

# Design and Development of Efficient Domestic Electric Cum Solar Oven

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**Abstract:** An improved design is proposed to investigate the characteristic study of an electric cum solar oven (ECSO) using circular cover in which both solar energy and electricity have been utilized as energy source for different food items. The newly designed solar oven has been fabricated by employing indigenous raw materials and it provides more reliable performance than the previously used solar oven for cooking of agricultural products and conventional food items. The new observations show that the cooking process of products is dependent on both the circular shape and climate conditions. The electrical heating has been used in combination with the solar energy to enhance the oven heating during the periods of lesser sunshine. The base of the oven was made up of the electric heating plate that is controlled by timer and an electric thermostat is used to control the heating of the oven. The performance and parameters obtained from the newly designed solar oven are found to be excellent than that obtained from previously known solar ovens for cooking of various edibles. It is shown that this newly designed solar oven can be efficient for cooking and preservation of all edible stuffs and appearance of cooked food products. The performance of the solar cooker has been checked under the local climate conditions of Faisalabad city to observe its efficiency with satisfactory results.

**Keywords:** Circular cover, ECSO, agriculture products, edibles and climate conditions.

## INTRODUCTION

Solar energy for cooking different agriculture products has been very actively used in the food processing industries, research laboratory [1, 2] and by the computer simulations [3, 4], and energy has played a dominant role in both system design and optimization [5]. The major outcome is to minimize operating and developmental cost in designing new solar systems in terms of shortening the time and reducing the uncertainty in going from process innovation at the small scale to industrial scale commercialization. Recent developments in food cooking and preservation technologies, and solar heat designing processes require the detailed understandings of the solar oven in many systems of interest industrially. Consequently, the suitable development, widely applicable, predictive economical method for cooking of agricultural products and commercial food items is an enduring goal of much of the food research in both engineering and science applications.

The world population is more than 6 billion and about 800-900 million people do not have enough food to eat. It has been estimated that world as a whole

more than 20-30% food grains and 30-50% vegetables, fruits and fishes etc. are lost before it reaches to the consumers. Cooking and drying are traditional methods for eating and preserving food. Solar oven is an effective method to cook food. Solar energy is diffuse in nature and thus suitable for commercial food cooking, locally available and thus saves transportation, solar ovens can be made locally of any size and capacity and solar ovens are economical if cash foods are cooked. The use of solar cookers is much required in many areas with good solar radiation intensity throughout the world. The reasons are economical, as the price of fuel for cooking is much higher and no longer affordable by many families; ecological, as in many areas deforestation is also associated with the use of wood as an energy source; and social, as the money used to buy fuel could be used to buy food, medications and other desires to improve the quality and standard of life. Because of the variety of solar cookers that has been presented in the literature, a general procedure to compare these cookers with one another is very complex [6]. The energy issues have been actively investigated in the laboratory by different researchers [7, 8]. It is important and beneficial for the consumer to have solar cookers of different varieties in terms of geometrical designs, performance and price however it is also a challenge to develop a uniform test standard for evaluating the characteristic performance of the cookers irrespective of their geometrical structure [9]. Many devices such as solar dryer, solar

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water heater, solar collector, solar concentrator and cooker etc. have been constructed. Our earth receives massive amount of solar energy i.e.  $5.4 \times 10^{24}$  joules/year, which is comparable to about 30,000 times the energy used at present time [10-12].

Effectiveness of solar energy and quality of cooked foods may be improved considerably by using an ECSO. Experiments conducted in many countries have clearly shown that solar oven can be effectively used for commercial food cooking/ baking. In a previously single family solar cooker, the thermal and cooking performance is tested, and this design development of solar cooker is small in size. The cooking of food product is a complex heat and mass transfer process which depends on external parameters such as temperature, relative humidity (RH), cooking material properties like surface characteristics, chemical composition, physical structure; size and shape of the product. The thermal profiles of this single family designed solar cooker make this oven more complicated for safe operation [5].

All methods of food cooking result in degradation of the food quality and cooking was no exception, cooking food does increase the concentrations of proteins, fats and carbohydrates. Direct cooking retains more vitamins than indirect cooking. Daily edibles and vegetables are generally rich source of carbohydrates and cooking especially direct sun cooking can retain these carbohydrates [13]. The presented research provides an improved design and performance study of electric cum solar for several food items, carrying a circular cover, during the winter season. Data regarding the ambient temperature, inlet temperature, outlet temperature, plate temperature and inner space temperature was recorded. To observe its performance under the local climatic conditions various baking and other edibles items were cooked and their cooking time and weight were recorded.

