

# Development of Reflector Integrated Solar Cooker and their Waste Heat Recovery for Drying Application

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**Abstract** – Food, cloth and shelter are the basic needs of all human beings. Today in developing country like India we are facing lot of problem regarding food making and food preservation. The use of fossil fuels is exhausted day by day, hence the time has coming to switch over this problems and find environment friendly energy source. Solar energy is abundantly available in the world. Solar cooking technique is most commonly used in all over world. This technique is having lot of advantages and dis-advantages. These paper include different methods to improve the performance of solar cooker in economical way. In this paper attempt has to be taken on improvement in design aspect of solar cooker, efficiency and cooking time.

**Key Words:** Solar Energy, Cooker, Food

## I INTRODUCTION

The use of renewable energy, particularly solar energy, is increasing day by day to promote its contribution to national economy. Solar energy is an important renewable energy that we get from the Sun. Solar energy is used for different purposes i.e. residential and commercial. Energy consumption for cooking in developing countries is a major component of the total energy consumption including commercial and non-commercial energy sources. Cooking is the most important energy consuming operation in the domestic sector, as energy for cooking accounts for 50% of the total primary energy consumption. According to Indian government survey, over 77% of rural households in the country were estimated to depend on firewood and chips for cooking. Over 7% used dung cake and only 9% used LPG. In urban areas, LPG was the primary source of energy in nearly 62% of households [1]. Hence, replacing the traditional cooking methods by solar energy can be considered as an alternative for meeting the energy crisis. A solar cooker or solar oven is a device which utilizes solar energy to cook food. All the energy consumed in India for various sectors such as industrial, agricultural, transport, households and others, about fifty percent of this issued for cooking alone. Most of the energy requirements for cooking are met by non-commercial fuels such as firewood, agricultural waste and cow dung cake in rural areas and kerosene and liquid petroleum gas (LPG) in urban areas. In India, 70% of population is living in rural areas. More than 80% of this population is dependent on firewood, dung-cake and agricultural waste for fulfilling their energy requirements. While in urban area, people are dependent on firewood, LPG, Kerosene oil and electricity. In rural areas, the dung-cake,

firewood, agricultural waste are available at free of cost but it requires a lot of effort in gathering these fuels and in urban areas the fuel is available at high cost. The fuel used by the population of India in rural or urban area is leading to deforestation and continuously polluting the environment. Solar energy represents non-polluting, inexhaustible renewable source of energy that can be utilized economically to supply man's needs for all the time. A solar cooker cum dryer was designed, developed and fabricated. The performance evaluation of the system was carried out. The solar cooker was used as the solar collector for the solar dryer. A solar cooker having size 750mm x 600mm x 150mm has been developed. Drying chamber of size 400mm x 500mm x 300mm was designed and fabricated. This equipment was tested under following conditions, solar cooker without blackening and reflector: It is seen that as solar radiations increases the temperature of cooker also increases. Solar cooker with blackening and without reflector: It is seen that the temperature is more than the cabinet temperature without black coating. Solar cooker with blackening and reflector: It is seen that the temperature is more than the cabinet temperature with black coating and without black coating.

## II LITATURE REVIEW

**1. Pankaj Saini, Vrind Sharma et al [2]** From this review on solar cooking technology, it may be concluded that solar cookers are beneficial to the community. This study covers solar cookers for off-sunshine cooking and energy storage materials for storage units. Solar energy is the most gifted energy source and solar cooking is one of the convenient and important techniques of harnessing solar energy. The main conclusions of this review are, Solar cookers are helpful in minimizing CO<sub>2</sub> emissions, conserving conventional fuels and helpful in making the environment green, The cylindrical storage unit is preferred over rectangular storage unit, off-Sunshine/Evening cooking is possible with solar cooker using PCMs as energy storage medium and PCMs having melting point above or close to 100°C are more promising for the storage unit of solar cookers.

**2. Chinnumol Francis, Victor Jose [3]** In this paper, an analysis on different performance improvement methods of box type solar cooker was done. Also, detailed description of various types of solar cookers, performance analysis and energy assessment of solar cookers were presented. Each discussed methods has certain kind of disadvantages. Future works can be done by changing properties of absorber plate

and by using latent heat storage materials for keeping food for a long time. Based on literatures, it is observed that box type solar cooker is the simplest device to collect the incoming solar radiation and convert it into heat energy. In this paper, a review is done in order to calculate and compare the different efficiency improvement methods of a box type solar cooker.

### 3. Aamir Shahzad, Teyyiba Kanwa et al [4]



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. The performance of the solar cooker has been checked under the local climate conditions of Faisalabad city to observe its efficiency with satisfactory results.

