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A REVIEW OF SOLAR COOKERS

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Abstract- This paper puts the insight of a short assessment on different types of solar cookers designed and developed worldwide. Numerous attempts have been made to introduce solar cookers in different countries and have achieved considerable successes for their applications. There are still, some critical issues so far to be resolved in order to make the technology acceptable for wider propagation. They include getting the most appropriate type of solar cooker for specific location, optimum size/capacity, types of materials to be used, optimal design and reasonable cost. In this paper an effort is made to resolve these issues by a comprehensive study of theoretical review of design and development work, experimental testing and evaluation of thermal performance of solar cookers conducted for different types of solar cookers. It throws light on features, limitations and feasible applications of different solar cookers. This helps the consumer in selecting most effective and appropriate solar cooker.

Keywords: Solar energy, box solar cooker, SK-14, PRINCE-15, SK-23, PRINCE-40, Scheffler cooker.

I. INTRODUCTION

India is a country that is blessed by Sun. The solar energy is available almost throughout the year and can be used as alternate source input to meet out energy demands. Solar energy is the cheapest, inexhaustible, environmental friendly and can be used for various domestic and agricultural requirements including cooking, drying, dehydration, heating, cooling and solar power generation [3].

A major concern of today is the speedily depleting natural energy resources. So it is the utmost 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.

Cooking with the energy of Sun is not a new or novel idea. Solar cookers had been used as a Akshay Patra by ascetics in era of Mahabharata [Rig Veda].

Solar cooker is a cooking device that cooks food by absorbing sun's thermal energy in the form of solar radiation. The solar cooking saves a significant amount of conventional fuels.

Worldwide, today there are about 60 major designs and more than 100 of variations. However the solar cooking could not get extensive acceptance among the peoples, except in places where shortage of conventional fuel like fire wood and the like is acute. Solar cookers have attracted the attention of many researchers so far and as result of continuous research, the different types of solar cookers have been designed, developed and tested all over the world. Currently, there is a competition to manufacture efficient and cheap solar cookers [1]. There has been a considerable interest recently in the design, development and testing of various types of solar cookers. [3].

II DIFFERENT DESIGN OF SOLAR COOKERS

A survey of solar cookers worldwide shows that a wide variety of cookers have been designed [4]. However, the available designs of solar cookers can be accommodated into four main categories namely, (i) Solar oven, (ii) Panel cookers, (iii) collector cookers, (iv) concentrating or reflector cookers and (iv) iindirect solar cookers.

The common feature to each design is the glossy reflective surface that directs the sun's rays onto the cooking area and dark inner walls of the cooking area and cooking vessel.

2.1. Solar Oven

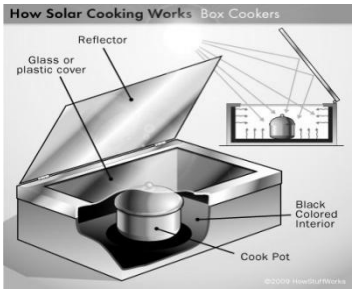

Fig 1. Box Solar Cooker

It is the popularly known as box solar cooker as shown in Fig. 1. 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. It operates on principle of green house effect. Up to four black painted vessels are placed inside the box with the food to be cooked [4]. In box type solar cooker only boiling and steaming are possible. The cooker takes 1 ½ to 2 hours to cook items such as rice, vegetables and pulses. The sunrays have short wavelength radiation, thus can easily enter the glass layers, while cooker body emits infrared radiation that cannot pass the glass covers. A greenhouse effect is built up to raise elevated temperature heat energy inside the cooker housing, which helps in cooking process.

Solar box cookers are ideally suited to preparing dishes, which require a long, slow cooking time. The cooker can be used to cook pulses, rice, hotchpotch etc. It can also be used to prepare simple cakes, roast cashew nuts, dry grapes, finger chips etc. The cooking takes place slowly at relatively low temperature, thus cooking is very similar to that of microwave cooking. The cooked items in box solar cooker are very tastier, healthier and with all natural minerals, vitamins and proteins. It however cannot be used for frying or Chapatti making.

2.2. Panel Solar Cooker

The panel cooker operates at principle of solar box cooker. Its construction is slightly different. It does not have an insulated box but has large (often multi-faceted) reflective panels. Panels direct the sunlight on a cooking vessel as shown in Fig. 2. Panel cookers are the easiest in construction 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. The convection and radiative heat transfer losses are higher in this cooker compare to solar box cooker. It can cook all items which can be cooked in solar box cookers.

