Processing of agricultural products in solar cooker for income generation

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Abstract

Solar cookers are generally used for cooking of food for domestic as well as community places. But solar cooker can also be used in agro based industries e.g. processing of Indian goose berry (*Aanwala*), jujube (*Ber*), for making jam & jelly, chutney and preparation of rose syrups & gulkand from rose and sugar. In this paper community solar cooker has been used for this purpose. These materials are prepared in agro based industries by using conventional fuels. Performance of a community solar cooker having absorber area 3.2 m^2 has been described. The cooker is based on hot box principle having a single reflector. The width to length ratio of reflector is four so that azimuthal tracking is not required. Therefore, cooker is kept fixed, facing equator. The maximum stagnation temperature inside cooking chamber during summer is 146 ^oC and 136 ^oC in winter. The efficiency of the cooker is 28.4 %. The cooker can be used twice a day for about 254 days and once a day for about 67 days in a year. The cooker can be used for preparation of rose syrup, gulkand and, processing of Aanwala, ber etc. for jam & jelly making. The cost of the cooker is only is Rs 40,000.00 (1.0 US $= Rs. 50.00) that can be recovered in less than a year. As per requirement more number of solar cookers can be used and more income can be generated.

Keywords: Solar thermal energy; Solar cookers; Community; Process products, agro based industries, income generation

1. Introduction

With fast growing population and rapid growth of industries, the consumption of energy is increasing enormously. At the present rate of energy consumption the world energy resources will be exhausted in 50 to 100 years. Therefore, there is need to harness solar energy and other alternative energy sources.

Cooking accounts for a major share of energy consumption in developing countries. Most of the cooking energy requirement is met by non-commercial fuels such as firewood (75%), agricultural waste and cow dung cake (25%) in rural areas. The fuel wood requirement is 0.4 tons per person per year in India. In rural areas firewood crisis is far graver than that caused by a rise in oil prices. Poor villagers have to forage 8 to 10 hours a day in search of firewood as compared to 1 to 2 hours ten years ago. One third of India's fertiliser consumption can be met if cow dung is not burnt for cooking and instead is used as manure. The cutting of firewood causes deforestation that leads to desertification. The solar radiation outside the earth's atmosphere remains practically constant and is 1.353 kW/m^2. The eccentricity of the earth's orbit results in variation of about $\pm$ 3 %. The radiation received at the earth's surface is considerably reduced below the extraterrestrial value due to reflection, absorption and scattering of radiation in the earth's atmosphere, therefore, the total solar radiation received at the earth's surface consists of direct and diffuse radiation. India occupies better position regarding solar energy potential. In the month of December, solar radiation increases from 2.6 kWh/m^2day at Gulmarg to 3.7 kWh/m^2day at New Delhi, 4.1 kWh/m^2day at Calcutta, 4.5 kWh/m^2day at Jodhpur and 4.3 kWh/m^2day at Kodaikanal.

During the period November to February i.e. winter season, most of the Indian stations receive 4.0 to 6.3 kWh/m^2. During summer season i.e. March to May, this value ranges from 5.0 to 7.4 kWh/m^2. The arid and semi-arid part of the country receive much more radiation as compared to rest of the country with the mean annual daily solar radiation received at Jodhpur i.e. 6.0 kWh/m^2. Therefore, solar cookers seem to be a good substitute for cooking with firewood.

The first solar furnace was fabricated by naturalist Georges Louis Leclerc Buffon (1707-1788). But Horace-de-Saussure (1740-1799) was first in the world to use the sun for cooking. Augustin Mouchot, a french physicist, described a solar cooker in his book “La Chaleur Solaire” published in Paris, in 1869. He has also reported in the same book earlier work on solar cooking by English astronomer, Sir John Herschel, in South Africa, between 1834 and 1838. Adams , an army officer, made India’s first solar cooker in 1878 and he cooked food in it at Bombay, India (Adams, 1878). Since then different types of solar cookers have been developed all over the world. The solar cookers can be classified into three broad categories (I) Reflector/focusing type (ii) Heat transfer type and (iii) hot box type. These are described below.

