Comparative Study of Solar Cookers

Tharesh K. Gawande, Dr. D.S.Ingole
Assistant Professor, Department of Mechanical Engineering PRMIT&R, Badnera-Amravati India
Professor & Head, Department of Mechanical Engineering PRMIT&R, Badnera-Amravati India
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Abstract: Now days the use of solar energy becomes very crucial because of its ample availability throughout the year free of cost, and on the contrary conventional fuels are becoming precious. So it became imperative to use this energy for maximum possible occurrences. One of the challenging areas of the use of solar energy is the solar cooking. This paper presents a comparative study of various types of solar cookers commercially available. The need of heat storage systems for solar cookers, their feasibility, materials and their properties are also discussed.

Keywords: Solar energy, solar cookers, heat storage system, renewable energy systems.

I. INTRODUCTION

Renewable energy is always a hot talk. As the energy demand is increasing day by day with increasing population, the need of renewable energy is becoming the very essential in every field. There are various sources for the renewable energy like wind energy, geothermal energy, solar energy, etc. Among all the solar energy is very popular and easily available source of renewable energy. This energy is used for various applications like generation of electric energy, home heating, drying and cooking, etc. To run these appliances one needs to extract or convert solar energy into some useful form. This is done by using either PV cells or solar collectors, which depends on the various parameters like need, economy or durability. One of the well-known uses of solar energy is cooking of food. The solar cookers are used for cooking. These solar cookers are being used since 17th century. Till now, lot of solar cookers have been developed and used. But, still it needs a lot of research before selecting any one type for its use at specific region. It depends on geographical area, heat requirement, and type of food to be cooked. The solar cookers are used for community cooking also. The adaptability of solar cookers can protect environmental pollution over the use of conventional wood cooking. At the same time, it can help to increase national economy as it will reduce the use of LPG. Hence the encouragement for use of solar cooker is very essential. This can be done only when solar cookers will show better performance than conventional cooking systems. Hence the selection and designing of solar cooker as per specific requirement becomes very crucial.

II. TYPES OF SOLAR COOKER

Solar cookers are mainly classified according to its characteristics.
i. Depending upon heat supplied
   a. Direct solar cooker
   b. Indirect solar cookers
ii. Depending upon heat storage
   a. Solar Cookers with storage
   b. Solar Cookers without heat storage
   c. Depending on application
      a. House hold (Small Scale) Solar cookers
      b. Community Solar Cookers
2.1. Direct Solar Cookers

Direct types are those which use the sun radiations directly to cook the food. They are
i. Box type Solar Cooker
ii. Panel Cooker
iii. Parabolic Cooker.

All these cookers of each type have been proposed by researchers. And also has been tested to investigate the performance parameters for each type. These direct cookers have advantages that these are simple in design and maintenance. They are economical and easy to operate also. Mostly these are used for the house hold purpose. But its limitation is that these can be used only in day time. Its productivity and efficiency decreases with clouds. Also these cannot be used in night.
2.1.1 Box Type Solar Cookers

Solar box cookers (sometimes also called as solar ovens) are the most common and economical type of solar cookers. The first solar box cooker was invented by a French–Swiss naturalist named Horace de Saussure in 1767. These box cookers are very simple in construction. Also they are made of low cost materials. The outer box is often made of wood or low thermal conductive material. The inner box is made of insulating material, which is covered with clear glass or with plastic, and often has a reflector of aluminum. According to Solar Cooker International, solar box cookers can accommodate multiple pots which can operate at moderate temperature. It generally operates up to 95°C but it can reach a temperature of 140°C. These cookers are sometimes classified depending upon the use of glazing glass. Single or double pain glasses are the most common structures. These enable to receive a higher solar transmission. The solar box cooker needs direct sunshine to operate and produces zero emission. Its temperature range is low as well it cannot be operated after day time. Many non-profit organizations promote these cookers worldwide in order to help reduce fuel costs and to slow down deforestation caused by the use of woods used for cooking.

2.1.2 Panel Cookers

The panel cooker are the next simple form of solar cooker after box type which is generally consists of a cooking pot or pan and usually is darkened or blackened. Also it has oven cooking bag or transparent glass bowl along with a reflective panel. These panels can be made from aluminium foil over corrugated carton, or from tin or sheet metal panels polished to a high sheen and also with mirrors. The oven bag or glass bowl allows the suns UV rays to penetrate towards the food in turn trapping the energy; (heat) preventing its escape.

The reflector panels concentrate the sun light onto the cooking vessel containing the food, in the same way the panels do so on the solar box cookers. A panel cooker are simpler in design and are more economical to develop also which results in the same cooking effectiveness for most all situations. Depending on the pot and the food being cooked some panel cookers can achieve comparably higher temperature. Since most foods cooked in these types of cookers usually contain more moisture (soups, stews, meats etc.) they will usually cook around 100°C-122°C. Performance of solar panel cookers do not seem effective under cloudy conditions as it highly depend on reflected radiation.

