VARIETIES OF SOLAR COOKER DEVICES AND USES

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ABSTRACT

Since 1979, author has been doing research on different models of solar cookers – hot box , hybrid sol- electric cookers, multiple uses solar cookers like cooker cum water heater/pasteurizer, cooker cum dryer etc. In addition to publishing results in technical journals, the author is disseminating the experience through lecures, TV, Radio, newspapers, workshops, seminars in Costa Rica and in more than 30 countries where he has had the chance to see various models.

Also through the printed literature and personal correspondence with other researchers and promoters the author also learned about more models of solar cookers throughout the world- including, heat, electrical, chemical and hydrogen storage cookers, cookers for medium institutions (50- 100 persons) and bigger institutions (more than 1000 persons) etc. The author and his family solar cook at home when ever the climate permits, about 7-8 months in a year. In this short presentation, I would like to share part of this information.

Keywords: Solar oven, solar cooker, hybrid cookers, multipurposes cookers, Heat and electric storage cookers**.**

1. INTRODUCTION

Its known that the temperature required for different food processings are:

45-50 ºC Most germs can not grow (For drying products, keeping the food warm,
65-70 ºC Water pasteurization,
70-75 ºC Food pasteurization,
80-85 ºC Food cooks,
100 ºC Water boils ,
120 ºC Sterlization.

The higher temperatures only accelerate the cooking process or reduce the cooking time. We can mention in brief the uses of solar energy for some food processes during the previous 4500 years. . In the year 2300 BC, Greek Arquemedes burnt a Roman fleet using the concepts of reflection/ concentration of solar radiations. Then in 1680 AD,a German Physicist used a large lens to boil water. Definitely both of them could have used this power for cooking the food. In 1776, Benedict de Saussure, a Swiss, used a hot box and could attain temperatures around 90-100 ºC inside a box with various glass layers. There are some indications of baking of fruits by him. In 1780. Ducarla, a French scientist using hot box of 5 glass layers could cook meat in one hour. One can continue mentioning more and more. In the year around 1889 a US patent was issued to W. Calver on a solar stove.

Most of these cookers were made for some specific needs or just for fun. The first official exhibition of solar cookers was organized at a (I)SES Conference at Phoneix, AZ, USA in 1955, and there was a second in Rome organized by FAO in 1961.

However after the oil crisis many researchers and promoters started working on solar cooking, some with the blessings of Governments (like India and China etc.) and others independently. More than 200 different cookers have been made (1-7). We have made, used and worked more on various cookers based on hot box concept (simplest to make), but also have had the chance to see personally other types of cookers in more than 30 countries. During the last 26 years in addition to theoretical and experimental studies, different meals were cooked for daily uses (rice, beans, vegetables, lentils, meat, desserts, etc.) and for the exhibitions, etc.

All solat cookers/ ovens can be classified in different categories - based on their basic principles, sizes, conveniences, prices, user sectors, temperatures, cooking times, do it yourself and commercial models, etc. Here we will discuss the cookers classified by how they work. Due to limitation of space and some permission etc., we show our own models, and models of others, in case we have not made in that category. However at the conference, 4-6 models in each category will be shown. The author's 15 individual papers referred to here can be seen in reference 4, published in 2005.

2. DIRECT SOLAR COOKERS (SUN- HEAT)

There are basically three types of solar cookers/ ovens**.**

2.1 Simple hot box oven

As the name implies it is like a box, made of a Wood/Metal/Cardboard/Stainless steel/ Mud etc, with galvanised iron/aluminium/ copper metal sheet painted black on top to absorb solar radiation, glass wool as heat insulation, single or double window glass to allow solar radiation to impact the metallic plate and at the same time, impede the exit of heat radiation emitted by the hot plate. The air in the box is thus heated through the greenhouse effect and is used for cooking meals, kept inside the box. The box can have one or more reflectors to increase the solar radiation.

In our particular model (Fig. 1), the maximum plate/air temperature reached about 150° C, without any food or load inside and between 110- 130 ºC while cooking. The food could be cooked in 1-3 hours. We got a patent on this Solar Oven in Costa Rica in 1984.

Fig. 1. Solar Oven Constructed in 1980 and still in use by authors family.

Fig. 2. Solar Concentrating Cooker
(type SK14)

2.2 Concentrating cooker

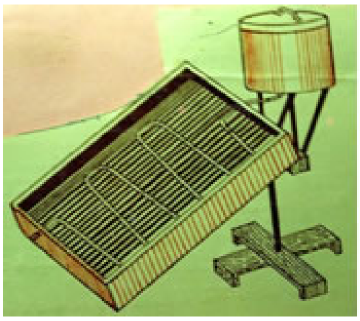
A hot box can work (bake and cook), even under some partial sunny climatic conditions, and takes 1- 3 hours. Although food cooked slowly is good from nutritional point of view, for some users it may not be as tasty and some also like to have fried food and food cooked in a short time. For this a concentrating cooker is used. Here solar radiation is received by a reflecting (parabola or cylindrical) surface, and is reflected at the focal point where the food to be cooked is kept. In different models, the focal point could be either inside or outside the parabola. In addition, the parabola can be fixed and the focal point movable, or the focal point can be kept fixed while the parabola is movable.

