Thermal Performance Analysis of a Box-Type Solar Cooker with Finned Pot: An Experimental Approach

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Abstract The thermal performance of a box-type solar cooker with finned cooking pot has been investigated experimentally under local climate conditions at Talcher, Odisha, India. Box-type solar cooker with finned and un-finned cooking pots of same sizes have been used for this experimental study. Fins can be thought of as an extension of the surface which enables additional heat flow from cooker cavity to pot. The performance of the constructed solar cooker was tested using the standard procedure for testing. Testing was performed over 3-month period between May and July 2016, with 1 L water load. Furthermore, various factors affecting the cooking performance like pot type, the solar intensity, and the local time were examined. The maximum temperature in the un-finned and finned pot reached 93 and 102 °C, respectively in the clear weather condition and 70 and 76 °C in cloudy weather condition. The cooker efficiency can reach 53% for finned pot and 50% for un-finned pot in cloudy weather and 72 and 54% respectively in clear weather. The cooker temperature found to depend on the solar radiation intensity and the type of cooking pot. The present solar cooker is of low cost, fabricated locally and simple in use.

Keywords Box-type solar cooker · Finned pot · Weather · Temperature Thermal performance

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1 Introduction

Indian subcontinent is blessed with sufficient amount of sunlight for most of the year, and so cooking with solar heat can be a promising alternative for fuel wood. Solar energy is a free and clean source of energy, and this can be a suitable substitute for traditional cooking fuels. Many factors like type of food, availability of conventional cooking fuels, and non-uniformity of solar heat during a day affects people's mindset about solar cooking.

The box-type solar cooker is an insulated container with a single or multiple glasses (or other transparent materials) cover at the top with or without reflectors. The principle of operation is similar to the greenhouse effect. The transparent glass cover permits passage of shorter wavelength solar radiation. Most of the longer wavelength radiation coming from relatively low temperature heated bottom surface cannot be re-radiated through the glass cover. Reflective mirrors are provided to reflect additional solar radiation into the cooking cavity. Solar box cookers cook through heating of the interior of the box using solar radiation. The bottom of a solar box cooker is selectively coated to absorb maximum solar radiation. It transfers the absorbed solar heat to anything that touches it through the process of conduction. As air at the bottom of the box is heated, it rises and is replaced by cold air from the top of the box. Then the cooker is heated and replaced in a continual circular motion [1–6].

Continuous research is still going on worldwide to optimize the performance of solar cookers. A thorough description of solar box cookers is presented by Nayak et al. [2] and Cuce and Cuce [3]. However, considering different weather condition and different types of pots inside the cooker, the performance is likely to be different. With this motivation, present analysis has been made to obtain the performace of solar cooker at varied weather condition and with different types of pots in it.

In this work, a box-type solar cooker was constructed at IGIT, Sarang, near Talcher, Odisha, India. The performance analysis of a box-type solar cooker with both finned and un-finned cooking pot of same size has been conducted experimentally under local climatic conditions at Talcher, Odisha, India.

2 Geometrical Construction

The solar cooker is constructed with a trapezoidal cavity of aluminum. The box-type solar cooker is shown in Fig. 1. Plane glass is provided at the top allows solar radiation to enter and minimizes re-radiation and convective heat losses. Glass wool insulation surrounds the cavity minimize conduction heat losses. The absorber plate which receives the most of the solar radiation is selective coated lies at the bottom [3]. Both direct and diffused solar rays enter solar cooker. The mirrors serve as reflectors. Refracted radiation from the glass cover is absorbed by the selective coated bottom absorber plate and converted to heat. Incident radiation on the mirror is reflected in the opposite direction, and it is absorbed by the glass on top of the box.