1.1 Reflector/focusing type

The reflector type solar cooker was developed in early 1950's (Ghai, 1953) and was manufactured on a large scale in India (Ghai *et al.*, 1953). Attempts were also made in 1960's & 70’s to develop a reflector type solar cooker (Duffie *et al.*, 1961; Löf & Fester, 1961; Tabor, 1966; Von Oppen, 1977). However a reflector type solar cooker did not become popular due to its inherent defects e.g. it required tracking towards sun every ten minutes, cooking could be done only in the middle of the day and only in direct sunlight, its performance was greatly affected by dust and wind, there was a danger of the cook being burned as it was necessary to stand very close to the cooker when cooking and the design was complicated.

1.2 Heat transfer type

In the heat transfer type solar cooker, the collector is kept outside and the cooking chamber is kept inside the kitchen of the house (Abot, 1939; Alward,1972; Garg and Thanvi, 1977). But this type of solar cooker also did not become popular because of its high cost and only limited cooking can be performed.

1.3 Hot box type

The third type of cooker is known as hot box in which most of the defects of above two types of cookers have been rectified (Ghosh, 1956; Telkes, 1959; Garg, 1976; Nahar, 1990; Grupp *et al*, 1991; Nahar *et al.,* 1994, Biermann et al 1999, Funk, 2000, Algifri et al 2001, Ahmad, 2001, Rao, 2003, 2005, Kumar, 2005). Different types of solar cookers have been tested and the solar oven (Garg *et al.*, 1978; Malhotra *et al.*, 1983; Nahar, 1986; Olwi & Khalifa, 1988) has been found to be the best. Though the performance of the solar oven is very good but it also requires tracking towards sun every 30’, it is too bulky and is costly. Therefore, the hot box solar cooker with a single reflector (Parikh & Parikh, 1978) is being promoted at subsidised cost by the Ministry of New and Renewable Energy, Government of India and the state nodal agencies in India since 1981-82 and 620,000 solar cookers were sold up to the August 31,2008 (MNRE, 2008). It is also not becoming popular in large scale due to its defects: it also requires tracking towards the sun every 60 minutes. Therefore, its operation also becomes cumbersome. Considering this, a two reflector hot box solar cooker was developed by Gupta and Purohit (1986) so that the tracking is avoided for three hours but the problem of poor performance during winter remains as well in this solar cooker also. Therefore, attempts were also made by Nahar *et al.* (1994) to improve performance of hot box solar cooker during extreme cold weather by using Transparent Insulation Material (TIM) in between two glazings and a hot box solar cooker with a TIM was tested in an indoor solar simulator of the University of Wales, College of Cardiff. It was further improved by Nahar (2001) by providing one more reflector and convective heat losses have been suppressed by using Transparent Insulation Material as suggested by Hollands (1965), Goetzberger *et al.* (1984, 1992), Hollands *et al.* (1992), Nordgard and Beckman (1992), Platzer (1992a, 1992b), Nahar *et al.* (1995). The cooker is kept in such a way that one reflector is facing south and the other is facing east in the forenoon so that tracking is avoided for 180 minutes. In the afternoon, one reflector is facing south and other is facing west so that again tracking is avoided for 180 minutes. The maximum time taken for cooking a dish is less than three hours. To avoid tracking completely a non-tracking solar cooker has been designed, developed and tested by Nahar (1998).

Solar cookers developed and described above are suitable for meeting the requirement of 5 people and are not suitable for processing of large quantity of agricultural produce for income generation. Considering this a community solar cooker has been developed by Nahar *et al* (1993) that can meet requirement of 80 people. This cooker is suitable for processing of products in agro based industries. In this paper potential of solar cooker for income generation by processing of Indian goose berry (Aanwala), jujube (ber) for making jem & jelly, chutney and preparation of rose syrups & gulkand (A sweet preparation mostly consumed with beetle leaves) from rose and sugar have been reported. These materials are presently prepared in agro based industries by using conventional fuels.