**4. Usha.C.Pawar, S. J. Shankargouda et al [5]** A review on the existing research and development in the field of solar cookers with latent heat storage system using phase change materials (PCM) is carried out in the increasing order of the year of work development. From the literature review it is concluded that the existing work in the field of solar cookers are more suitable for community purpose and can be used to cook food at late evening. However the suitable solar cookers for urban buildings are not yet to be developed as convenient as domestic gas cookers.

**5. Neha Garg and Dr. Noor Danish Ahrar Mundari [6]** In this paper gives a short review on box type of solar cooker using different types and number of reflectors. Paper wise review has been done which makes it easier to compare and evaluate the work of researchers. This review covers various box cookers designed and fabricated by altering geometrical parameters which effect thermal performance of the cooker, by using different type of reflector and varying number of booster mirror. Moreover, result of each paper has been discussed in the study.

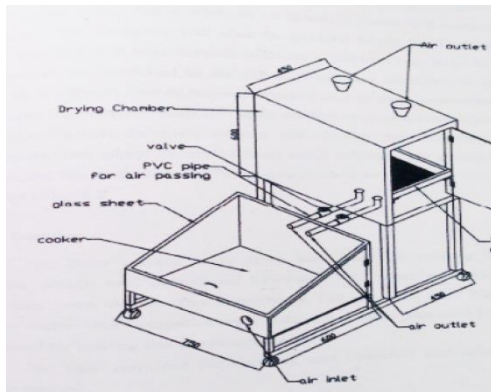
**6. Ismail Isa Rikoto, Dr. Isa Garba [7]** A comparative investigation was conducted using a box type solar cooker with two different cooking pots at the testing area of so KO to Energy Research Centre, Usmanu Danfodiyo University. The two pots are identical in shape and volume with one of the pots external surface provided with fins. The result of two tests (water heating and boiling test) revealed that 75cl of water was raised to 95oC in 112 and 126 minutes for finned and unfinned cooking pot respectively. These figures represent 11% reduction in heating time. Similarly 0.3kg of rice was cooked in 120 and 150 minutes for the finned and unfinned cooking pots respectively. This clearly demonstrates that fins improved the heat transfer from the internal hot air of the cooker toward the interior of the pot where the water and rice to be heated and cooked were kept.

### 7. Gore Mithun K, Taware Shridhar C et al [8]

In this paper it is observed that system producing steam for solar heating of water will be very useful in the industrial and commercial sectors this system can help to reduce the load the fossil fuel energy used to steam generation also will the help of black coating it is to achieve boiling temperature as well as to improve the efficiency of the system receiver surface temperature increases The solar cooker is always capable of cooking food within the expected length of time and based on the solar radiation levels. The bottom portion of the cooking vessel is directly exposed to the solar radiation and the remaining parts of the cooking vessel are having contact with the atmosphere. With minimum cooking power, the coated pressure cooker of capacity cook's the food at faster manner. This is due to the conductivity of the coating material provided in the cooker. Using coated surface cooker given more efficiency.



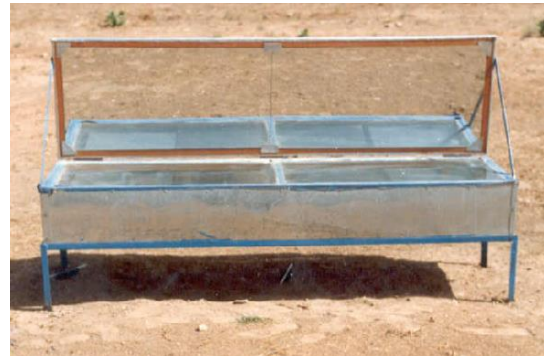
**8. Farid Sayyad, Nilesh Rajendra Sardar et al [9]**



The solar cooker cum dryer was designed and fabricated for cooking and drying of food materials. The solar cooker used as solar for drying operation. A solar collector of the size of 0.49 m<sup>2</sup> was designed along with separate drying chamber. Inlet and outlet holes were provided for exhaust air. Two PVC pipes with valves were provided for carrying hot air to drying chamber. While working as cooker, the holes and valves were closed and during drying operation they were opened. On the basis of the findings of investigation following conclusions were drawn. Solar intensity on collector surface was about 8 to 10 % more than that of horizontal surface. The average heat utilization factor and coefficient of performance of the dryer were 0.2 and 0.8 respectively. Solar cooker could be effectively used as dryer.

**10. N. M. NAHAR [11]**

The performance and testing of large size non-tracking solar cooker have been carried out by measuring stagnation temperatures inside cooking chambers, conducting cooking trials and comparing the performance with hot box solar cooker.