Fig. 1 Constructed box-type solar cooker with pots

Table 1 Specification of constructed solar cooker under consideration [2]

Parameters	Details
Casing	
Dimensions	59.6 × 59.6 × 16.5 cm^3
Thickness	1.8 cm
Material	Aluminum
Absorber plate	
Dimensions of bottom surface	36.6 × 36.6 cm^2
Dimension of top surface	47.5 × 47.5 cm^2
Cooker cavity shape	Trapezoidal
Material	Aluminum
Glaze	
Area	52.8 × 52.8 cm^2
Spacing between glazes	15 mm
Glazing material	Glass of 4 mm thickness
Insulation	
Thickness	2.5 cm
Material	Plywood and sawdust

Inside the box, the mirror can be slanted at an angle by slotting it into the groove made for it. Rubber gasket is provided to prevent air leakage. Finally, the cooker is equipped with four wheels to facilities its easy movement. The dimensions of the box-type solar cooker are provided in Table 1.

3 Experimentation

Experiments were conducted outdoors in IGIT, Sarang, located at 21.0863° latitude and 85.13908° longitude over 3-month period between May and July 2016, with 1-L water load. The objective was to compare the performance of the solar cooker while using a finned pot and an un-finned pot when loaded with 1 L of water at the same initial temperature. The two cooking pots were kept in solar cooker cavity. Temperature measurements were recorded at interval of 30 min during the day with K-type thermocouples.

4 Results and Analysis

Ambient temperature, pot water temperature, cooker cavity air temperature, and the solar irradiance were recorded during the experiment. Figure 2 shows temperature variation with time in clear weather condition. It was found that for clear weather condition in the month of May 2016 water in the finned cooking pot always maintained higher temperature than water in the un-finned cooking pot. In the finned pot boiling temperature of water was attained at 1.00 PM. The water in the un-finned cooking pot reached boiling temperature nearly 1 h later. The ambient temperature almost increases from 35 to 39 °C during the test period.

International Standard for Testing Solar Cooker and Reporting performance was followed for conducting tests [4]. The experimental performances of the cooker with the two cooking pots for the two different weathers are shown in Figs. 3 and 5

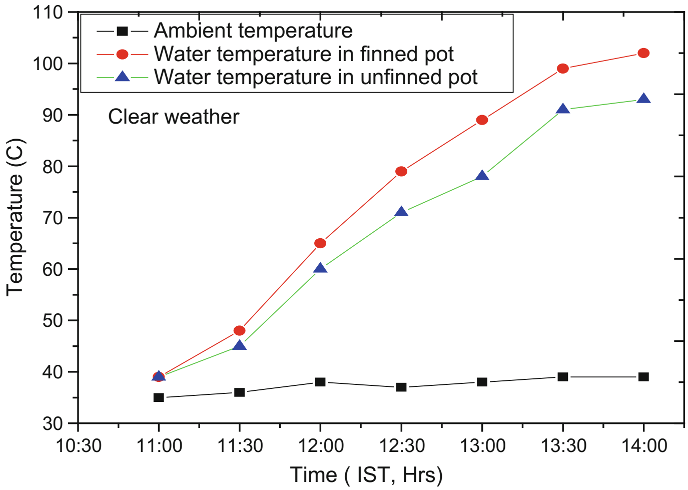

Fig. 2 Variation of temperature with time in clear weather condition

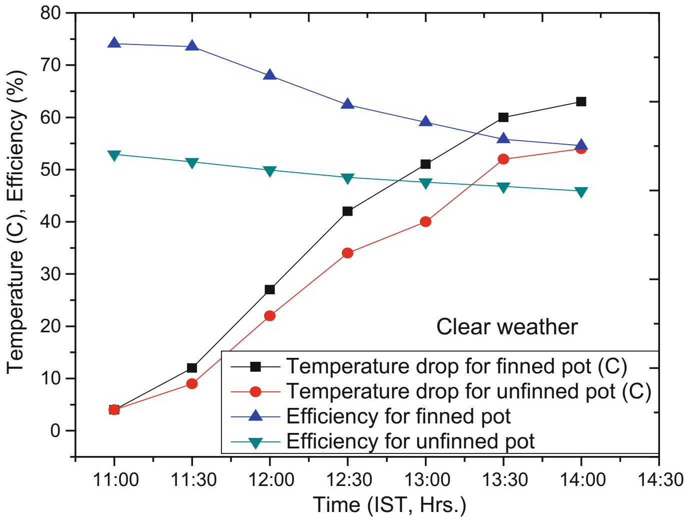

Fig. 3 Variation of temperature drop and efficiency with time in clear weather condition

