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Performance Analysis of an economical portable housing solar cooker (EPHSC)

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Abstract *— This paper presents design development and extensive study of thermal and cooking performances and economic analysis of a highly economic solar cooker, that can be a boon to lower and middle-income group people. Costs of this cooker are less than one third that of commercially available models (CSC) whereas it's thermal and cooking performance are slightly better than CSC. The average values of F_1 & F_2 are as per recommended values of Bureau of Indian Standards. This can be easily prepared and repaired by users.*

Keywords— Solar cookers, thermal performance, payback periods, energy savings.

I. INTRODUCTION

Energy consumption for cooking is a major component of the total energy consumption, it accounts for 64% and 92% of total household energy demands in urban and rural areas, respectively, in India (Ramanathan and Ganesh, 1994). The demand of energy consumption for cooking is increasing annually at the rate of 8.1%. In rural India 90% of primary energy used is biomass, of which wood accounts for 56% crop residues for 16% and dung cakes for 21% (Parikh 2001). The felling of trees for fuel is an offence against environment as it leads to serious ecological imbalance, which shows it's after effects as droughts, famines and floods.

Incomplete combustion of bio-mass is one of the major sources of carbon monoxide, carbon dioxide and other green house gases. The use of bio-fuels with conventional low efficiency (~10%) chulhas / stoves results in economic burden on poor households. Moreover, cooking in a poorly ventilated kitchen is threat to health (Bhide 1984 and Rana 1997) as it leads to release of large amount of suspended particles and noxious gases. The cook (mainly women), children and old age people who are generally exposed to these pollutants are at the risk of serious diseases such as chronic obstructive pulmonary disease, acute respiratory infection among children, cataract, adverse pregnancy outcomes, pulmonary tuberculosis, asthma and cancer (Kandpal 1994 and Parikh 2001).

The invention and use of simple, inexpensive, and low-tech solar box cookers, may result in the emergence of solar cooking as a solution to these of problems. So far solar cookers have not gained desired popularity among the people probably due to the following reasons: parabolic cookers are costly (above Rs.5000/-), require frequent sun tracking, food can get burnt; user may get burns if care is not taken and performance deteriorates in high wind speeds (Garg 2000). Available hotbox solar cookers are heavy (8-18 kgs.), show poor performance in winters, are not affordable by lower income group people as these cost around Rs. 1200-4000 and have glass glazes which is heavy and fragile (Bashir 2000).

Motivated by these issues, authors have fabricated and extensively studied various types of solar cookers. It was felt that dry tree leaves are natural occurring insulating material which otherwise create a solid waste only. So we have selected these as one of the cheaper (free of cost) material for insulation. The problems of solid waste generation by packaging and transportation sectors are also becoming graver day-by-day. Cardboard is widely available and It makes a fairly durable, biodegradable unit. Cardboard is rigid, lightweight, and has good insulation qualities. Cardboard solar box cookers may be appropriate for many cultures because the materials are widely available and inexpensive.

This paper presents the design, development and performance analysis of highly economic, cardboard solar cooker. These cardboard hotbox solar cookers are quite durable. These can be easily prepared and repaired by the users themselves. Three designs are presented in this paper along with their thermal and cooking performances and payback periods. The performances have been found to be comparable, even better than the commercial hotbox solar cooker.

II. DESIGN DETAILS AND FABRICATION OF PHSC

The body of the solar cooker has been fabricated though cardboard boxes, which are used as packaging material having sufficient load bearing capacity and strength, with dry tree leaves insulation. The metal trays that have been used as absorber trays are prepared through empty oil cans. One of the main problems associated with commercial hotbox solar cooker is glass glaze, which is very heavy and fragile. To solve this problem recently authors have used specially designed transparent polymeric glazes (Dashora 2002, 2003). The polymeric material used as glaze has optical properties comparable to glass, is very light weight, is not as fragile as glass and has good weather resistance and UV stability along with good mechanical strength. Double glaze has been fabricated with two identical sheets of 3 mm thickness, 13 mm air gap in between and wooden beading.

III. EXPERIMENTAL METHOD

The thermal and cooking performances of the above mentioned cardboard solar cookers have been studied extensively. The temperature profiles of base plate and water load in the containers have been recorded through K-type thermocouples and CIE 305 digital temperature indicator. The ambient temperature is measured using a mercury thermometer of least count 0.1°C. During experiments, the instant solar radiation intensity on a horizontal surface I (W/m^2) has been measured using a pyranometer (National Instruments Ltd. Calcutta, instrument no. 0068). Figs.2-4 show the performance of systems over the day length on different days.

IV. COOKING PERFORMANCE

The cooking performance of the systems studied for various days for various months of the year is presented in Table.1

V. ANALYSIS OF RESULTS AND DISCUSSION

Figs.2-4 show the performance of systems over the day length on different days.. temperatue profile of PHSC when it was loaded with 2 kg. Water in four containers and the temperatures of both the base plate and water are recorded with solar insolation is shown in fig 2.