It has been found that stagnation temperatures were 118.5°C and 108°C in large size non-tracking solar cooker and hot box solar cooker respectively. Cooking trials have also been conducted and rice, lentils, kidney beans, cauliflower, backing of bati (local preparation made of wheat flour) etc. have been cooked successfully. It takes about 2 h for soft food and 3 h for hard food. The cooker is capable of cooking 4.0 kg of food at a time. The efficiency of the large size non-tracking solar cooker has been found to be 27.5%.

**9. Rushiprasad Patel, Raj Patel, et al [10]**



From this work, it is concluded that in hexagonal solar cooker due to concentration of radiation it behaves like black body and so compare to conventional cooker more temperature is gain. So in short period of time cooking can be achieve as faster rate. Due to rapid depletion in the supply of fossil fuels, the solar energy can be the most appropriate option compared to other alternative energy resources. The solar cookers have a relevant place in the present fuel consumption pattern. But the position of the sun varies continuously throughout the day time which affects the absorption rate. An advance design is to be proposed for the maximum utilization of solar radiation concentrated over solar cooker. In the proposed hexagonal solar cooker, the shape will be such that the solar radiation incident upon the surface gets concentrated towards the center of the cooker.

**III METHODOLOGY AND EXPERANTATION**

**Methodology:**



**Experimental Set up**

**1. Frame:**

The outside portion of cooker is made of wooden having wood thickness 10mm. The size of wooden frame is 750mm×600mm×150mm. The frame gives support to the system. While fabricating the wooden frame the angle of inclination is kept as 26°. The wooden frame also acts as an insulator.



2. G.I. sheet frame:

The inside portion is made of G.I. sheet of 22 gauge. The size of G.I. sheet frame is 742mm×589mm×605mm. The main function of G.I. sheet is to absorb the solar radiations and increasing the cabinet temperature. The G.I. sheet frame is smaller in size than wooden frame and in-between G.I. sheet frame and wooden frame the insulation is provided.

3. Insulation:

The insulation is provided to reducing the heat loss from cooker to atmosphere. The gap on 10mm is kept between G.I. and wooden frame for insulation. For insulation the glass wool is used as insulating material. Thermal conductivity of glass wool is 0.03-0.04 w/m<sup>2</sup>k which is very less hence act as thermal resistance.

4. Air circulating valves:

Air circulating valves are provided at bottom side and top side of cooker for air circulation. These valves are in closed position when we cooking rice in cooker but when cooking complete then these valves are opened. Cold air from atmosphere is come in cooker through bottom side valves. When cold air enters in cabinet it take heat from cabinet and get heated due to heating density of air become less and it move upward and supply to dryer through valve which is at top side of cooker also the flow rate of air is controlled by this valve.

5. Drying chamber:

Drying chamber is also made of G.I. sheet of 22 gauges. In drying chamber trays are provided on which item which has to dry is placed. The dryer take extra heat from solar cooker and drying take place rapidly.

**Experimental Procedure:**

Before start the cooking in cooker the further advices are taken the cold air inlet and hot air outlet valves are closed if this valves are not closed then the heat is not trapped in cooker and cooking does not take place. When solar radiations incidents on mirror they pass through mirror and trapped in cooker.

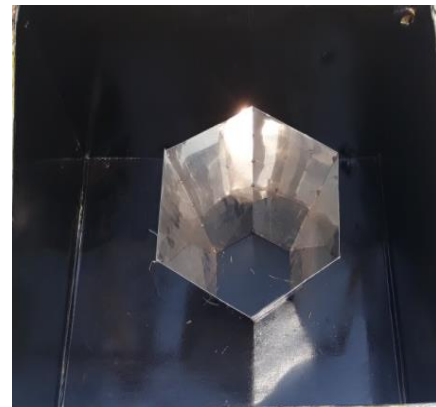
The heat from solar radiation is absorbed by sheet metal and temperature of cooker increases and cooking take place. It is seen that as solar radiation intensity increases temperature of solar cooker also increases.

The experiment is carried out as follow:

1. Rice is cooked in solar cooker without hexagonal reflector and without blackening the cooker. The time at which the rice is kept to cook in solar cooker from this time to time at which cooking take place the temperature readings are taken after every half hour at different points in cooker also the solar radiation energy is measured using flux meter. Similar procedure is followed for solar cooker with blackening and blackening with reflector.