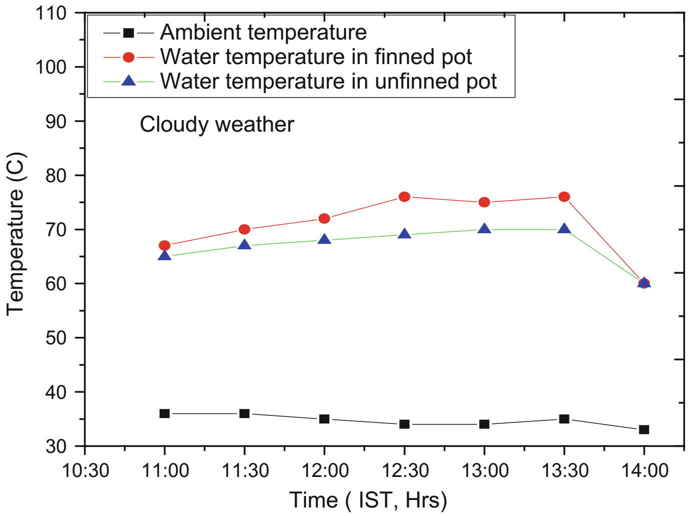

Fig. 4 Variation of temperature with time in cloudy weather condition

with 1-L water load. The temperature distribution in cooking pots, variation of ambient temperature, variation of water temperature in cooking pots and efficiencies are represented in Tables 2, 3, 4 and 5. Table 2 shows the various temperature distributions during the heating test for clear weather, and Table 4 expresses the same thing for cloudy weather condition (Fig. 4).

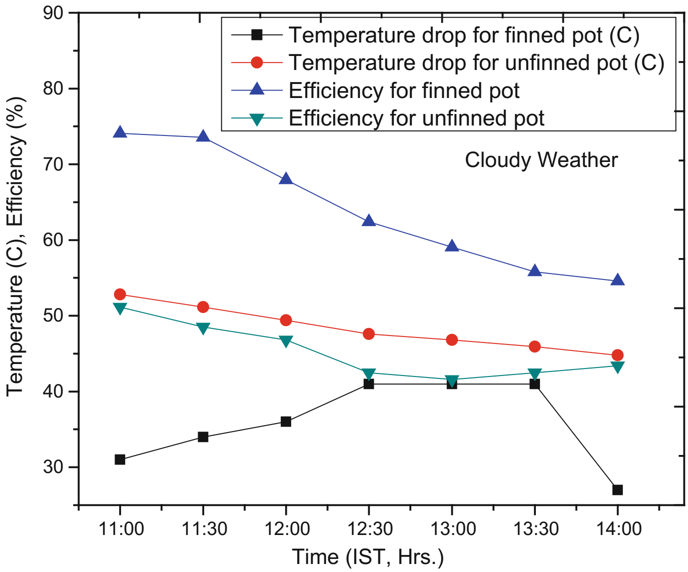

Fig. 5 Variation of temperature drop and efficiency with time in cloudy weather condition

Table 2 Temperature distribution in clear weather

Sl. No.	Time	Ambient temperature (°C)	Water in finned pot temperature (°C)	Water in un-finned pot temperature (°C)	Temperature drop (°C)		Solar radiation (W/m^2)
					For finned pot	For un-finned pot	
1	11:00 AM	35	39	39	4	4	700
2	11:30 AM	36	48	45	12	9	
3	12:00 Noon	38	65	60	27	22	
4	12:30 PM	37	79	71	42	34	
5	1:00 PM	38	89	78	51	40	
6	1:30 PM	39	99	91	60	52	
7	2:00 PM	39	102	93	63	54	