2. Design

The cooker is based on hot box principle having a single reflector. The cooker has been designed in such a way that the width to length ratio for reflector and glass window is about 4 so that maximum radiation falls on the glass window. This has helped in eliminating azimuthal tracking, which is required in simple hot box solar cooker towards the Sun every hour because the width to length ratio of reflector is 1. This cooker is always kept fixed facing equator. The device consists of a double walled hot box. The outer tray is made of galvanised steel and the inner of aluminium. The space between them is filled with glass wool insulation. The inner tray is painted black by black board paint. Two clear window glass panes of 4 mm thickness have been fixed over it with a wooden frame. Three doors have been provided in the rear side for loading and unloading the cooker. The doors have been made leak proof by rubber gaskets. A 4 mm thick plain mirror reflector is fixed over it and arrangements have been made so that it can be tilted to 120^o from the glass window. Therefore, it is effective in summer as well as when the altitude of the sun is very low. The absorber area of the cooker is 3.12 m^2. Specially designed cooking utensils are rectangular in shape, having dimensions of 560 X 540 X 75 mm^2. These are made from aluminium sheet. Twelve such utensils can be kept inside the cooker. The schematic of the cooker is shown in fig.1 and actual installation is shown in fig.2.

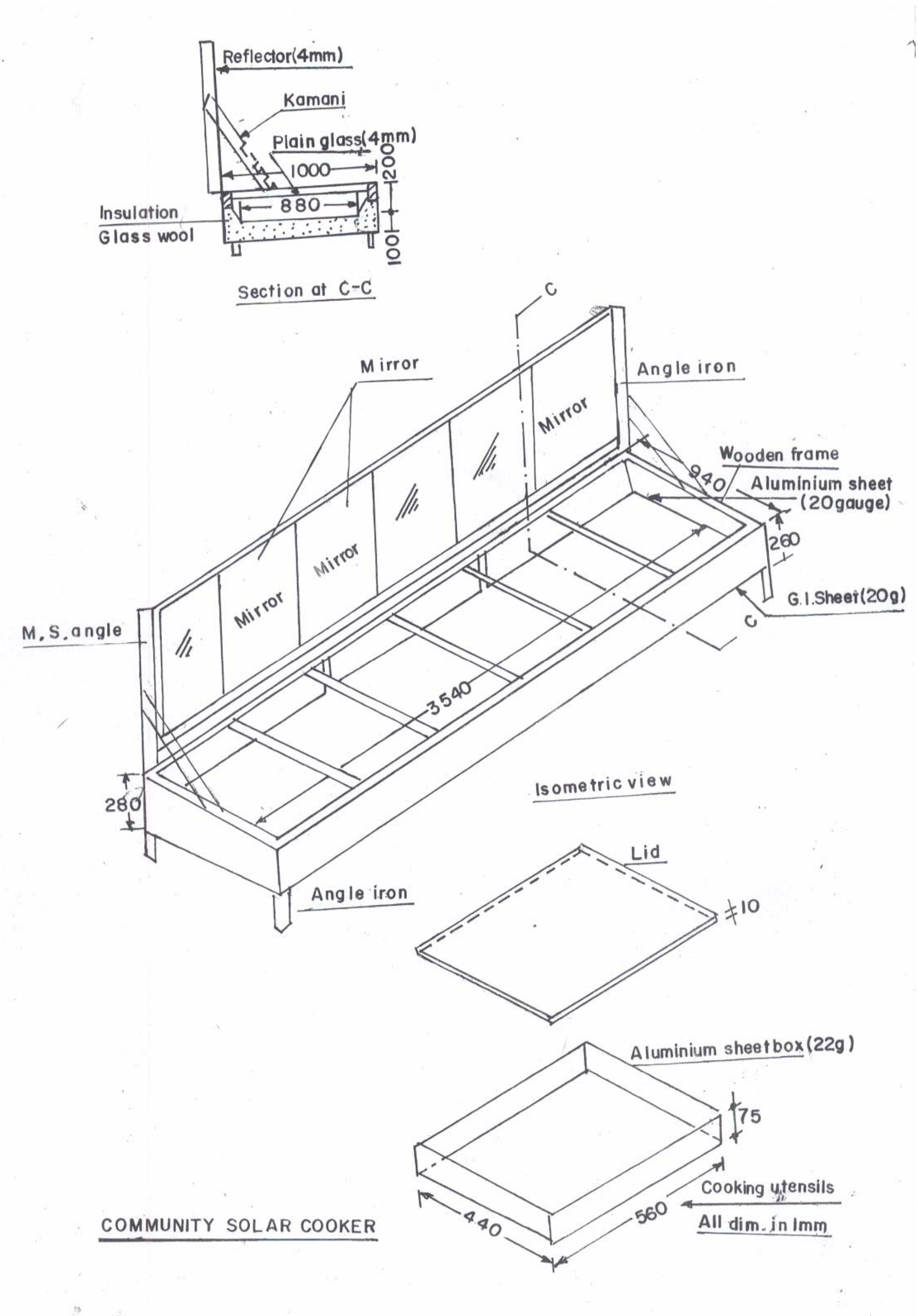

Fig.1 Schematics of community solar cooker

Fig.2 Community solar cooker installed in the field

3. Performance

Performance of solar cooker has been carried out extensively by measuring stagnation plate temperature and rise in water temperature in cooking utensils in known interval of time. The stagnation plate temperature was measured by putting number of thermocouples on the plate and on air inside cooking chamber and temperature of each was measured by the temperature recorder and average was taken. The maximum stagnation temperature has been observed as high as 146 ^{o}C in summer and 136^{o}C in winter. The efficiency of the cooker has been obtained by putting 1.25 litre of water in each cooking utensils. There are twelve cooking utensil that can be accommodated in the cooker. Therefore cooker was loaded with 15.0 litre of cold water. The initial temperature of cold water was measured and when it reaches near to the boiling point temperature of water, the final temperature of hot water was measured and time interval was also measured. The efficiency of the cooker has been found by the following relations:

$$\eta = \frac{m_u C_p (tu_2 - tu_1) + m_w C_w (tw_2 - tw_1)}{A\, C \int H d\theta}$$

Where

A = Absorber area (m^2)

C = Concentration ratio

Cp = Specific heat of material (kJ /kg ^{o} C)