In our particular case Fig. 2 shows one of our cooker assembled based on model developed by the EG Solar, Alttoting, Germany. This model produces higher temperature (about 400 ºC). However for its proper working, it needs mostly the direct radiation and thus requires some frequent (15-45 minutes) tracking (manual or automatic).

2.3 Steam/ vapor or inside cooking cookers

In the previous cookers, the cook needs to go out in the sun at least for placing the food, to make some adjustments and to take the cooked food out. Some users may not like to do this and prefer to cook inside the house. In this case either solar energy is firstly converted to heat outside and then the heat is transported inside the house for cooking (Fig. 3a), or solar energy is first taken into the house and then converted to heat for cooking(Fig. 3b).

Figure 3a shows one commercial model developed in India in 1977. Here a flat plate collector is used to heat a small quantity of water in various tubes. When heated, this rises through a thermo syphon effect to another container kept inside the house, where the food is kept. After the hot liquid or vapor transfers heat to the food, it is condensed and returned to the collector for further heating.



Figures 3a . Cooking inside the house- with vapors.

Figures 3b . Cooking inside the house transporting solar energy .

In Figure 3b, again a cooker for a school, in India, one big concentrator of 7 m^2 is used with a set of acrylic reflecting mirrors. It produces around 450 ºC, at the focal point (window) and is designed to cook for 60- 80 persons. In this case the concentrator is moved automatically to keep the focal point at a fixed place.

2.4 Hybrid cookers

All the models mentioned so far work as long as there is sufficient solar radiation. Although we do not expect the solar cookers to work at night, or when rainy or completely cloudy, nevertheless we would like to cook during partially/sunny cloudy periods, in order to use part of the this sunny energy. To satisfy this demand, heat storage cookers and hybrid cookers have been made.

In hybrid cookers, solar energy is integrated with conventional energy sources, such as electricity, firewood or other fossil fuels (as backup fuel). The switching between two fuels could be manual or automatic.

One example of this type of cooker (probably the first of this kind at that time), a solar/electric oven, (Fig. 4a) was designed by the author in 1986. It is basically similar to a hot box, but the black metallic plate has an electrical resistance beneath and a thermostat to regulate the temperature. The hybrid cooker is connected with electricity, and the thermostat is fixed at 90-100°C. If solar radiation alone enables the system to reach this temperature, electricity will not be consumed. If the solar intensity falls below the level needed to keep the air/plate at the prescribed temperature, electricity is connected automatically to the electric plate to raise the temperature, and is disconnected if the solar intensity is increased. In this way the food is cooked reliably and automatically with the minimum consumption of electricity.

This model was designed mainly for the areas where electricity is available and a cook wants to save the conventional energy, and it has been used by the author at his house since 1986.

In the year 2000 the author collaborated with Mr. Marco Flores of Honduras to design and construct Sol- Gas (LPG) hybrid cooker. As shown in the Figure 4b in ths case, beneath the metallic plate there is a gas heating system and a thermostat.

Fig. 4. Hybrid Solar Oven , with 110 VAC Electricity in Costa Rica (a, upper) and with LPG in Honduras (b, lower).

2.5 Heat storage cookers

Here firstly the solar energy is converted to thermal energy, which is then stored either in the form of sensible heat (solid mass, water or oil), or latent heat (salts or vapors), or through chemical reaction. Later on we will mention storage of solar energy in electricity and hydrogen, etc.

Depending on the climate, the storage time could be small (30-60 minutes) just to compensate some intermittant clouds or large (6-12 hours) for cooking dinner and breakfast. It is known that the storage of energy is relatively expensive, however we can mention one model.

2.5A Short term heat storage

The author has studied these aspects through the storage of heat in the form of both sensible (firebricks) and latent (High Density Plastic, Vestolene and Mg NO_3. From these and other studies it can be concluded that food could not be cooked with stored heat, but it could be kept hot for a few hours. Some more work is needed to make this oven more practical.

Fig. 5. Long term heat storage cooker using oil (Germany, 1986)

2.5B. Long term heat storage

There are some solar cookers made under this category, mainly by German scientists, which cost around US$1500 for a single family. These use heavy mass of cast iron or good quantity of oil etc. for the heat storage.

Figure 5 shows one model designed by Rommel et. al at Freiburg, Germany in 1986 using oil as a heat storage (8).

INDIRECT SOLAR COOKERS (SUN- ELECTRICITY- ----------- HEAT)

So far we have mentioned the cookers where solar energy is converted to heat, which is either used directly to cook food or stored to cook later on.

However there are other types of cookers – although comparatively expensive - which have its utilities too. For our self sufficient solar house, we have made some of these. Here solar energy is converted to electricity using solar panels, which is used for cooking either directly or through stored electricity.

