Solar Cooker for Evening / Night Cooking Using Solar Heat Storage Materials

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Abstract:
In this paper, Use of Phase Change Materials (PCMs) for evening / night cooking is discussed. The use of a solar cooker is limited because cooking of food is not possible due to frequent clouds in the day or in the evening. If storage of solar energy can be provided in a solar cooker, then there is a possibility of cooking food during clouds or in the evening, and the storage will increase the utility and reliability of the solar cookers. Hence, PCM is the heat option to store the solar energy during sun shine hours and is utilized for cooking in late evening/night time Phase Change Materials (PCMs) are latent heat storage materials. As the source temperature rises, the chemical bond within the PCM breaks up as solid to liquid (as is the case for solid-liquid PCMs, which are of particular interest). The exothermic process and therefore, the PCM absorbs heat. Upon storing heat in the storage material, the material begins to melt as the phase change temperature is reached. The temperature then stays constant until the melting process is finished. The heat stored during the phase change process (melting process) of the material is called latent heat. Latent heat storage has two main advantages. (i) It is possible to store large amounts of heat without a large increase in temperature density. (ii) Because the change of phase at a constant temperature takes some time to complete, it becomes possible to smooth temperature variations. The comparison between latent and sensible heat storage shows that using latent heat storage, storage densities typically 5 to 10 times higher can be reached. Author has been published few papers on Solar Cooking using PCMs for evening and night cooking. Author intention to write this paper to introduce all of you about this technique. You will find here few designs on this technique, which are published by the author in past.

Keywords: Solar Energy, Solar Cooker, Latent Heat Storage Material, Evening / Night Cooking, Phase Change Materials

Design, Results & Discussions

Fig.1: Box Type Solar Cooker with PCM Storage in the Bottom (Buddhi and Sahoo, 1997)

The prototype solar cooker based on evacuated tube solar collector with PCM storage unit (S.D. Sharma et al, 2005) has two hollow concentric aluminum cylinders, and its inner and outer diameters are 304 mm and 441 mm, respectively, and is 420 mm deep and 9 mm thick. The space between the cylinders was filled with 45 kg of erythritol (melting point 118 °C, latent heat of fusion 339.8 kJ/kg) as the PCM. A pump circulates the heated water (HTF) from the ETSC through the insulated pipes to the PCM storage unit by using a stainless steel tubing heat exchanger that wraps around the cooking unit by closed loop. During sunshine hours, heated water transfers its heat to the PCM and is stored in the form of latent heat through a stainless steel tubing heat exchanger. This stored heat is utilized to cook the food in the evening time or when sun intensity is not sufficient to cook the food. They concluded that two cooking times (noon and evening) were in a day. Noon cooking did not disturb the cooking in the evening, and evening cooking using PCM storage was found to be faster than noon cooking. Experiments and analysis indicated that the prototype solar cooker yielded satisfactory performance in spite of low heat transfer; the modified design of heat exchanger in the thermal storage unit will enhance the rate of heat transfer in the present set up.

Fig.2: Latent Heat Storage Unit for Evening Cooking in a Solar Cooker

Sharma et al. (2000) recommended that the melting temperature of a PCM should be between 105 and 110 °C for evening cooking. As Sharma et al. (2000) recommended that the melting temperature of a PCM should be between 105 and 110 °C for evening cooking. Therefore, there was a need to identify a storage material with appropriate melting point and quantity, which can cook the food in the late evening. To store a larger quantity of heat in a PCM, more input solar radiation would be required. Hence, Buddhi and Sharma (2000) used a latent heat storage unit for a box type solar cooker with three reflectors. They used acetanilide (melting point 118 °C, latent heat of fusion 222 kJ/kg) as a PCM for night cooking. To conduct the cooking experiments with the PCM storage unit, a double glazed (glass covers) box-type solar cooker having a 50 cm × 50 cm aperture area and being 19 cm deep was used. In this solar cooker, three reflectors were provided, i.e., the middle reflector was mounted in a hinged manner on the PCM container. From the experimental results one can conclude that the cooking experiments were successfully conducted for the evening cooking time up to 20:00 h with 4.0 kg of PCM. No work has been performed on solar cookers with latent heat storage using ETSC. We tried to develop a solar cooker based on Evacuated Tube Solar Collector (ETSC) with PCM storage, as shown in Fig. 4. It consists of an ETSC, a closed loop pumping time-containing water as Heat Transfer Fluid (HTF), a PCM storage unit, cooking unit, pump, relief valve, flow meter, and a stainless steel tubing heat exchanger.

Fig.3: Box Type Solar Cooker with PCM Storage Having Three Reflectors

Photograph of the stainless steel tube around PCM heat storage unit.

Thermo physical Properties of Various PCMs used for Solar Cooking

<table>
<thead>
<tr>
<th>Chemical formula</th>
<th>Molecular weight</th>
<th>Melting point °C</th>
<th>Latent heat of fusion (kJ/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERYTHRITOL</td>
<td>122</td>
<td>118</td>
<td>339.8</td>
</tr>
<tr>
<td>ACETAMIDE</td>
<td>46</td>
<td>110</td>
<td>98</td>
</tr>
</tbody>
</table>

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Conclusion
We can conclude that Phase Change Materials (PCMs) is capable for solar heat storage and best option for night / evening cooking. We had designed, developed and tested our cylindrical unit with box type solar cooker having single or three reflectors and found that PCM unit was successfully to cook the food in night 8 P.M. We also tested our cylindrical unit design with evacuated tube solar collector as a indirect type solar cooker and results was satisfactory for Japanese climate.

References

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