SOLAR COOKING- An Overview

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Abstract:

In many developing countries people rely on firewood as a primary energy source which has negative health and environmental consequences. Solar cooking offers a solution to overcome those problems. The promotion of solar cookers has become very popular over the years and a wide range of organizations promote different types of solar cookers around the world. However, it is not clear how many of those cooking systems are still in use. The literature on solar cookers is very limited and has focused mainly on household solar cookers, while solar cookers for institutional applications have been ignored. This study contributes carried by comparing application levels type of solar cooker.

This paper presents a short review on different types of solar cookers. Several attempts have been made to introduce solar cookers in different countries and have achieved asymmetrical successes. There are still critical issues so far to be resolved in order to make the technology acceptable for wider propagation. They include getting the most appropriate types of solar cookers for specific locations, optimum size/capacity, types of materials to be used, optimal design and affordable cost. In an attempt to resolve these issues, a comprehensive study involving theoretical review, development work, experimental testing and evaluation of solar cookers is carried.

Keywords: Solar energy, box solar cooker,solar concentrator.

I. INTRODUCTION

Solar cooker is a device that cooks food using only sun energy in the form of solar radiation. The solar cooking saves a significant amount of conventional fuels. The solar cooking is the simplest, safest, clean, environment friendly, and most convenient way to cook food without consuming fuels or heating up the kitchen.

A major concern of today is the rapidly depleting natural resources. So it is the urgent need of time to reduce the dependency on non-renewable sources, judiciously using the remaining sources and at the same time switching to new and better alternatives and renewable source of energy. [1,2]

In most parts of India, solar energy is available almost throughout the year and can be used as alternate input to meet out energy needs. Solar energy is the cheapest, inexhaustible and can be used for various domestic and agricultural requirements including cooking, drying, dehydration, heating, cooling and solar power generation [3].

Solar cookers have a long history dating back almost 18th century when Nicholas-de-Saussure built first ever Solar Box Cooker. Today there are about 60 major designs and more than 100 of however the solar cooking has not caught the imagination of peoples, except in places where shortage of conventional fuel like fire wood and the

II. REVIEW OF SOLAR COOKERS

Cooking with the energy of Sun is not a new or novel idea. The Solar cookers are needed due to the following ;

1. High cost or Unavailability of commercial fuels – Kerosene, Coal, cooking gas and Electricity.
2. *Deforestation* caused by increasing firewood consumption.
3. Use of dung and agricultural waste as fuels instead of for *soil enrichment*.
4. Diversion of human resources for fuel collection.

Advantages of solar cooking

1. No attention is needed during cooking as in other devices.
2. No smoke evolution, thus clean.

3. No pollution, thus environment friendly.
4. Vitamins of food are not destroyed; therefore, solar cooked food is with natural taste, aroma and healthier.
5. No soot accumulation on pots.
6. Available every day, thus *renewable*.
7. Solar Energy does not contribute to global warming, acid rain or smog.
8. Solar Energy systems are maintenance free and long lasting.

Most solar cookers convert sunlight to heat energy that is utilized for cooking. The ability of a solar cooker to collect sunlight is directly related to the projected area of the collector perpendicular to the incident solar beam radiation. The geometric concentration ratio is defined as

CR = $\frac{A_t}{A_{rc}}$, where A_t is the total collector area and

A_{rc} is the area of the receiver/absorber surface [6].

III.Types of solar cookers

1. Solar box cooker or solar oven- It is the most common type of solar cooker made for personal use. It is very simple in construction, consists of a box (square, rectangular, cylindrical) painted black from inside and insulated from all sides except window side which is double glazed is used. Up to four black painted vessels are placed inside the box with the food to be cooked. The cooker takes 1 ½ to 2 hours to cook items such as rice, vegetables.

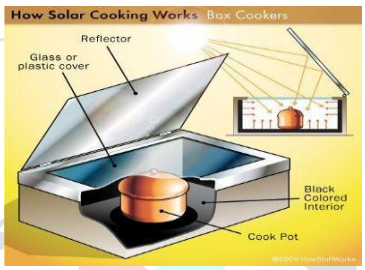


Figure 1. Box Solar Cooker.

Feasible Applications of Solar Box Cooker

The cooker is used to prepare simple cakes, roast cashew nuts, dry grapes, etc. It is an ideal device for domestic cooking during most of the year except the monsoon season and cloudy days. The cooking takes place at relatively low temperature, thus cooking is very similar to that of microwave cooking. The cooked items are very tastier, healthier and with all natural minerals, vitamins and proteins. It however cannot be used for frying or Chapatti making.

2. Panel Solar Cooker

The panel cooker is quite similar in operation to the solar box cooker. The same principles are employed but instead of an insulated box only, the panel cooker typically relies on large (often multi-faceted) reflective panels, which focus the sunlight on a cooking vessel. Panel cookers are the easiest and least costly to make, requiring just four reflective panels and a cooking vessel, but they are unstable in high winds and do not retain as much heat when the sun is hidden behind clouds

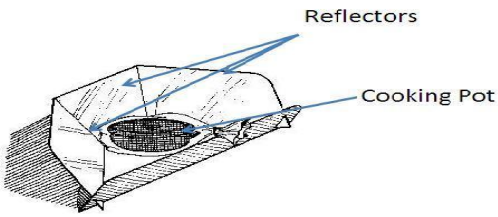


Figure 2. Panel Solar Cooker.

