ALL TIME OPERATING SOLAR COOKERS FOR INDOOR AND OUTDOOR COOKING

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Solar cooking is one of the best clean and environment friendly option for developing as well as developed countries. Different types of solar cookers are designed and developed around the world but still they are not as popular as they should be. Two user's friendly all time operating small scale solar cookers were designed and developed. One solar cooker was developed using a small scale box type solar cooker and modified into a hybrid solar cooker by connecting five solar panels in place of the mirror. Heaters inserted in the cooker were connected with a battery to supply additional cooking power. The battery was charged by a solar PV panels attached with the cooker itself. Solar thermal power and electrical power supplied by the batteries made cooking faster than the conventional box type solar cooking. The light weight solar cooker was made with a solar casserole with a plate type heaters. The heaters were connected with a battery to supply electrical power for cooking. The battery was charged by a solar PV Panel which was installed at the terrace of the department. In this cooker the south facing window was selected inside the laboratory from were solar radiation partially incident on the cooker. Both the cookers were tested at the department of Physics, Sardar Patel University, Vallabh Vidyanagar, Gujarat, India. The weight of empty solar cooker was only 1.6kg. Both the cookers were found to work with satisfaction. To scale up the box type solar cooker the dimensions of cooker, solar panel, battery etc. has been estimated in this paper. The commercialization of designed solar cooker can become a boon to the society.

Introduction:

Food is one of the basic needs of human being. Cooking food requires fuels may be wood, cow dung liquid petroleum gas or electrical conduction or convection microwave ovens. All this alternatives are fast depleting and their cost also increases day by day. Moreover they cause deforestation and polluting the environment. Solar energy is a clean energy which has the potential to meet a significant proportion of the world's energy needs. It can be broadly classified into two systems; thermal energy system which converts solar energy into thermal energy and photovoltaic energy system which converts solar energy into electrical energy. The vital component in solar energy system is the solar collector. In the thermal system, the collector is heated by the sun and the heat is then transferred to a working fluid. In the photovoltaic system, the collector is comprised of photovoltaic cells which convert the solar radiation into electrical energy. Normally, these two collection systems are used separately. It has been shown that these systems can be combined to form hybrid photovoltaic/thermal (PV/T) system. The system generates both thermal and electrical energy simultaneously. The number of the photovoltaic cells in the system can be adjusted according to the local load demands. A number of simulation as well as experimental studies have been reported on the photovoltaic-thermal (PV/T) system. Among the first, Kern and Russell [1], gave the concept of PV/T collector using water or air as the heat removal fluid. Florschuetz [2]. Solar cookers offer smokeless way of cooking without continuous observation of the user. Unfortunately the conventional box type solar cooker are not easily accepted by the society because of the large time requirement for cooking and the unavailability of nearby shadow less open space. The increase in cost of land forces the consumer to select high rise buildings where it is hardly possible to have open space for solar cooking. The need of time is to design a solar cooker which can be used in kitchen itself. Not many solar cookers in market have used solar panels for cooking due to the relatively high cost, compared with more conventional energy sources such as oil, gas, coal.

History of solar cooking technology started with the invention of box-type solar cookers. The first solar box cooker was invented by a French–Swiss naturalist named Horace de Saussure in 1767. Especially in the twentieth century, this solar cooker type demonstrated a considerable development in terms of design and performance parameters. A solar box cooker basically consists of an insulated box with a transparent glass cover and reflective surfaces to direct sunlight into the box [3]. The inner part of the box is painted black in order to maximize the sunlight absorption. Maximum 4 cooking vessels are placed inside the box [4, 5]. It is a clear fact from the literature that solar cookers are very promising devices in the upcoming future. However, there are some handicaps concerning the solar cooking technology. Perhaps, the most challenging point of solar cookers is that they are not able to serve when the sun goes down. Some researchers performed intensive efforts on solar box cookers in order to allow late evening cooking. The cookers available in national and international market are not as popular as they should be. A photovoltaic (PV) generation offers advantages such as its simplicity of allocation, high dependability, absence of running fuel cost, low maintenance and lack of noise and less were and tear of parts of cooker and panel. Furthermore, the solar energy characterizes a clean, pollution free and inexhaustible energy source. In addition to these factors are the declining cost and prices of solar modules, an increasing efficiency of solar cells, manufacturing technology improvements and economies of scale [6].

Most of the current commercial solar modules are made from multi crystalline silicon. These are prepared from large-grained multi crystalline cells. The grains are generally much larger than the wafer thickness therefore the grain boundaries do not interfere much with the flow of electrons. Thus the cell yield efficiencies not very inferior to those obtained by mono crystalline cells, and have advantage of lower cost. Multi crystalline cells can be manufactured easily in square shape and hence when used in modules, a more a more complete utilization of the module area is realized. Consequently, the lower efficiency is compensated at module level. [7]. The size of the solar collector area and mass of PCM mass needed in order to provide adequate energy for several family-size. Different researchers have studied ionic liquid for heat storage in solar energy devices [8-10].