Solar cooker without reflector



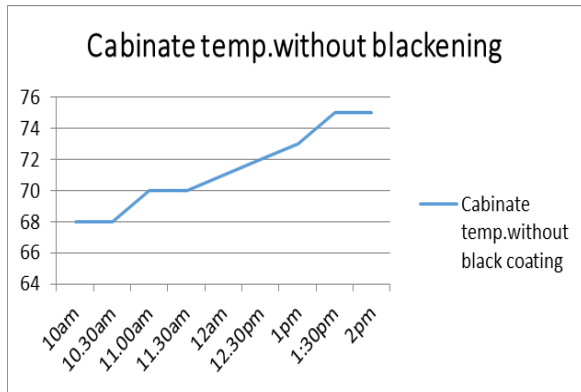
Solar cooker with reflector

2. After cooking take place the cold air inlet valve which is at bottom side and hot air outlet valve which is at top side of cooker is opened. When we open these valve the cold air from atmosphere come inside the cooker and take heat from cooker due to heating take place the density of air become less and it move in upward direction and enters in dryer when it pass through hot air outlet valve.

**IV OBSERVATIONS AND GRAPHS**

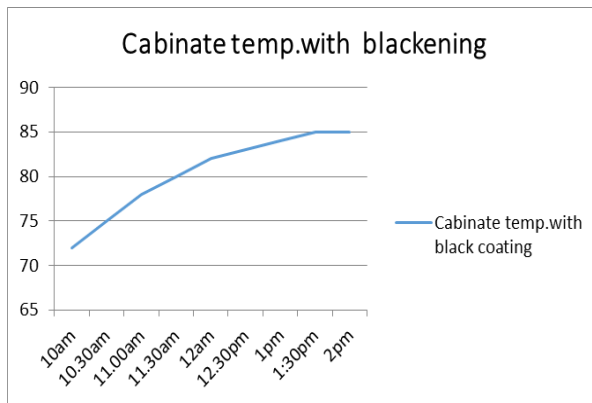
| Time (Hr) | Cabinete temp.with out black coating (°c) | Cabinete temp.with  black coating (°c) | Cabinete temp.with black coating and reflec- tor (°c) | Solar Radiation (W/M2) |
|-----------|---|--|---|------------------------|
| 10am      | 68  | 72                                     | 73  | 121                    |
| 10.30am   | 68  | 75                                     | 76  | 212                    |
| 11.00am   | 70  | 78                                     | 76  | 321                    |
| 11.30am   | 70  | 80                                     | 79  | 452                    |
| 12am      | 71  | 82                                     | 81  | 569                    |
| 12.30pm   | 72  | 83                                     | 82  | 647                    |
| 1pm       | 73  | 84                                     | 83  | 789                    |
| 1:30pm    | 75  | 85                                     | 87  | 815                    |
| 2pm       | 75  | 85                                     | 90  | 856                    |

The readings are taken at every half hour and graphs of time vs cabinet temperature is as follow.



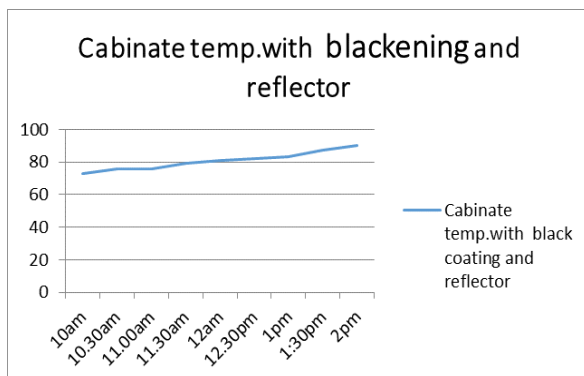
Graph 3 Variations in temp. of cabinet without blackening in a day

The graph shows that as the time increases the temperature of cooker also increases. From graph we saw that rise in temperature.



Graph 1 Variations in temp. of cabinet with blackening in a day

From graph it is clear that the cabinet temperature is more than the cabinet temperature without black coating.



Graph 2 Variations in temp. of cabinet with blackening and reflector in a day

The graph time vs cabinet temperature with black coating and reflector shows that the temperature is more than the cabinet temperature with black coating and without black coating.

## CONCLUSION

This experimental set up is to be designed and fabricated for simultaneous cooking and drying purpose. In this experimentation we compared the performance of solar cooker with and without hexagonal reflector with blackening effect. After experimentation we found that due to reflector mechanism and blackening effect we can achieve higher temperature in cooking box. The main specialty of this set is running dryer with the help of excess heat of solar cooker. After experimentation it was found that we can achieve 5-6°C more temperature with blackening effect and 9-10°C more temperature with reflector mechanism. Also time required for cooking is reduced by one hour as compared with experimental set up without blackening effect and reflector mechanism.

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