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A Review on Different Techniques of Solar Food Cooking

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Abstract :-Energy consumption for cooking is unavoidable, though there is continuously increasing the fuel price as well as scarcity of exhausting fossil fuels. Because cooking is the prime priority of human life all over the world. Cooking contributes a major part in sharing of total primary energy consumption in India. Hence it needs an alternative energy source for this purpose. Solar cookers are the best substitute for, heating, cooking and pasteurizing applications. In this paper a review has been made to study the existing literature in the field of solar cookers with the latent heat storage system using PCM.

Keywords: Solar Energy, Thermal Energy Store, Phase Change Material.

1. Introduction

Energy requirements for cooking in the countries like India and China are very high, particularly due to the large population. In India about 47% of the energy comes from wood for the cooking application, and this value is higher than 75% in many African countries, such as Mali or Burkina Faso, it reaches up to 95% [1]. Approximately 34000 and 140,000 solar cookers are used in India and China respectively [2]. The different energy distribution in India is as shown in Figure 1.

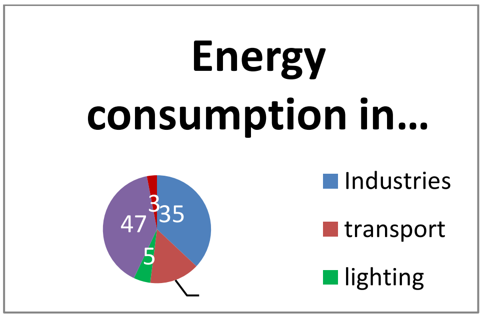

Figure 1: Energy Consumption in India

Cooking by using solar energy is the best substitute over wood and fuel all over the world. Since solar energy is the most promising alternative energy which is available freely and abundantly. It is free of pollution and as well high nutritional value of the cooked food [3]. Solar cooking is the process of heating food up to boiling temperature of water, and being kept at that temperature for a particular period of time depending upon the characteristics of the food. The Mass flow rate of the gas is 2-3 more at the beginning [4]. As per the principle of Lof [5-6], maximum cooking energy is required during the sensible heating period, and less heat is required for physical and chemical changes. Boiling temperature of food, consumes 20% of heat, the vaporization of water consumes , 35% of heat and 45% of heat goes as convection losses from cooking vessels.

2. Classification Of Solar Cookers

Solar cookers are broadly classified as (1) Solar cookers without storage and (2) Solar cookers with storage. The classification of solar cookers is as shown in figure2. In the present review an attention is given to solar cooker with latent heat of storage type because to solve the problems related to cooking like, cooking at off sunshine hours, cooking at shed and to make cooking as convenient as domestic cooking stoves.

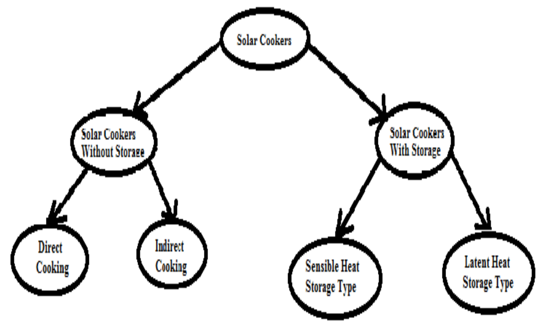

Figure 2: Classification of Solar Cookers

3. Solar Cooker With Latent Heat Of Storage

Domanski *et a*l. [7] in the year 1995 developed a solar cooker and investigated for whether cooking is possible during off sunshine hours using Phase change materials (PCMs) .They developed a cylindrical shaped cooking unit with a two concentric aluminum (0.0015-m thick),vessel with gap between inner n outer walls, and are connected together at their tops using four screws. The annular gap is filled with 1.1 kg of stearic acid (melting temperature 69^{o}C; latent heat of fusion 202.5kJ/kg; thermal conductivity 0.172 W/m^{o}C for liquid; density 848 kg/m^3), or 2 kg of magnesium nitrate hexahydrate (melting temperature 89^{o}C;latent heat of fusion 162.8kJ/kg; thermal conductivity 0.490W/m^{o}C for liquid; density 1550 kg/m^3) which leaves sufficient space for expansion of PCMs during melting. They reported that the performance of cooker depends on the solar irradiance, the mass of the cooking medium and the thermo physical properties of PCM. The overall efficiency of the Cooker during discharging of the PCM was found to be 3–4 times greater than that for steam and heat-pipe solar cookers, which can be used for indoor cooking. However, the rate of heat transfer from the PCM to the cooking pot is slow, and more time is required for cooking the evening meal. The model is as shown in figure 3.

