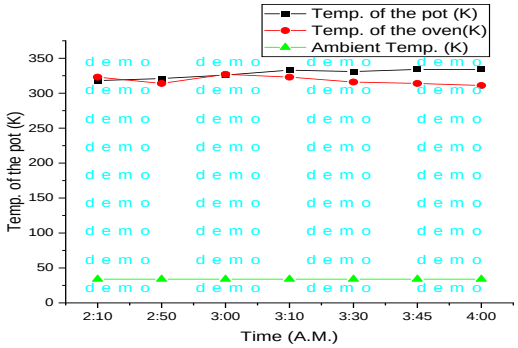

Fig. 5 Pizza box solar cooker's temperature compared to ambient temperature, and pate Temperatur.

4. Conclusion

After conducting the experiments, we found the following:

1- Using the solar cooker in cold weather reduces the performance of the cooker. The temperature of both types of box cooker dose not reach 100C

2- When using the solar cooker in the presence of active winds and clouds, reduces the performance. maximum power found at 3:00 pm of the shoebox solar cooker, and maximum power found at 3:00 pm of the shoebox solar cooker.

5. Recommendations

1. Conducting experiments in different months of the year, taking into account the different annual seasons (winter-summer-autumn-spring).
2. 3- Doing more experiments with changing the angle of fall of the rays on the cooker to find the angle that gives the highest efficiency.
3. 4- The presence of active winds or clouds affects the performance of the solar cooker

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