2.1.3 Parabolic Solar Cookers

Parabolic cookers are also called curved concentrator cookers which can reach much higher temperatures and can cook more quickly. This concentrate the incident sun rays on a cooking vessel. It needs more accuracy to focus the sunlight on the vessel (i.e. food pan). If the sunlight is not correctly focused on the food in the pan, lesser will be the solar concentration which will reflect in poor food cooking quality. There are
many designs proposed by the researchers for parabolic solar cooking appliances. Because of the parabolic shapes and with the aid of reflecting material quite a lot of solar energy is concentrated in the focal point. A high temperature of the range 200°C to 300ºC can be reached because of a combination of the circular design, the size and the better sun rays reflecting material surface. It is suitable for baking, roasting and grilling also.

![Parabolic Solar Cooker](image)

Parabolic solar cookers functioning depends upon the operating skills as its sun ray tracking is require for continuous concentrated sun rays. Hence these cookers are difficult to handle and operate. Like other solar cookers, parabolic cookers also work in day time only and cannot be operated after sunshine (in evening or night time). The effectiveness of parabolic solar cooker depends upon the size of the collector as it would generate less heat in case of small size whereas may generate intense heat if it is too large.

2.2 Indirect Solar Cookers

In indirect type solar cookers, the cooking is carried out at a distance or at another place from the solar collector. And then this heat needs to be transferred to cooking vessel from collector. These indirect solar cookers are mainly sub classified as i. Flat plate collector, ii. Evacuated tube collector and iii. Concentrating type collector.

2.2.1 Flat Plate Collector Solar Cookers

A flat plate collector solar cooker was designed and tested by Schwarzer et al. having one plastic and one glass cover to study its performance. The experimental results of their study showed an increase from 0.35 to approximately 0.4 in the sensible efficiency of the solar collector. The possibility of indoor cooking with less time is the advantage of this cooker. Whereas; the main disadvantage is a non-removable vessel which makes cleaning of vessel and food difficult.

2.2.2 Evacuated Tube Collector Solar Cookers

Solar cooking system based on evacuated tube solar collector provides high thermal power and temperatures without tracking and allows cooking in the shadow. Kumar et al. has designed a solar cooker based on evacuated tube solar collector. These cookers are consists of an evacuated tubular solar collector and a pressure cooker. The heat transfer mechanism in Kumar et al.’s system may be explained as: when the incident solar radiation falls onto the collector tubes which heats up the working fluid inside these tubes. Due to which the vaporized fluid rises upwards to the heat exchanger and conveys energy by condensation to the water flowing in the secondary loop of the heat exchanger. Then this condensed fluid returns to the collector tubes where again heating is takes place and the process of heat transfer repeats again. It is observed that, the heat supplied in evacuated tube is more than normal flat plate collector which means these cookers operates at more temperature than flat plate collector cookers. The collector is made up of evacuated double-wall (concentric) glass tubes mounted on parabolic concentrating chrome-nickel reflectors. The cooking time depends on meteorological and thermo-physical properties of fluid used in a pipe.

2.2.3 Concentrating-type Collector Solar Cookers

In this type of cooker either parabolic or spherical shape dish is used to concentrate the solar radiation. It is mainly divided into two types i. Fresenel lens concentrator cooker ii. Scheffler dish Cooker

Fresnel lens Cookers:

In this type of solar cooker, a lens is used to focus the incident rays on a evacuated tubes which increases the concentration of the rays. The Fresnel lens can be designed according to the condition that the incident light is perpendicular to the surface of the lens. This cooker can provide cooking temperature more than 200° C.
Scheffler Dish Cooker:

A scheffler dish cookers are generally used for community cooking. In this type of solar cooker, steam is generated which is further used for cooking. It consists of the dish parabolic or elliptical which focuses the incident rays on receiver as shown in figure 5. This receiver then absorbs the incident solar energy and transfers it to the water flowing through it. The energy is sufficiently high to convert water into steam. This generated steam is then stored continuously in the steam storage tanks until the required temperature and pressure are attained. Then this steam is transported to the kitchen through insulated pipes. This steam is either injected directly into the cooking pots or made to circulate in the jacketed wall of the cooking pots. An array of a minimum of three Scheffler dishes is required to obtain satisfactory performance from such SSC systems and therefore, these systems are suitable only for kitchens involved in the cooking of more than 200 meals at a time. This type of system is used in kitchen of temple’s kitchen at Shirdi, Maharashtra and Mount Abu, Rajasthan (India).
2.3. Solar Cookers with Storage

Solar cooking without storage is time limited. It cannot take place in the evening or in cloudy environment. It can be carried out only in sun shine hours. This can be solved by providing heat storage systems. In which heat will be stored at the time of pick hours of sun shine and then this heat can be provided to cooking pot at required time by proper heat transfer system. There are some heat storage systems like sensible heat storage and latent heat storage. Specific heat capacity of the material is utilized to store the thermal energy in sensible heat storage. While storing and retrieving the thermal energy is based on the latent heat of fusion of the material, where storage medium undergoes a phase transformation which can be either solid to solid or solid to liquid is latent heat storage. These phase change material (PCM) possesses some thermal, physical & chemical properties. Like suitable phase-transition temperature, high latent heat of transition, good heat transfer, favorable phase equilibrium, high density, small volume change. Low vapour pressure, long-term chemical stability, compatibility with materials of construction, no toxicity, no fire hazard etc.