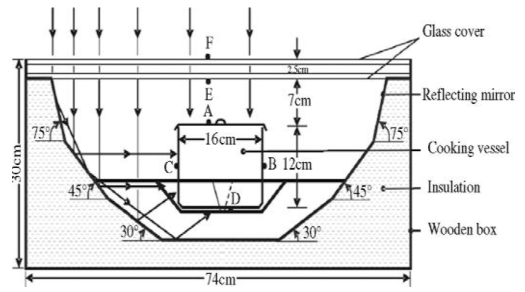

Figure: 3 Schematic diagram of the solar cooker by Domanski et al.

Buddhi and Sahoo [8] in the year19997 designed and tested a box type solar cooker by using commercial grade stearic acid (melting temperature 69^{o}C; latent heat of fusion 202.5kJ/kg; thermal conductivity 0.172 W/m^{o}C for liquid; Density848kg/m^3) as a Phase Change Material to store latent heat. Phase change material was filled below the absorber plate. The authors reported that, during the mode of PCM discharge, the heat transfer rate is very slow from PCM to the Cooking pot. And the time required for evening cooker is more as shown in figure 4.

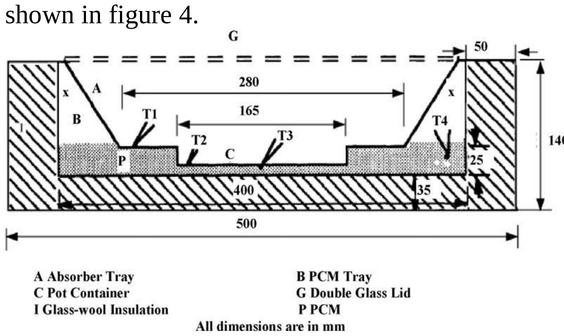

Figure: 4 Box type solar cooker (By Buddhi et al. 1997)

Sharma *et al.* [9] in the year 2000 developed a cylindrical PCM storage unit for box solar cooker with three reflectors for night cooking. Acetamide (melting temperature 82^{o}C; latent heat of fusion 263kJ/kg; thermal conductivity 0.5 W/m^{o}C; density998 kg/m^3) is filled in the cylindrical storage unit and it was concluded that by using 4.0kg of acetanilide, cooking can be done up to 8:pm and due the rate of heat transfer from PCM to cooking vessel is high due to this cooking can be faster. The model is as shown in Figure 5.

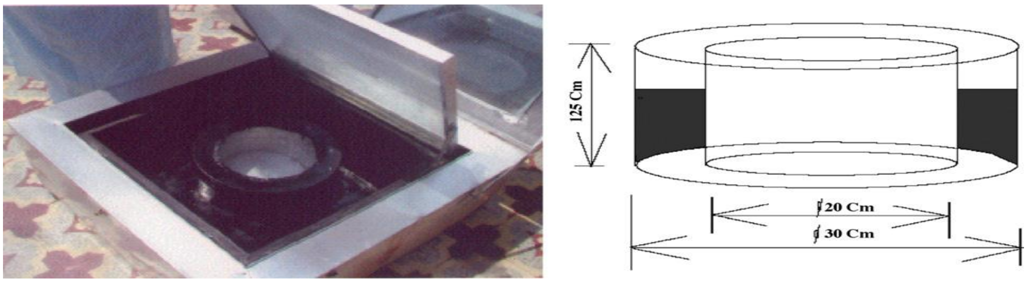

Figure: 5 Box type solar cookers Model (By Sharma et al. 2000)

Sharma *et al.* [10] in the year 2005 developed a solar cooker using evacuated tube solar collector (ETSC) with Erythritol (melting temperature 118oC; latent heat of fusion 339.8kj/kg;themal conductivity 0.326 W/m^{o}C; density 1300 kg/m^3)as Phase change material (PCM) for heat storage .They reported that the heat can be stored whenever sun energy is available and can be used for cooking during off sun shine time. And cooking is possible for two times a day i.e. at noon and at evening time. And during the evening, cooking rate is faster than noon due to use of PCM storage heat energy. The solar cooking unit is as shown in figure6.