The small scale Photovoltaic and Thermal Hybridized (Casserole type) solar cooker as designed was developed and tested for the performance with (a) Thermal Energy Storage materials (TES), sand (b) Ionic liquids (IL) BF_4^- and PF_6^- [11-14]. The cooker was modified and made users friendly all time working solar cooker and The maximum utilization of the solar cooker was studied by cooking different dishes in it [15,17]. The hybrid cooker was made more efficient by tracking the solar panel with dual axis solar tracker [18].The hybrid cooker was converted into solar dryer and was used for agricultural applications. [19, 20].

The objective of present research work is to design user's friendly solar cooker which can cook little faster than the conventional box type solar cooker for more than 300 days per year. The electrically boosted heater has made it 24 hours usable cooker. 12 volt dc heater fixed in the cooker heats the food kept in the pot of cooker. The heater is connected with a battery which is charged by a photovoltaic panel.

2 Testing with power supply:

Initially, the solar cooker was tested inside the laboratory by connecting it with a fixed power supply. The minimum power required for cooking was confirmed by variable power supply. The cooker was tested for both the conditions i.e. with load condition and without load condition. Pt-100 thermocouples were used for the measurement of temperatures at different places of the cookers as they offer high accuracy and rapid response. These temperature sensors were connected with fifteen channel temperature indicators having least count of 0.01 °C.

2.1 Testing of casserole cooker with variable power supply:

The water heating test of solar cooker was performed with variable power supply with 45.6watt input power. The water temperature was measured with a pt-100 sensor which was connected with a temperature indicator. The temperature of water was recorded at an interval of 5 minutes. Initially the water temperature was at 29.1°C.As the power supply was switched on, there was rise in temperature of water .Within 30 minutes it reached to 99.5°C. This is the temperature when the food to be cooked starts to boil. After 60 minutes the supply was switched off and as a result, fall in temperature of water was observed. It was concluded by this test that the food can be cooked with 45watt power. On this basis, a solar module of 75watt capacity was utilized for power generation which can generate required power for cooking food. If the cooking is to be done in early morning or late night, then the power can be stored in battery backup and utilized as per the requirement.

2.2 Testing with solar PV module

Fig.1 solar cooker with test facility

Fig.1 show the test facility of the hybrid solar cooker respectively. 75 W solar PV module was mounted on the terrace of department while the cooker battery and test facility were kept in the laboratory. The PV module was connected to the battery backup through a charge controller. Two multi meters were connected for the measurement of voltage and current to calculate the power input to the heater. The heater is fixed at the bottom of the solar cooker. The pot with the water was kept on the heater. The testing was done in the laboratory so the cooker was closed with its lid. Pt-100 thermocouples connected with temperature indicator were used to measure the temperatures. The battery was connected for 60 minutes with the cooker then after it was disconnected and the temperature profile of the cooker was studied. Within one hour the boiling temperature was obtained which was essential for cooking.

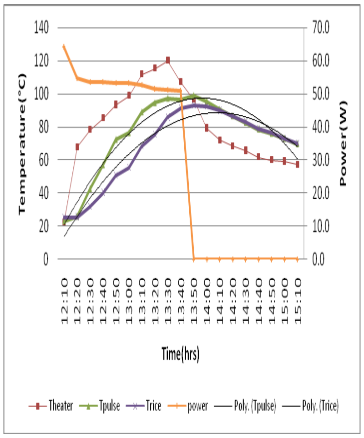


Fig2Temperature vs. time plot for rice and pulse **Fig3 rice and pulse cooked in solar cooker**

Fig. 2 and 3 shows Temperature vs. time plot for rice and pulse the rice and pulse cooked in solar cooker. It is very well known that the hard nuts cooking requires very large amount of time and energy. So hard nuts cooking test was also conducted for confirmation of better performance of solar cooker. Similar cooking tests were conducted for hot dog too. Fig 4 and 5 show the temperature vs. time plot for hard nuts and the photograph of hard nuts cooked in solar cooker. Fig. 6 and fig.7 show the graphs of temperature vs. time for hard nut cooking test and hot dog cooked in solar cooker.