This paper is organized as follows: In materials and method section, the design fabrication of solar oven is described, and this section also describes the working principle and parameters used. Next, the results are presented and discussed with earlier data published by other authors in third section. The work is summarized in last section.

## **MATERIALS AND METHOD**

An improved design of solar cooker has been fabricated using indigenous materials. This research

presents with different methodologies to enhance design efficiency of solar oven for food items. The design, development and performance study of a circular type solar food oven named as electric cum solar oven (ECSO) which consists of two main parts, a circular type solar oven design and, an electric heating plate with temperature control device. The cooker was circular shape and made of wooden chipboard, painted inside with mat black board paint. The solar cooker was covered with a circular glass sheet of thickness 5mm [14, 15]. The solar cooker was consisted of following major steps: In the first step the whole unit (external frame cover) was circular shape and made of  $\frac{1}{2}$  inch wooden chipboard sheet. The diameter of external frame cover was 26inch and it is sufficient for domestic cooking of food items. The inside of the external box was painted with mat black paint which act as an insulator and its outer was painted blue. Two metallic handles were also screwed on the opposite sides of this cover to lift or carry the oven. In this cooker the second step was the fabrication of interior unit and this unit was the actual part in which the cooking utensils were placed for cooking purposes. The interior container/unit was circular shape and made of 24-gauge thickness copper sheet with diameter of 24inch. For solar thermal radiation, this copper sheet was ensured the maximum absorption of the sunlight. This interior unit was screwed to the inner side of the external unit on the rigid wooden supports, which already fixed to it [16]. The space between the external frame and internal unit was  $1\frac{1}{2}$ inch and this space was filled with insulation of glass wool. This insulation was black, dry and free from dust, and the weight of insulation used was 1kg [17, 18]. It was also painted from inner side with mat black board paint and its outer side was painted white. Thirdly, one transparent ordinary glass pan window of thickness 3mm was fitted in a circular wooden chipboard frame of diameter 26inch. The glass pan was fixed with  $\frac{3}{4}$ inch long thin iron nail in the housing made in the wooden frame for it. Strips of foam (20 x 1.5 x 0.2 inch) were pasted, under the glass sheets, in the housing for glass pan in the wooden frame to block air current and for safety of glass pan. A foam lining of width 1.25inch and thickness 1inch was made at the top of inner container for better air sealing. In the fourth step, the cooking utensils were designed and fabricated which were made of aluminum cans of 5.5 inch in diameter and 3 inch in depth. The outer surface of each can was painted black with mat black paint. Four such cans were used for cooking purpose of different food items and these pots have a capacity of nearly  $\frac{1}{2}$  kg of food



**Figure 1:** View of actual cooking chamber fitting with electric thermostat.

[19]. Finally, the electric heating plate that was fixed in the base of this newly designed solar cooker and the required temperature of ECSO was controlled through timer device. A thermostat was used to control the electrical supply of ECSO and it was turned off the electric supply when the cooker has attained a required set temperature (depending on the nature of food being cooked in the cooker). Figure 1 displays the actual cooking chamber fitted with thermostat. The light rays were focused on the base of the inner container of the solar oven with the help of concentrator. A reflector was used to reflect the light into the oven through upper glass cover. As a result, the temperature inside the oven was increased and it could be used to cook the food items inside the ECSO. The efficiency of this electric cum solar oven has been checked by cooking and baking various types of daily used food items.

In order to check the efficiency of the solar cooker we measured the ambient air, base and inner space temperatures. Base temperature was noted by a thermometer ranging 0 to 250°C, which was connected to the surface of interior container inside the cooker. The performance of the dryer has been investigated and we have also measured the cooking times of various conventional food items. The reduction in

cooking times due to use of electric thermostat has also been found.

## RESULTS AND DISCUSSION

The performance of the solar oven using electrical heating plates with temperature controller has been tested during the winter season in the months of January and February. We have tested the cooking of the conventional food items like frying and boiling of eggs, boiling of milk, pudding and custard using the ECSO under the local climatic conditions. Baking of fruitcakes was also carried out. Average cooking time was ranging from 20-45 minutes as compared to Azam *et al.* [15], where the average time was between 20-60 minutes. The purpose of the study was to utilize the solar energy and to accumulate the unadventurous fuels and money. It was observed that solar oven under study was much efficient at noon without combination of electricity. The solar energy provides adequate temperature for cooking and preservation purposes. The presented oven was much efficient when the electricity was also applied along with the solar energy. Different food edibles were cooked in this newly designed electric cum solar cooker. The food products to be cooked in this ECSO were pretreated appropriately and then placed in the cooking tray can decrease the cooking time.