Comparison between temperature profiles of the base plate and water temperature for the PHSC and CSC when the cookers are with reflector and fully loaded with 2lt. of water in four containers at 10:00 a.m. and reloaded at 1:00 p.m. have been shown in Fig.3. fig3 shows that water temperature rises to 80°C in less than two hours and the base plate temperature is around 100°C in the first loading. In the second loading even lesser time is taken, as the initial base plate temperature is quite high (72.3°C). It shows that PHSC with reflector can be used for preparation of two meals per day.

fig 4 shows the Variation in second figure of merit (F_2) with different load.The average values for the figures of merit F_1 and $F_2$for the system is found out 0.14 and 0.44which are compatible with the values recommended by the Bureau of Indian Standards. (BIS 2000).

The cooking performances of all the systems show that these are ideal for boiling, roasting and baking purposes as can be seen from the Table 1. The food cooked has good taste, aroma, nutritive contents and acceptability.

Besides, being better in performance, the cost of the three solar cookers is less as compared to the cost of CSC, moreover their maintenance and handling is also easier.

VI. CONCLUSIONS

Beside using the solid waste material the developed solar cooker can be a boon to lower and middle income group people and can help in solving the problems of fuel deficiency, adverse impacts on health and environment to some extent. These cooker is highly economic, very light weight (2-3 kg.) and can be easily prepared and repaired by the users. its thermal and cooking performances are found to be comparable with the commercial solar cookers.

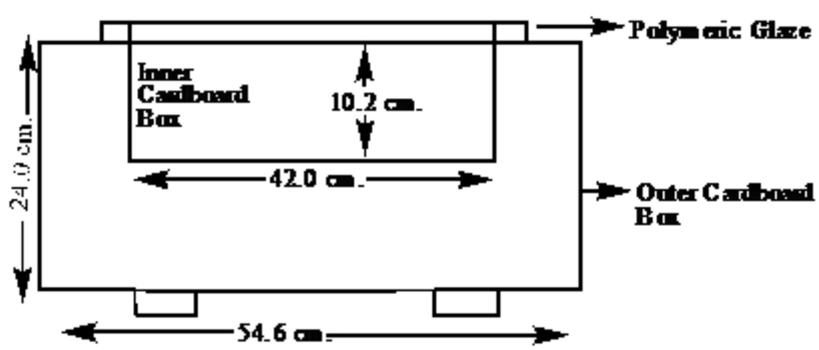

Fig.1: Schematic diagram of PHSC

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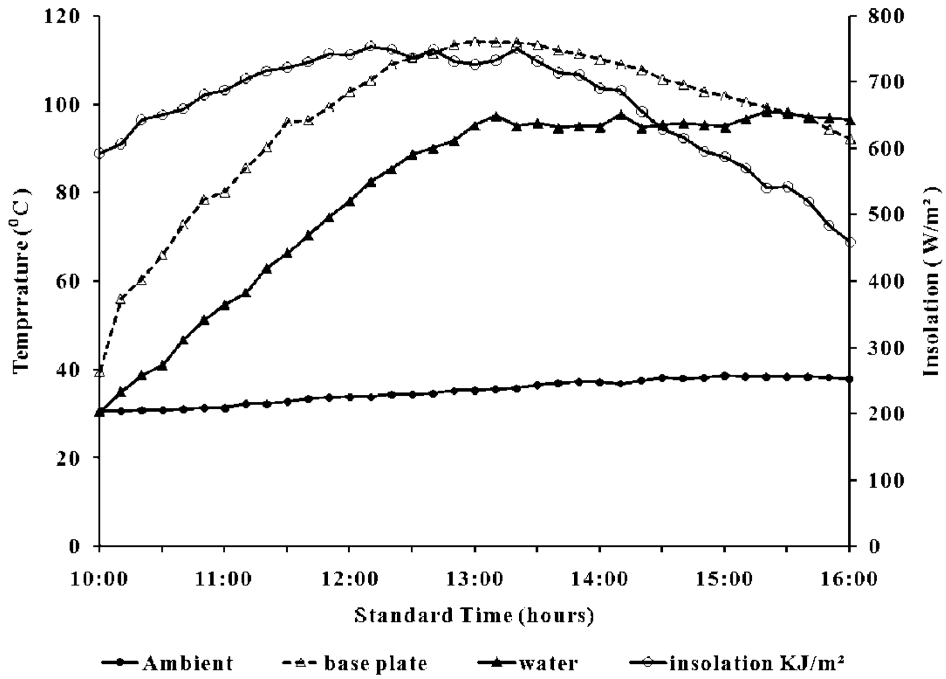

Fig.2: Temperature profile of base plate and water of PHSC with standard time when cooker was with full load and without reflector.