As latent heat storage has more capacity and ability to retrieve heat, it is an area of research since last few years.

Latent Heat storage System:
It uses phase change material to store the heat which can retrieve the energy when outside temperature will be less. For cooking purpose PCM should have the following thermodynamic properties:

- Melting temperature in the desired operating temperature range
- High latent heat of fusion per unit volume
- High specific heat, high density and high thermal conductivity
- Small volume changes on phase transformation and small vapour pressure at operating temperatures to reduce the containment problem
- Congruent melting
- Kinetic properties
- High nucleation rate to avoid supercooling of the liquid phase
- High rate of crystal growth, so that the system can meet demands of heat recovery from the storage system
- Chemical properties
- Chemical stability
- Complete reversible freeze/melt cycle
- No degradation after a large number of freeze/melt cycle
- Non-corrosiveness, non-toxic, non-flammable and non-explosive materials
- Economic properties
- Low cost
- Availability

There are availability of PCM available in market. It can be classified as

- Organic – i. Paraffin compound  ii. Non-paraffin compound
- Inorganic- i. Salt Hydrate  ii. Metallic
- Eutectics- i. organic-organic  ii. Inorganic-inorganic  iii. Inorganic-organic

Organic Materials - Organic materials are further described as paraffin and non-paraffin. Organic materials include congruent melting means melt and freeze repeatedly without phase segregation and consequent degradation of their latent heat of fusion, self-nucleation means they crystallize with little or no supercooling and usually non-corrosiveness.

Inorganic materials - Inorganic materials are further classified as salt hydrate and metalloids. These phase change materials do not supercool appreciably and their heats of fusion do not degrade with cycling.

The major problem in using salt hydrates, as PCMs is the most of them, which are judged suitable for use in thermal storage, melts incongruently. As n moles of water of hydration are not sufficient to dissolve one mole of salt, the resulting solution is supersaturated at the melting temperature. The solid salt, due to its higher density, settles down at the bottom of the container and is unavailable for recombination with water during the reverse process of freezing. This result in an irreversible melting–freezing of the salt hydrate goes on decreasing with each charge–discharge cycle.

Eutectic - A eutectic is a minimum-melting composition of two or more components, each of which melts and freeze congruently forming a mixture of the component crystals during crystallization.

So, As per the requirement one has to select the suitable PCM which will be best one in terms of thermal, chemical and physical suitability.

III. CONCLUSION

Various types are solar cookers are discussed in this paper. The selection of type of cooker depends upon the parameters of cooking like amount of food to be cooked, where to be cooked, time availability etc.
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Also it depends on geographical condition, economical aspect also. Depending upon the literature survey mentioned cookers can be compare depending upon their performance. Table 1 gives the brief idea for the selection of solar cooker.

<table>
<thead>
<tr>
<th>Type of cooker</th>
<th>Maximum attainable Temperature for cooking after certain time, in °C</th>
<th>Preferred for Household (small Scale)/ Community cooking</th>
<th>Availability</th>
<th>Limitation</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Box Cooker</td>
<td>95-100°C</td>
<td>Small Scale</td>
<td>Sun shine hours</td>
<td>Takes More time</td>
<td></td>
</tr>
<tr>
<td>Solar Panel Cooker</td>
<td>100-122</td>
<td>Small Scale</td>
<td>Sun shine hours</td>
<td>Not useful in cloudy condition</td>
<td></td>
</tr>
<tr>
<td>Parabolic Cooker</td>
<td>120-170</td>
<td>Small Scale</td>
<td>Sun shine hours</td>
<td>Need a large aperture are of collector</td>
<td></td>
</tr>
<tr>
<td>Evacuated Tube Cooker</td>
<td>250-300</td>
<td>Small scale / Community</td>
<td>Sun Shine hours</td>
<td>Too costly</td>
<td></td>
</tr>
<tr>
<td>Fresnel Lens Cooker</td>
<td>250-300</td>
<td>Community</td>
<td>Sun Shine hours</td>
<td>Costlier and need skilled operator</td>
<td></td>
</tr>
<tr>
<td>Scheffler Cooker</td>
<td>150 – 180</td>
<td>Community</td>
<td>Day Time as well sometime after it</td>
<td>Need large area and suitable for community cooking only</td>
<td></td>
</tr>
<tr>
<td>Solar Cooker with heat storage</td>
<td>120</td>
<td>Small scale</td>
<td>Day time as well evening</td>
<td>Need a separate design for storage as well as for transfer system</td>
<td></td>
</tr>
</tbody>
</table>

It also becomes very important to focus on the heat storage system so as to improve the efficiency and availability of cooker for cooking at any time, irrespective of the sun shine. Solar cooker with latent heat storage system looks more promising option where it needs proper designing for better efficiency and adaptability.

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