3. Collector cooker

The collector cooker is made up of two parts that often share a single casing: a collector for collection of heat and a cooking part for exploiting the yield. A typical collector cooker would consist of a flat plate solar collector, side and head mirrors, and the cooker part. The user is not affected by radiation and heat as the cooking part is separate and protected from radiation. Oil is used as the heat transfer medium in order to allow higher temperatures to be reached.

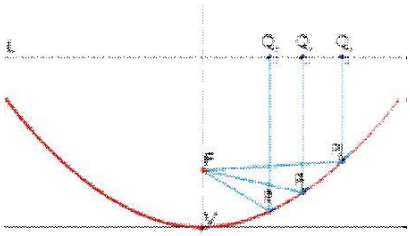


Figure 3. Parabolic curve showing focus (F), vertex (V), and rays of light brought to the focus.

4. Concentrating type solar cooker- It uses the principles of concentrating optics. The concentrating solar cookers primarily consists of a reflector to focus the incident solar radiation on the cooking pot, a support with turning mechanism to keep the reflector facing the sun and a cooking pot. Hence the cost and size of reflector is determined by heating capacity desired. Following are the important types of concentrator type solar cookers a) Wisconsin solar cooker (Spherical parabolic type)

Figure 4. SK-14 Domestic Solar Cooker

5. SK-14 parabolic concentrator

SK 14, is a solar concentrator developed by Dr. Ing. Dieter Siefert. It is a concentrating type parabolic dish solar cooker useful for households and small establishments. A typical dish solar cooker has an aperture diameter of 1.4 meter and focal length 0.28 meter. The reflecting material used for fabrication of this cooker is anodized aluminum sheet which has a reflectivity of over 80%. The tracking of the cooker is manual and thus has to be adjusted in 15 to 20 minutes during cooking time. It has a delivering power of about 0.4 kW which can boil 2 to 3 liters of water in half an hour. The temperature achieved at the bottom of the vessel could be around 300^0C to 350^0 C which is sufficient for roasting, frying and boiling. The cooker having a thermal efficiency of around 45% can meet the needs of around 4-8 peoples and can be used from one hour after sunrise to one hour before sunset on clear days. The cost of the cooker may vary from Rs. 3,500 to Rs. 6,000 depending on

Figure 5. PRINCE-15 Solar Cooker

6. PRINCE-15 (Fabricated) parabolic concentrator

It is a concentrating type parabolic dish solar cooker with square geometry and useful for households and autoclaving. A typical dish solar cooker has dimension of 1250 mm × 1250 mm and focal length 0.460 meter. The reflecting material used for fabrication of this cooker is anodized aluminum sheet which has a reflectivity of over 80%. The tracking of the cooker is manual and thus has to be adjusted in 15 to 20 minutes during cooking time. It has a delivering power of about 0.6 kW which can boil 2 to 3 liters of water within 20 m minutes. The temperature achieved at the bottom of the vessel could be around 350^0C to 400^0C which is sufficient for roasting, frying and boiling. The cooker having a thermal efficiency of around 50% can meet the needs of around 8 peoples. PRINCE-15 is a concentrator with square or rectangular dish shape. This shape permits use of same sized strips of steel to make bowl. This makes the bowl sturdy. As the members of the dish have same geometric shape this reflector is easy to assemble even by novice people with the help of construction manual.

Figure 6. PRINCE-15 Segmented Solar Cooker

7. PRINCE-15 (Segmented) parabolic concentrator

PRINCE-15 is a square dish. Such dish can be obtained by cutting Paraboloid with parallel planes. Paraboloid square dish is manufactured in four symmetrical segments as shown in figure 6. One such segment is to be manufactured in sheet metal using die with flange such that flanges can be bolted together to form complete dish. Total dish size in plan is 1250 mm × 1250 mm. One segment size in plan will be around 625mm × 625 mm and with flange of around 25 mm on all sides

Figure 7. SK-23 Community Solar Cooker.

8.DESIGN CONSIDERATIONS:

The prime intention was to fabricate a CPC solar cooking system which can harness maximum solar radiation throughout the day. Hence it had been decided to incorporate 3 troughs with different orientations without tracking. The various parameters to be considered in the design and performance

A. Energy requirement for cooking

It has been observed that to cook 500gm of rice, approximately 0.28 kWh of energy is required [9]. The width (W) of the CPC can be calculated as:

$$C=(W-D_o)\pi D_i \quad (1)$$

Absorbed solar flux isd given by ;

$$S=[I_b+R_b+(I_d/C)]\tau\rho c\alpha \quad (2)$$

Where Rb is the tilt factor for beam radiation

The intensity of radiation and the absorbed flux have been calculated analytically (as shown in Table 1) by referring to the specifications mentioned in Table 2. This is to ensure the effective working of the solar cooker.