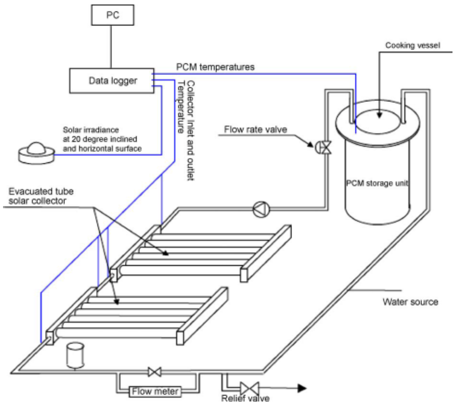

Figure: 6 solar cooker based on ETSC with PCM unit. (By Sharma et al. 2005)

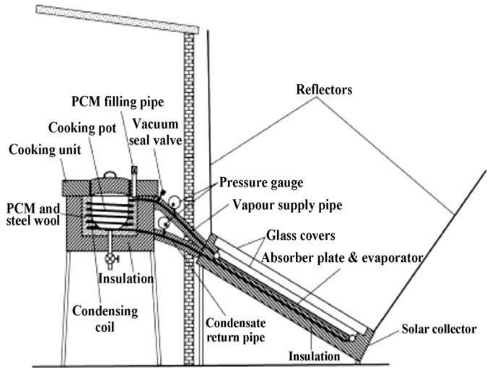

Figure: 7 solar cooker (by Hussein et al.2008)

Hussein *et al*. [11] in the year of 2008 reported a novel indoor cooker by using wickless heat pipe of elliptical cross section kept at outdoor, flat plate solar collector with an integrated indoor PCM thermal storage and a cooking unit. Magnesium nitrate hexahydrate (melting temperature 89 8C, latent heat of fusion 134 kJ/kg) is used as the PCM inside the indoor cooking unit of the cooker. Different experiments have been carried out on solar cooker and results found have reported that present solar cooker can be successfully used for cooking three times meals as well to keep food warm at night and in the early morning. The arrangement of solar cooker is shown in figure 7.

Muthusivagami *et al* [12] in the year 2009 presented a novel concept of solar cooker which is under experimental investigation by using PCM-A-164. Thermic fluid is selected as the heat transfer fluid to exchange the heat between the collector and the cooking unit. PCM A-164 filled in 1 m long; 22 mm diameter tubes will be made as a heat exchanger to store the energy during sunshine hours and to retrieve the energy during off-sunshine hours. Oil will be circulated below the finned hot plate to keep the surface temperature around 140–150 8C.The concept diagram is shown in figure 8.

Kedare *et al*. [13] in the year 2014 submitted the project named as Arun Dish based solar system to the Ministry of New & Renewable Energy Government of India. The project concludes that, it can prepare 2,000 to 3,000 meals on a clear sunny day and it can save average fuel of 40 to 50 kg LPG on a clear sunny day. It is also reported that the project is more suitable for community use. Arun solar cooker is shown in figure 9.

Rane *et al*. [14-15] in the year 2014have reported, solar collector with absorber integrated heat storage that generates steam at 2 to 3 bar. The size of solar collector is 1.7 m^2 and its weight is about 40 kg. Using steam, 28 kg rice was cooked in the first week of January 2017 at IIT Bombay. However, boiling water was initially used, which was collected from other solar collector. Using cold water in the beginning, 12 kg rice per clear sunny day can be cooked. This solar collector is non - seasonal tracking type and costs INR 10,000/m^2 of solar collector. The solar collector is shown in figure10.

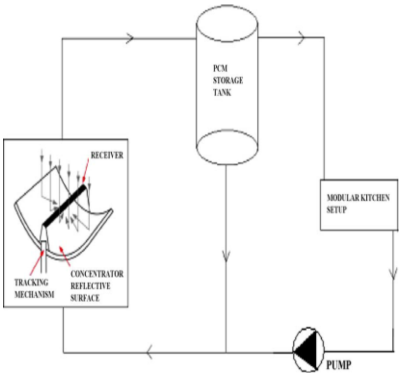

Figure: 8 solar cooker (muthusivagami et al.2009)

Figure: 9 Arun dish based solar cooker (By IIT Bombay 2014)

Figure : 10 solar collector with integrated heat storage (By IIT Bombay 2014)

The summery of review is as shown in Table 1 below

Table: 1 PCM used in solar cooking

Reference	Domanski et al.	Buddhi and Sahoo	Sharma et al	Sharma et al	Hussein et al	Muthusivagami et al	Kedare	Rane et al.
PCM tested	stearic acid & Magnesium Nitrate Hexa-Hydrate	stearic acid	Acetamide	Erythritol	Magnesium Nitrate Hexa-Hydrate	PCM-A-164	Water	---
Maximum T_{stag}	95°C	122°C	127°C	138°C	140°C	140°C	170°C	130°C

4. Conclusion

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.

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