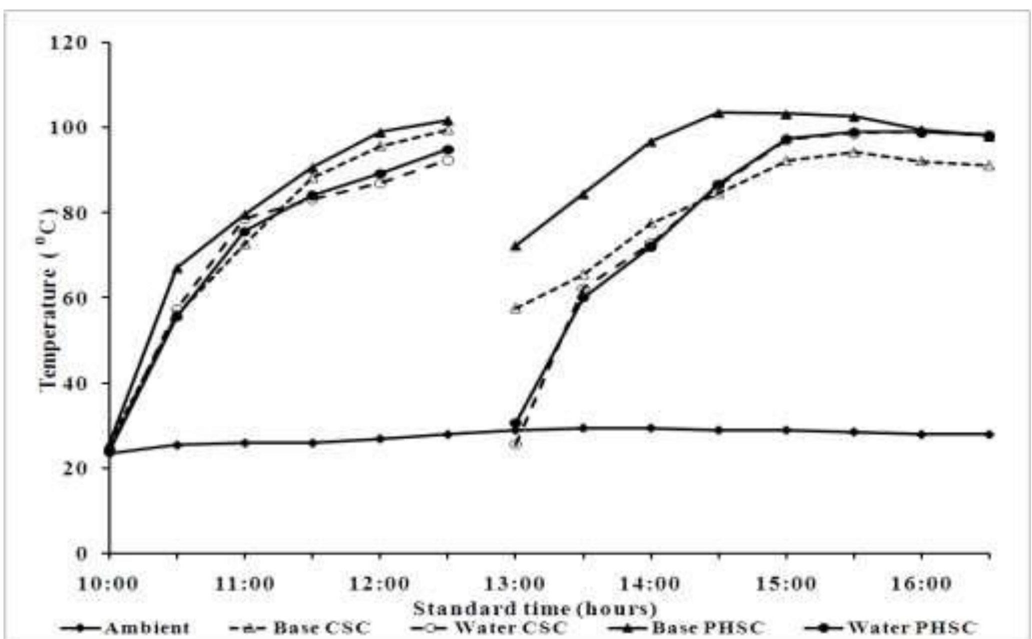

Fig.3: Temperature profile of base plate and water of PHSCand CSC with standard time when cooker was fully loaded at 10:00 am and reloaded at 1:00 pm with reflector.

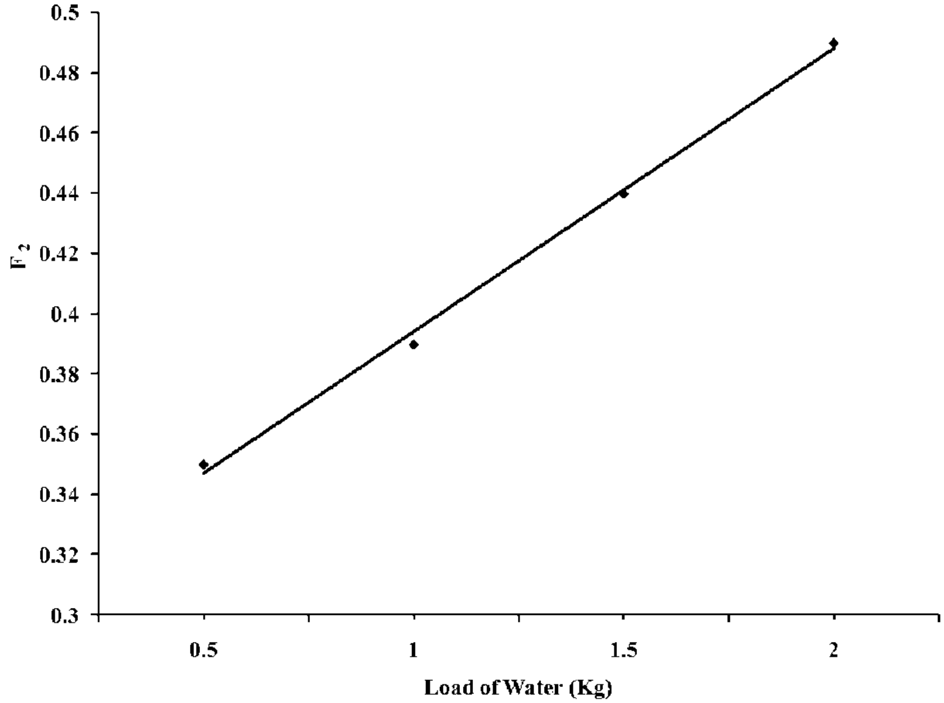

Fig.4: Variation in second figure of merit (F_2) with different load.

Table.1: Cooking performance of cardboard solar cookers

Months	Amount of load	CSC	PHSC
February	0.500 kg. Potatoes + 0.250 kg. water and 0.350 kg. soaked Kabuli Chana + 0.300 kg. water	10:00am–1:00 pm	10:00am–1:15 pm
May	0.800 kg. Rice + 1.2 kg. water	11:00am–12:30 pm	11:00am–12:45 pm
	0.700 kg. Moong Dal + 1.4 kg. water	10:30am–12:30 pm	10:00am–12:30 pm
	0.700 kg. Arhar Dal + 1.4 kg. water	10:30am–1:00 pm	10:30am–1:30pm
November	0.200 kg. Rice + 0.300 kg. water	11:00am–12:45 pm	11:00am–01:00 pm

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