The main results of solar oven are shown in Figures 2-4 for ambient air, base and inner space temperatures, respectively. These figures illustrate the bang of three different parameters of the development and performance study of ECSO fitted in addition of electric heater with temperature controller. Working of this electric cum solar oven is not restricted upon the availability of sun shine and it can effectively be used throughout the year as well as in hazy or cloudy days by using electricity along with solar energy. The cooking times for various food items are given in Table 1.

**Table 1: Cooking Time for Different Food Items**

Cooking Operation	Food Items	Quantity	Time
Baking and Frying	Fruit cake	¾ kg	45 minutes
	Frying eggs	2	20 minutes
Boiling	Boiling of eggs	2	25 minutes
	Boiling of milk	500 ml	20 minutes
Other Edibles	Pudding	½ kg	25 minutes
	Custard	175 grams in 500 ml of milk	35 minutes

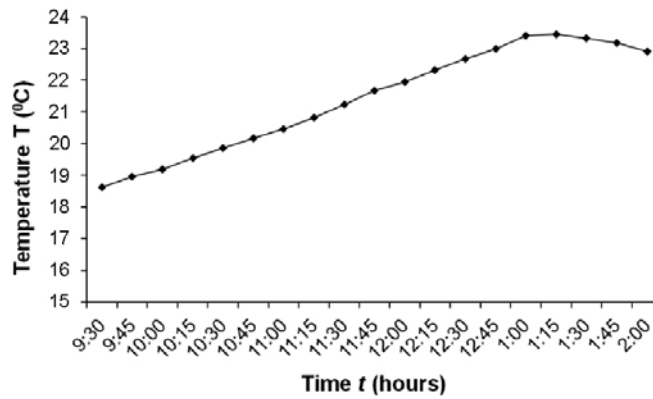


Figure 2: Variation of obtained average temperature (°C) values of ambient temperature with time T(t).

Figure 2 shows information about ambient air temperature that was recorded after an interval of every 15 minutes by hanging a mercury thermometer, ranging 0-100°C, in shadow outside the solar cooker. The ambient temperature was actually a source of measure of the solar energy and it varies with respect to time. It was observed that higher the ambient temperature more was the energy accumulated in accumulating devices which was solar oven [9-11]. The maximum observed ambient air temperature was 26.5°C and figure was plotted between the average values of ambient air temperature versus time. It is observed that the present ambient temperature is significantly lower than the earlier work of Azam *et al.* [15], showing that the presented results are more valuable.

Now consider the results observed for the case of inner space temperature. For the purpose of space temperature a mercury thermometer, having range 0-250 °C, was placed inside of the inner container. The data regarding the inner space temperature was recorded after an interval of every 15 minutes. The observed maximum value of inner space temperature attained during the working of the solar dryer was 96°C. The results (inner space temperature) obtained from the present ECSO agree well the results calculated by Azam *et al.* [15], for the solar cooker. The average data regarding inner space temperature versus time was plotted in Figure 3. It was seen that at starting time, the inner space temperature nearly equal to the ambient air temperature on every day. As the time increases, the increase in inner space temperature was rapid during first 3 hours and slows afterwards. The graph plotted between average values of inner space temperature versus time shows the variation in space temperature. It was observed from obtained data that inner space temperature decreases

slightly when the cooking pot was placed in the solar cooker. But after time it once again began to rise and continued to increase with the tumble of time. Clearly, in sunny days, it was noted that the optimum value of the inner space temperature was 80°C, confirming the earlier results of Azam *et al.* [15] and their references within.

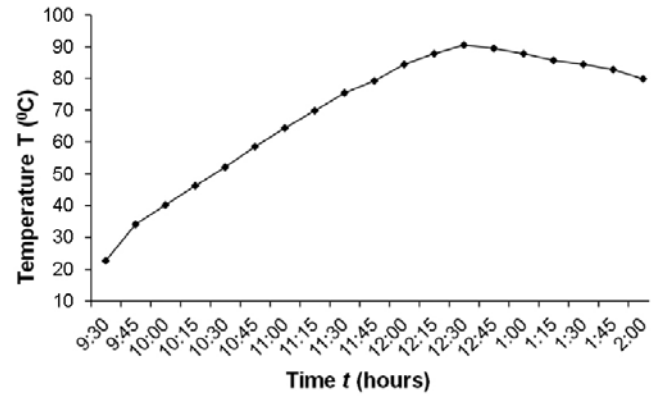


Figure 3: Variation of obtained average temperature (°C) values of inner space temperature with time T(t).