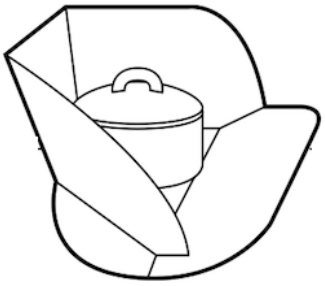

Fig 2. Panel Solar Cooker

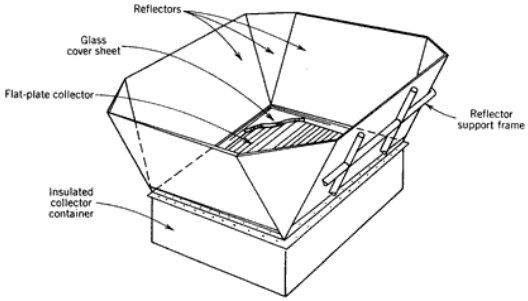

Fig 3. Collector solar cooker

2.3. 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 [5].

A typical collector cooker would consist of a flat plate solar collector, side and head mirrors, and the cooker part as shown in Fig. 3.

The large reflectors direct sun rays onto the collector. The collector is insulated from all sides except side exposed to sun rays. Thus collector can operate at elevated temperatures and still provide significant quantities of useful thermal energy.

The operator is not affected by radiation, since heating of 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.

2.4. Concentrating Type Solar Cooker

It uses the principles of concentrating optics as shown in Fig. 4. The concentrating solar cookers primarily consist of a reflecting collector and a receiver at point of focus [2]. The incident solar radiation is directed by reflector onto the cooking pot located at the focus.

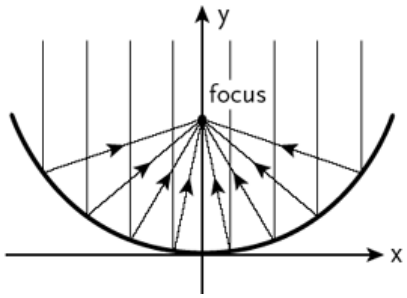

Fig 4. Principal of Solar cooking

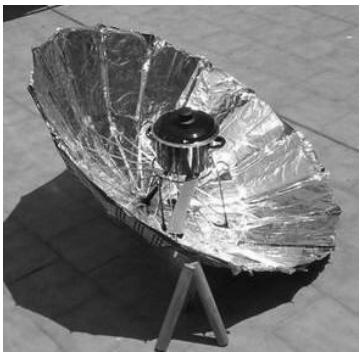

Fig 5. SK-14 Domestic Solar Cooker

A concentrating solar cooker uses large inexpensive reflective surfaces like anodized aluminium sheet or glass mirrors, which are usually less expensive. The smaller absorbing (receiving) surface is insulated from all sides except the side exposed to concentrated solar energy.

The mild steel structure supports the reflectors sun tracking mechanism to keep the concentrating collector normal to sun rays. The tracking mechanism adds a significant cost to the construction of a concentrating collector system.

The cost and size of reflector is determined by heating capacity desired. The concentrating solar cooker involves direct sunlight to function and thus concentrator must be frequently orientated towards the sun [16]. Advantages include high cooking temperatures, virtually any type of food can be cooked and short heat-up times are possible. Most direct-focusing cookers are also unstable at wind speeds exceeding 10 km/h [12]. Further, size, cost, the risk of fires and sun burns and the inconvenience to adjust the cooker are additional disadvantages.

Following are the important types of concentrating solar cookers

a) Spherical parabolic type b) Folding Umbrella type solar cooker

c) Paraboloid type solar cooker d) Light weight molded aggregate reflector type solar cooker
e) Cylindro-parabolic solar cooker, f) Multi- mirror or Multi-facet type solar cooker
g) Spiral reflector type solar cooker.

Out of these cookers only Paraboloid type solar cooker have received the commercial attention. A paraboloid solar cooker is a spherical parabolic cooker. It is a direct concentrating cooker with a dish-type reflector directing most of the intercepted solar radiation to the focus. The cooking vessel is supported at this focus point, thus creating a heating situation very similar to traditional open fire cooking [5]. The different designs of concentrating solar cookers are discussed below.

2.4.1 SK-14 Parabolic Concentrating cooker

SK 14 parabolic concentrator as shown in Fig.5 is a dish type solar concentrating cooker designed and developed by Dr. Ing. Dieter Siefert. It 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 can deliver thermal 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°C to 350°C which permits all operations like boiling stewing steaming, roasting, and frying [8]. 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 [10, 11].

2.4.2 PRINCE-15 Parabolic Concentrator

PRINCE-15 concentrating type parabolic dish solar cooker is developed by Dr. A. G. Chandak [10-12] and approved by Ministry of New and Renewal Energy sources, New Delhi. It is parabolic dish cooker with square geometry and it is useful for households and autoclaving. 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°C to 400°C which is sufficient for all operations of cooking like roasting, frying and boiling [15]. The cooker having a thermal efficiency of around 50% can meet the needs of around 8 peoples.