The efficiency decreases continuously with the cooking pot and the ambient temperature difference. When this difference becomes lager, the losses increase and the efficiency decreases. In addition, the efficiency for the finned pot is much higher that the water temperature increasing with time rapidly in early morning. The un-finned pot is especially at the lower values of temperature difference. The cooker efficiencies are calculated for 30-min period and assumed constant during this period. It is obvious that the efficiencies are high at early periods of the tests and decreases during afternoon. This behavior is due to the decrease in the rate of increase in ambient temperature with time.

Table 3 Temperature and efficiency in clear weather

Sl. No.	Temperature drop pot (°C)	Efficiency	Temperature drop for un-finned pot (°C)	Efficiency
1	4	74.1	4	52.9
2	12	73.54	9	51.5
3	27	67.96	22	49.9
4	42	62.4	34	48.5
5	51	59.05	40	47.6
6	60	55.79	52	46.8
7	63	54.6	54	45.9

Table 4 Temperature distribution in cloudy weather

Sl. No.	Time	Ambient temperature (°C)	Water in finned pot temperature (°C)	Water in un-finned pot temperature (°C)	Temperature drop(°C)		Solar radiation (W/m^2)
					For finned pot	For un-finned pot	
1	11:00 AM	36	67	65	31	29	700
2	11:30 AM	36	70	67	34	31	
3	12:00 Noon	35	72	68	36	33	
4	12:30 PM	34	76	69	41	35	
5	1:00 PM	34	75	70	41	36	
6	1:30 PM	35	76	70	41	37	
7	2:00 PM	33	60	60	27	54	

Table 5 Temperature and efficiency for cloudy weather

Sl. No.	Temperature drop finned pot (°C)	Efficiency	Temperature drop for un-finned pot (°C)	Efficiency
1	31	52.8	29	51.13
2	34	51.13	31	48.53
3	36	49.4	33	46.8
4	41	47.6	35	42.46
5	41	46.8	36	41.6
6	41	45.93	37	42.46
7	27	44.8	27	43.4

The heat transfer area of cooking pot is increased by addition of fins to the external surface. For this the water temperature inside the finned pot was higher than that of the un-finned counterpart. It can be seen that the water temperature reaches a maximum at about the 1.00 PM. Also, it is obvious that comparing the performance curves presented in Figs. 2 and 4 it can be seen that the water temperature in the month of May is more than that in the month of July. This is due to higher solar intensity in May compared to July. Also, it is worth noted that the water temperature decreases during the afternoon hours.

5 Conclusion

A box-type solar cooker was constructed at IGIT, Sarang, Odisha, India. The thermal performance of the constructed cooker was investigated experimentally in local climatic conditions using both finned and un-finned cooking pots of same size. The heat transfer from cooker cavity to the pot surface was improved due to addition of fins. Fins can be considered to be extension of the pot surface which increases transfer of heat from and to the medium it is in contact depending upon the applications. The performance study of the constructed solar cooker was performed using the standard procedure for testing. The maximum temperature in the un-finned and finned pot reached 93 and 102 °C, respectively, in the clear weather condition and 70 and 76 °C in cloudy weather condition. The cooker efficiency can reach 53% for finned pot and 50% for un-finned pot in cloudy weather and 72 and 54%, respectively, in clear weather. The cooker temperature found to depend on the solar radiation intensity and the type of cooking pot it was found that, by using finned cooking pot higher temperature can be reached. The present solar cooker is of low cost, fabricated locally and simple in use. Further study is required to optimize this solar cooker. Further work can be planned to carry out similar experimentation in all the months to understand the cooking profile throughout the year.

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