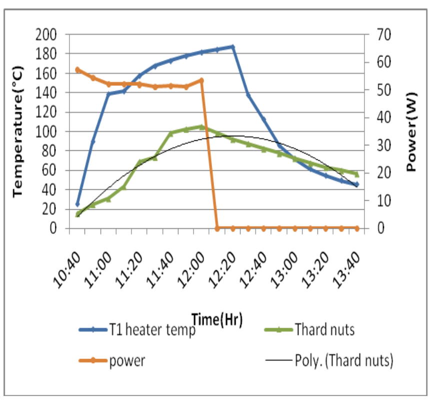


Fig4 Temperature vs. time plot for hard nuts cooking **Fig5 hard nuts cooked in solar cooker**

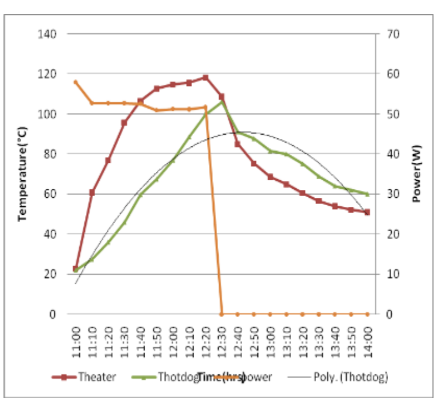
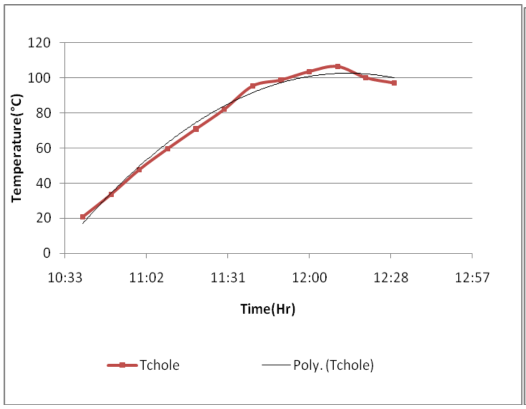


Fig6Temperature vs. time plot for hotdog cooking test **Fig7 hotdog cooked in solar cooker**

2.3 Outdoor Testing

Rice cooking test was conducted after conducting the hard nuts cooking test. The presoaked rice was kept in the cooker at 10:00 am. As the cooker was pre heated, the rice reached to boiling temperature within 30 minutes only. The supply was given for 40 minutes and then the battery was disconnected from the cooker. The cooker was allowed to get cool and then the rice was taken out of it. Figure 8 and 9 show the hardnuts and rice cooking respectively.



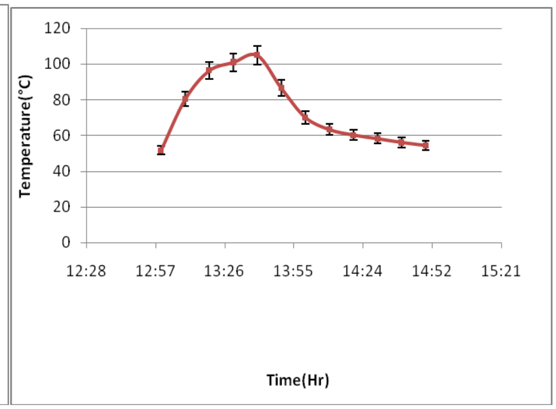


Fig. 9 Temperature vs. time for hard nuts cooking Fig. 10 Temperature vs. time for rice cooking

3 Result and Discussion

The experimental observations related to the temperature profile indicate that the developed solar cooker can be easily used for cooking of the soft food materials like rice as well as hard nuts.
The conventional cooker needs two hours in attaining 80°C. Reflector is essential for cooking two meals in winter days. The cooking performance of the cooker shows that it is ideal for boiling, roasting and backing purposes.
The food cooked has delicious taste, aroma, high nutritional value and acceptability. The sensory evaluation test was performed by the panel of twelve judges on the attributes of texture, flavour, appearance, aroma and mouth feel. For most of the dishes the scores were higher or equal for solar cooked food compared with conventionally cooked food.

4 Conclusions

1. Cooking needs only 50 watt power which can be easily generated by the solar panel of 75 watt and can be stored in the battery so that this power can also be utilized for light and fan of the house in case of power failure or even it can provide power to night lamp for the whole night.
2. The battery operated cooker does not need any preheating and tracking like conventional cooker and can make it more user's friendly. The cooker can cook at any convenient time of the user and hence even breakfast and dinner can also be prepared. It is sufficient for cooking food for a small family of four members. Although it is possible to scale it up even for a large family. It does not need any open space like terrace so can be used easily in high rise buildings or flats in cities. The designed solar cooker can have optimum utilization.
3. There were two types of energy utilized for cooking. 1) Thermal energy and 2) Electrical energy generated by PV module. As a result of this although the food quantity was triple fold, the cooking time was only half compared to the cooking done inside the laboratory.

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