2.6 Sun- electricity- heat

In these types, solar energy is converted into electricity (DC) using solar cells. This electrical energy is used for cooking with an electric range. In our study, one commercial 12VDC Portable Cooker, run mainly with car cigarette lighter, was converted so that it could be used with electricity produced from solar energy, and/or with solar energy directly (Fig. 6). The preliminary results were presented in Iberoamerican Conference and real cooking has been done.

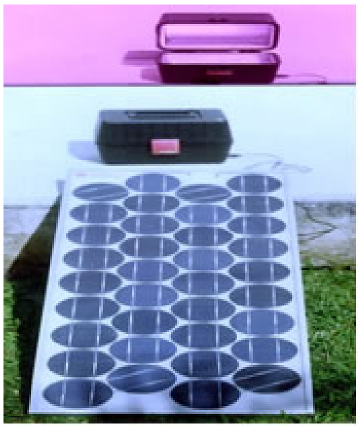


Fig. 6 12VDC Solar electric range (Author)

2.7 Sun- electricity- battery- electricity- heat (hybrid- solar- dc electric oven)

Here the electricity generated from solar cells is stored in the battery and then is used for cooking. The Figure 7 shows one of this model studied by the author.

Fig. 7. Cooking from Solar charged Battery.

2.8 Sun – electricity - microwave- heat oven

Here solar cells are used to convert solar energy in DC electricity. This is then stored in specialized (deep cycle) batteries. The stored electricity is then converted to 110 VAC through an invertor, which can be used efficiently for running a conventional 110 VAC Microwave Oven. This could make sense for the remote places of rich and nature conserving persons. Photo 8 shows one of the system assembled, studied and used at our solar house.

Fig. 8. Solar/ Electric Powered Microwave Oven at authors solar house.

Fig. 9. Self sufficient solar house in Germany, with Solar/Hydrogen cooking.

2.9 Sun- electricity- hydrogen – heat cookers

In this model (Fig. 9) installed at a self sufficient solar House at Freiburg, Germany, electricity produced with a solar cell is used to electrolyse the water, and the hydrogen produced is stored in the pressurized tanks. Liquid hydrogen stored in the cylinders is used later on for cooking at any time of the day. The author saw this the model in 1996.

MULTIPURPOSES COOKERS

With some modifications in the hot box ovens, it can be used (in addition to cook and pasteurize water), for heating water, drying agricultural products, and for drying and distillation (this model not shown here). The justification is that for cooking, the minimum plate/ air temperature should be between 80- 90°C, whereas for heating water for making tea, coffee, bath, dish washing, water pasteurization and drying etc. one requires less temperature (50-60 ºC). Thus a multipurpose solar oven can be used for more days per year, rather than using only for cooking.

2.10 Solar oven cum water heater

It is similar to a conventional hot box except that the metallic plate is replaced by a metallic tank in the form of a U. The inner flat portion is used for keeping utensils for cooking. One of the models dsigned and studied by the author is shown in the Figure 10.

2.11 Solar cooker cum dryer

It is similar to conventional hot box with basically two changes. The transparent glass covers are not flat but inclined by 15-20° C, and secondly there are some holes in the front of the box (for the entrance of fresh/ ambient air) and some holes on the back of the box and at higher level (as compared to the front side), for the exit of humid air. The holes could be closed (for cooking) or opened (for drying) as required. One of the models designed and studied by the author is shown in the Fig. 11.

Fig. 10. Solar Oven cum Water Heater.

Fig. 11. Solar Oven cum Dryer.

The objective of these two multipurpose devices is not to perform two processes simultaneously - like cooking and heating water - but to use one at a time. In other words use for heating water (or drying), instead of cooking or after cooking is finished.

3. NON COOKING APPLICATIONS OF SOLAR COOKERS

Due to limitation of space, we can just mention that solar heat or solar electricity is similar to heat and electricity produced from conventional fuels, and thus different types of solar cookers/ovens mentioned already have unlimited uses-requiring low temperature or higher temperatures. As an example some students and professors at our university warm their lunches daily using direct solar cookers and the solar electric microwave oven, etc.

4. CONCLUSIONS

We have mentioned the principles behind various types of solar cookers. There are more than 200 varieties of solar cookers for different requirements - cheap (US$5-10), expensive (US$500-10,000), small (cook for 3-4 persons) and bigger (cook for 30,000 persons) sizes, slow and fast cooking, portable, hybrid etc. In addition, solar energy is a free, abundant and pollution-free fuel.

In spite of these benefits, the cookers are not used on a massive scale (the total could be around 1.3- 1.5 million, throughout the world). Different reasons will be mentioned by other authors.

Based on the personal experience I can confirm, if the cookers are designed, constructed, promoted properly with instructions about their use and honest information about their limitations beforehand, and there is after sale service available. etc, more persons will be using them every day to save their family budget and consequently save conventional fuels and/or the environment.

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