Figure 6. PRINCE-15 Fabricated Solar Cooker

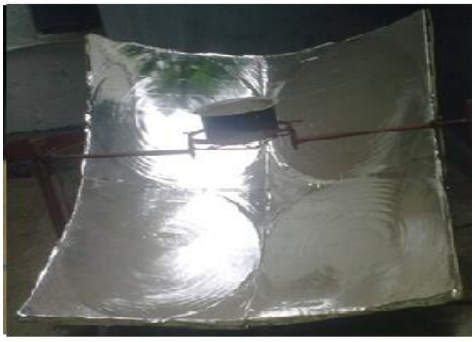

Fig 7. PRINCE-15 Segmented Solar Cooker.

PRINCE-15 solar cooker is fabricated with sheet of dimension of 1250 mm × 1250 mm and focal length 0.460 meter. The square shape of PRINCE-15 permits use of same sized strips of steel to make bowl sturdy. As the members of the dish have same geometric shape thus reflector is easy to assemble even by novice people with the help of construction manual. The reflecting material used for fabrication of this cooker is anodized aluminum sheet which has a reflectivity of over 80%.

PRINCE-15 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. One segment size in plan will be around 625mm × 625 mm and with flange of around 25 mm on all sides.

2.4.3 Community Parabolic Dish Cooker

SK-23, PRINCE-40 are the Community dish Solar cookers.

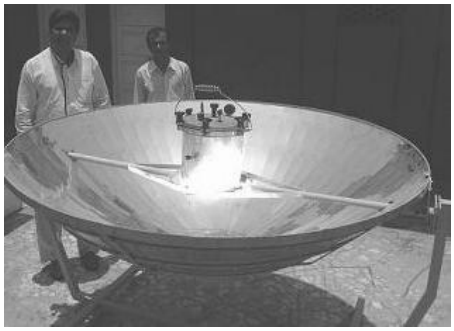

Fig 8. SK-23 Community Solar Cooker.

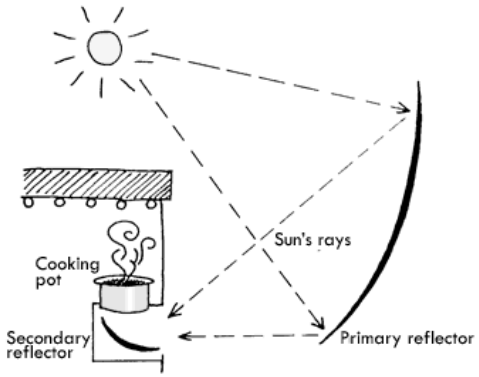

Fig. 9. Arrangements of Standing Dish with Secondary Reflector Indoor Cooking

The PRINCE-40 unit is also developed by Dr. A. G. Chandak [10-12] and manufactured, tested and commercialized by PRINCE. Dish diameter of PRINCE-40 is 2.3 m, its aperture area is 4 m^2, and its heat rate at pot is approximately 2.5 kW. It uses best quality anodized aluminum reflectors with more than 85% reflectivity. It has cooking capacity of 40 to 50 persons. Few units are already supplied and in use for community cooking, agro-processing, and industrial applications.

2.4.4. Scheffler Solar Cooker

Wolfgang Scheffler launched an idea of oblique paraboloid solar reflectors, now well known as Scheffler solar concentrators. Scheffler solar concentrators are termed as flexible surface concentrators. The unique feature of this cooker is that it is possible to cook using solar energy within the kitchen itself. A scheffler solar cooker consists of

- Primary parabolidal reflector,
- Secondary flat reflector
- Receiver or absorber, and
- Dish tracking arrangement with sun movement.

Fig. 9 shows indoor cooking facility and depicts how concentrated solar heat is diverted to cooking pot located in the kitchen with the help of primary and secondary.
The parabolidal dishes are designed in size of 7 m^2, 8m^2 and 16 m^2. These dishes are symmetrical about their axes. These dishes can be used as standing dishes or sleeping dishes or combination of both. When combination of dishes is used, the stand height becomes too large. Fig. 9 shows the standing primary solar reflector of 16 m^2 and secondary flat reflector.

A Scheffler solar cooker with 16 m^2 primary reflector has Cooking for about 40 to 50 persons is possible with this cooker. One dish may take around 1 to 1 and 1/2 hours depending on the type of dish and solar insolation available. World's largest installation at Shirdi, uses only standing dishes of 16 m^2, 73 units, with total collection area of 1168 m^2 and heating rate of 37840 kcal/day.