Figure 4 shows the average data of base temperature of the cooker versus time which were recorded by a thermometer, having range of 0-250 °C, placed in the oven touching the base after an interval of every 15 minutes. When the oven was placed in the sunshine for cooking, the time was considered as zero time. Data for various working days of the oven were noted. Data regarding the base temperature were also noted when only electricity applied. The obtained data reveals that the gain in base temperature was faster during the first 3 hours and slow after wards. These trends are similar to those observed in Azam *et al.* [15] where the gain in base temperature was only for 45 minutes. The observed maximum base temperature achieved was 104°C when ambient temperature was 25°C, which was close to the earlier base temperature

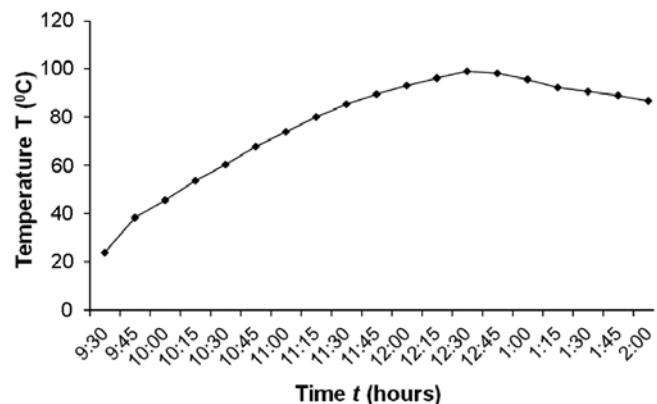


Figure 4: Variation of obtained average temperature (°C) values of base temperature with time T(t).

(115°C) noted by Azam *et al.* [15]. There were wide variety of cooking techniques used and the most common forms of daily used food items required cooking temperature above 90°C [5, 9]. It was remarkable that the base temperature which was suitable for cooking in this oven was 100°C for most of the edibles. It is observed from figure that the increase in temperature was rapid during first 45 minutes then it slows down afterwards. In some days, the temperature was not reached up to its optimum value; the reason may be the higher humidity.

We have checked the consistency and performance with the previous results taken from the experimental observations of Azam *et al.* [15]. They have designed and fabricated of a slope type electric cum solar oven (ECSO) and reported its performance in summer weather conditions. We have also compared our work with a previously published work by Stumpf *et al.* [20] as well as experimental design of Mishra *et al.* [21]. On shining days the shortest heat-up times from 40 to 99.5°C for 5 kg water were 36, 32 and 17 min corresponding to an average thermal power of 580, 653 and 1220 W for the three systems reported by Stumpf *et al.* [18]. The design performance and test of parabolic sphere oidal type solar cooker was checked by Mishra *et al.*, [21]. The aperture area of the cooker was 2.27m<sup>2</sup> with a 100 mm focal length. The efficiency of solar cooker was found to be 19.5%. It was capable of cooking with open utensils as well as pressure cooker type of containers. It was found that this box type cooker was not appropriate in the case of concentrator type solar cooker. Our locally fabricated solar cooker has shown good efficiency in comparison as depicted from the Figures 2, 3 and 4. In this cooker the inner space temperature and base temperature in sunshine were 100°C and 115°C without electrical heating and 110°C and 120°C with electrical heating respectively, confirming earlier results reported by Azam *et al.* [15].

Weather conditions play a significant role in order to check the performance of a solar cooker. The efficiency of solar oven depends upon the availability of sunrise and falls in ambient temperature, percentage of humidity, wind speed etc. The newly designed solar oven has been tested for cooking, boiling and baking time of various edibles and found more efficient than previously known solar cookers. The taste and cooking time of the food items was perfect and more reliable in all weather throughout the whole year.

## CONCLUSION

A newly designed electric cum solar oven has been developed and tested for different daily cooked edibles the home environmental circumstances of our country. The parameters under investigation in order to check the performance of the solar oven are ambient air temperature, average base temperature and inner space temperature, and time course of presented ECSO. The efficiency and simplicity of the ECSO are strong advantages, easy to fabricate, low cost for a family of average income, portable and allowing fast cooking time on sufficient load, making the cooking of conventional foods very efficient. The additional electrical backup setup ability makes it valuable in hazy days. Finally, the improved design is expected to be helpful for the predictions of cooking food items on commercial and industrial basis with more comprehensive design which fulfills the needs of all families.

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