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Experimental investigation of a box type solar cooker employing a non-tracking concentrator

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Abstract

The present work aims at development of a box type solar cooker utilizing non-tracking concentrator optics to enhance the solar energy availability in the box of the cooker for efficient cooking. A laboratory model of a box type solar cooker employing a non-tracking concentrator has been designed and fabricated, and its thermal performance has been investigated experimentally. The concentrator, consisting of two planar reflectors suitably positioned in an east–west configuration on an inclined framework, is mounted on the box of the cooker to reflect incident solar radiation on the base absorber of the cooker. The design angle of inclination of the framework is taken equal to the latitude of the location and it is adjusted seasonally. The thermal performance of the experimental solar cooker has also been compared with that of a conventional box type solar cooker whose dimensions and make are identical to the box used with the former and which was also tested simultaneously under similar solar insolation and ambient conditions. The experimental results obtained show that the concentrator solar cooker provides a stagnation temperature 15–22 °C higher than that of the conventional box type solar cooker using a booster mirror. It is also observed that the boiling point of water with the concentrator cooker is reached faster, by 50–55 min, than with the conventional box type cooker using a booster mirror. Thus, the solar cooker utilizing non-tracking reflectors provides increased heat collection and faster cooking compared to the conventional box type cooker. The results of the tests conducted have been analyzed and discussed.

Keywords: Non-tracking concentrator; Box type solar cooker; Optical design; Stagnation temperature; Load test

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Nomenclature

T_{pr}	plate temperature of solar cooker using non-tracking planer reflector
T_{pc}	plate temperature of conventional cooker
H	total solar radiation on cooker level
F_1	first figure of merit
F_2	second figure of merit
T_a	ambient temperature
α_1	angle of first mirror with concentrator base
α_2	angle of second mirror with horizontal
Φ	latitude of place
θ_m	acceptance half angle
W_1	width of first mirror
W_2	width of second mirror
D	width of absorber plate
D'	length of aperture
CF	concentrator factor

1. Introduction

Solar cooking offers an effective method of utilizing solar energy for meeting a considerable demand for cooking energy and, hence, protecting the environment. Considerable efforts have gone into the development and performance testing of a variety of solar cookers and their suitability for cooking different foods [1–4]. Solar cookers are mainly of two types: box types and concentrating types. Box type solar cookers are simple and suitable for limited cooking due to their relatively low heat collection capacity, while concentrating type solar cookers are capable of generating higher temperatures and can efficiently be used for a variety of cooking applications. However, the latter require continued adjustment of the orientation of the concentrator to reflect the incident solar radiation on the focus where the cooking pot is placed.

Different designs of solar cookers reported in the literature have separate provisions for energy collection and the cooking units. Morrison et al. [4] have utilized an evacuated type solar collector for high temperature, while Schwarzer et al. [6] utilized a double glazed solar flat plate collector. A solar cooker for inside the kitchen has also been developed using a flat plate collector as the energy collection unit [3]. Mills [5] developed a concentrating type solar cooker using a frequently adjusted Fresnel mirror system and a seasonally adjusted mirror with an evacuated tube collector, wherein thermal storage allows the stove to be permanently placed indoors for cooking. Field testing conducted on different designs of solar cookers has demonstrated their ability to cook a variety of foods and acceptability of the various designs by users [7,8]. The box type solar cooker is the most popular one due to its simple design and easy handling requirements. Mullick et al. [9,10] conducted extensive experimental studies and developed a test procedure for performance evaluation and standardization of box type solar cookers [11]. In India, half a million box type