Major installations till date are in direct and steam cooking applications. (Tirupati, Shirdi, Hyderabad, Mount Abu, Shantivan, for army camp at Leh etc.)

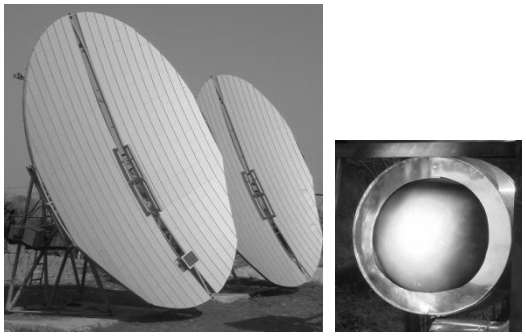

Figure 10. Standing Scheffler primary and secondary reflectors

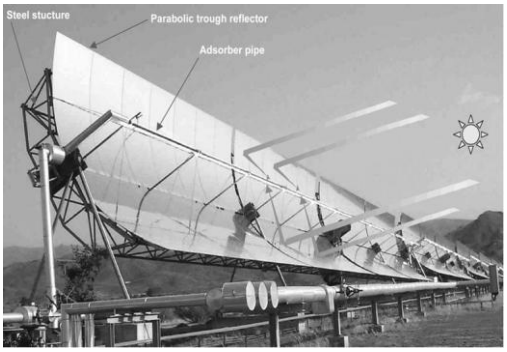

Figure 11. Parabolic tough collectors with steam generation system

Although, Scheffler concentrators look attractive to use but they also have some limitations:

1. It requires high capital investment per unit.
2. Its design, manufacturing and installation are complex.
3. It requires heavy and robust permanent structure for its support.
4. System installation needs shadow free area throughout the year.
5. Seasonal adjustment and sun tracking mechanism throughout the day are required.
6. It requires its typical orientation of kitchen with east-west wall and shadow free south side.

Applications:

One Scheffler of 16m^2 size can usually saves approximately 35 to 40 LPG cylinders per year on full use in community kitchens.[8,9,10], therefore it can be used for

1. Community Cooking.
2. Industrial heating applications for Low and medium temperature requirement and for autoclave applications in hospitals.
3. Processing of Agricultural products.

Further, research and development work is ongoing at Abu by Wolfgang Scheffler and his team members for developed of large dish size for power project.

2.6 Parabolic trough collector

The parabolic trough collector is used for steam cooking system. It can attain the temperatures greater than 260°C, which is sufficient to generate steam at pressure of 8-10 bar. This generated steam can be used for steam cooking or for industrial process heat applications. A typical installation of Parabolic tough collectors with steam generation system is shown in Fig.10.

The parabolic tough collectors can have maximum concentration ratio of 213 and maximum temperature of 1300°C at focal line. Table 1 summarizes the advantages and disadvantages of the four types of solar cookers described above.

Table 1 Comparison of different Solar Cookers [6]

Type of Cooker	Advantages	Disadvantages
Solar box cooker **(solar oven)** T = 150 ^{O}C	• Uses both direct & diffuse radiation. • Requires little intervention by the user. • Very easy & safe to use. (2-6 kg/day) • Easy to construct but • High acceptance angle.	• Slow but even cooking *i.e.* 1.5 to 2 hours • Not use for frying/chapatti making.
Panel cooker T=200-250 ^{O}C	• Better performance than box cooker.	• Poor performance on cloudy conditions. • Relies more on reflected radiation.
Collector Cooker	• Uses both direct and diffuse radiation. • Simple , safe and Convenient to use.	• Complicated to build. • Expensive.
Concentrating (reflector) cooker η = 50%	• Quite efficient. • Can achieve extremely high temperatures 300 - 350^{O}C. • Cooking is quicker. (1/2 to 1 hour)	• Complex design • Requires the user's attention. • Strong reliance ondirect beam. • Low acceptance angle • Relatively high cost. • Safety problems (burns or eye damage)

CONCLUSIONS

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 even after governments' promotion scheme. In last two decades, researcher did the excellent job to develop concentrating cookers and various designs of concentrators. Parabolidal solar cookers like SK-14, and PRINCE-15 are designed for a family of 4-6 persons and SK-23, PRINCE-40 are proposed 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.

Further, with use of solar energy, the following objective can be accomplished for healthy environment.

1. Costly high grade energy fuels: Kerosene, Coal, cooking gas and Electricity can be conserved.
2. *Deforestation* caused for increasing firewood consumption can be minimized.
3. The animal's dung and agricultural waste (rural fuels) can be used as inorganic manure for *soil enrichment*.

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