Useful heat gain by the system is

$$Q_u=F_R WL[S-(U_L/C)(T_{hi}-T_a)]t \quad (3)$$

$$=mC_p(T_{ho}-T_{hi}) \quad (4)$$

Table 1

.No.	Time interval (t) (h)	Beam radiation (I_b)(W/m^2)	Diffused radiation (I_d)(W/m^2)	Absorbed flux (S)(W/m^2)
1	10 - 11	751.87	102.48	499.84
2	11- 12	861.92	104.59	547.27
3	12- 13	899.45	105.22	567.34
4	13-14	861.92	104.59	547.27
5	14-15	751.87	102.48	499.84

***Table 1**: Solar radiation analysis with time*

Table 2

S. No.	Description	Value
1	OD of the evacuated tube (D_o)	58 mm

2	ID of the evacuated tube (D_i)	48 mm
3	Length of the tube (L)	1800 mm
4	Transmissivity of cover material (τ)	1(no cover)
5	Reflectivity of Aluminium Foil (ρ_C)	0.6
6	Absorptivity of the inner tube (α)	0.9
7	Collector heat removal factor (F_R)	0.95
8	Overall heat loss coefficient (U_L)	7.5
9	Concentration ratio (C)	1.6

***Table 2**: Specification of CPC [10]*

Where, 'm' is the mass of oil in the container in kg, 'T_a','T_{hi}' and 'T_{ho}' are the surrounding temperature, oil inlet and outlet temperature respectively.

Initially a CPC trough was designed, fabricated and fitted with an evacuated tube and container. The used engine oil (ρ = 850 kg/m^3 and Cp = 2395 J/kgK) of 5 litres was taken to evaluate the analytical (referring Eq. 4) and experimental final temperature as shown in Figure 1. The analytical (assuming adiabatic vessel) and experimental energy content of oil (effectively 1.75 litres) at 1430 hrs is calculated to be 0.144 kWh and 0.147 kWh respectively. Since both the values were closely matching and the total energy content from three troughs was more than the actual energy requirement, it had been decided to proceed with three troughs

ANALYSIS

Galvanized Iron (GI) has been selected as the most economical material for the CPC Trough. Moreover, GI Sheets can be bended and welded easily. To further enhance the reflectivity of CPC, it has been decided to stick aluminium foils along the entire trough length. The CPC troughs and side covers are fabricated using a 24 gauge and 18 gauge sheet respectively. The surface area of the designed CPC is calculated to be 1m^2. The fabrication steps involved are as follows:

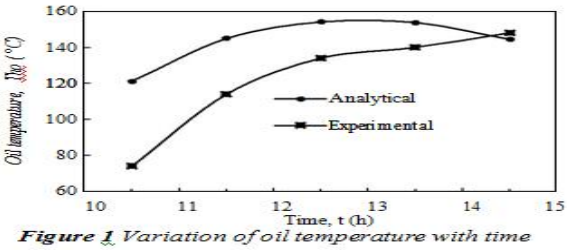
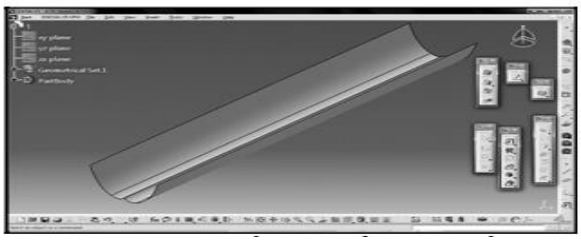


***Figure 1** Variation of oil temperature with time*



The set up was tested with solar cooker and the highest temperature of oil recorded was 110˚C and it was dropped to 75˚C during 1930 hours as shown in

Figure 10. It has been found out that the time required for cooking 500 gm of rice was less than an hour during afternoon period. Whereas the temperature available wasn't enough to cook rice during late evening. But this temperature is sufficient to warm up the food. This inefficient nature of the system have been diagnosed as follows:

(i) The complete experimentation period was partially cloudy.

(ii) Since the evacuation process wasn't perfect, the outer container surface temperature was high.

(iii) Since the pipe size is bigger, the conduction heat loss from pipe wall to container wall was considerable.

Heat loss from the outer surface of hose pipe and outer container as they weren't insulated

APPLICATIONS:

1. Community Cooking.
2. Industrial Heating applications for
   Low and medium temperature requirement for autoclave applications in hospitals.
3. Major installations till date are in direct and steam cooking applications. (Tirupati, Shirdi, Hyderabad, Mount Abu, Shantivan, for army camp at Leh etc.)
4. Processing of Agricultural produce.

CONCLUSION

Although, the box solar cooker cooks the food with excellent taste and full of vitamins, minerals and proteins. But due to its slow heating rate, its design could not acquire a significant attraction in the society. In last two decades, the thrust is put to develop concentrating cookers and various designs of concentrators are developed. Parabolidal solar cookers like SK-14 and PRINCE-15 are designed for a family of 4-6 persons and SK-23, PRINCE-40 are intended as solar cooker for small community, while Scheffler cookers bring sun to kitchen and can be used for small family to community cooking, depending on the collection area of Scheffler dish. These cookers get recognition in the society due to their fast heating rate.

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