C_w = Specific heat of water (kJ /kg ^{o} C)

H = Solar radiation (kJ /m^2 h
m_v = Mass of cooking utensils (kg)
m_w = Mass of water in cooking utensils (kg)
tu_1 = Initial temperature of cooking utensils (^oC)
tu_2 = Final temperature of cooking utensils (^oC)
tw_1 = Initial temperature of water (^{o}C)
tw_2 = Final temperature of water (^{o} C)
θ = Period of test (h)
η = Efficiency of solar cooker

The efficiency of the community solar cooker has been found to be 28.4 % .

Rose water has been prepared. Rose petals 100 gm per litre in water was boiled in the cooker for two hours. After boiling rose water was collected and 500 gm sugar per litre was mixed and again put into the cooker for boiling. The solution is rose syrup and remaining material was mixed with sugar and again put into the cooker and it became gulkand. The cooker can be used to prepare 32 litres of syrup per day. Similarly Indian goose berry (Aanwala chutney) was also prepared. Crushed green Aanwala mixed with sugar and put into the cooker. It was ready within three hours. The cooker can be used to prepare 32 Kg. of Aanwala chutney per day.

4. Community solar cooker for income generation

Based on experience, it has been assumed that the cooker will prepare rose syrup or Aanwala chutney twice a day if the duration of bright sunshine hours exceeds 9 h/day, it can be used only once a day if the duration of bright sunshine hours is less than 9 h but more than 6 h. It will not be able to prepare anything on days when the bright sunshine hours are less than 6 h. By analysing bright sunshine hours at Jodhpur, it has been found that the cooker will be used twice a day for about 254 days and once a day for about 67 days in a year. Therefore, about 9,200 litres of syrup can be prepared in a year. The expenditure per litres is only Rs.15.00 while retail price in the market is about Rs.60.00 Even if it is sold for Rs.30.00 per litre to whole seller than net earning per year is Rs.138,000.00. The cost of the cooker is only is Rs 40,000.00 (1.0 US $= Rs. 50.00) that can be recovered in less than a year. As per requirement more number of solar cookers can be used and more income can be generated.

5. Conclusion

The maximum stagnation temperature inside cooking chamber during summer is 146^{o}C and 136 ^{o}C in winter. The efficiency of the cooker is 28.4 %. The cooker can be used twice a day for about 254 days and once a day for about 67 days in a year. The cooker can be used in agro based industries for preparation of rose syrup, gulkand, processing of Indian goose berry (Aanwala), Jujube (ber) etc. for jam & jelly making. The cost of the cooker is only is Rs.40,000.00 that can be recovered in less than a year. As per requirement more number of solar cookers can be used and more income can be generated.

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