Evaluation of Several Original and Commonly Used Solar Cooker Designs

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Abstract

I spent the summer of 2002 at BYU in Provo, Utah testing and evaluating a number of different solar cooker designs under the guidance of Dr. Steven Jones. Temperature measurements were made with a TI CBL to evaluate cooking effectiveness, and other factors were taken into account to determine the utility of each design. Eight cookers were tested over a ten week period. The purpose of this research was both to judge the merits of the specific solar cookers being considered and to reveal common principles that can be applied to general solar cooker design. The project was successful in both of these objectives as well as in suggesting directions for further research.

Introduction

Partaking of solar cooker research begs the question of just what solar cookers are good for and who could use them. The main body of the solar cooker market is families in developing countries who use wood for cooking, or approximately half of the world's population. The French organization Synopsis estimates that with the right type of solar cooker these families could use on average 60% less firewood. [6] The benefits of solar cooking for the families themselves are easy to see: less time or money spent obtaining firewood and less time spent cooking over a smoke-producing fire. The improvement of the welfare of the world's poverty stricken individuals is one major motivating factor behind the numerous non-profit and charitable organizations that promote solar cooking around the world; the other is the environmental boons that could come about as a result of widespread solar cooking. In nearly all developing countries at least 20% of energy comes from burning wood; in most the figure is more than 40%, and in many, nearly 100%. [7] Because of this, the UN Environment Program estimates the annual deforestation rate due to fuelwood collection be 20,000-25,000 square kilometers, much of it in tropical or sub-tropical regions with abundant solar energy. [2] This is quite serious business, because deforestation is one of humankind's most devastating ecological impacts. A good article on the environmental impacts of wood burning, with many sources cited, is [4].

But let us not be blind to the uses solar cookers could have for the middle class. Some solar cookers are very small and portable and could be used on hiking and camping excursions. This would, once again, eliminate the need to collect firewood and would also eliminate the risk of starting a forest fire. Beyond such limited uses, though, a prudent individual could, with a little foresight, incorporate solar cooking into his or her daily routine, even here in America where microwaves and gas and electric stoves are commonplace. Solar cookers obviously won't do everything such modern conveniences will, but if a comparison is to be made then let it be made fairly. Consider the analogy with cars, which many of us consider to be a modern-day necessity, and bicycles, which can't do everything cars are capable of, but which many Americans find quite suitable for at least a portion of their transportation needs. In these days of growing environmental awareness, many residents of affluent nations are choosing to take steps to reduce their ecological footprint, and solar cooking is an avenue towards green living that lies open to them.

A solar cooker itself has multiple uses besides cooking. Uses that have been found so far include canning, [9] drying, [1] and refrigeration, [4] all of which are means of preserving food under just about any conditions, as well as water pasteurization [8] and disinfection (http://www.sodis.ch/), which are especially important in developing countries where infectious diseases transmitted by water are a major cause of death. Many of these uses have only begun to be explored and very little work has been published on them.

Evaluation of Solar Cookers

There are six main factors that I used to rate solar cooker designs. They are as follows:

1. **Cost** - The availability of materials and local economic conditions in the region where the cooker is to be built or deployed, including the economic means of the target demographic.
2. **Convenience** – How portable the cooker is and the range of conditions in which it can be used.
3. **Safety** – The likelihood of starting a fire or causing burns or blindness. These are mainly problems with parabolic cookers that have a sharp focus.
4. **Cooking** – Likely cooking time, maximum and average attainable temperatures, and cooking capacity. Can the cooker prepare enough food to feed a family?
5. **Durability and maintenance** - Wind stability and endurance under frequent usage, packing, and exposure to the elements.
6. **Ease of use and simplicity**

This list is partly inspired by the one compiled at http://solarcooking.org/rating.htm.

Experimental Procedure

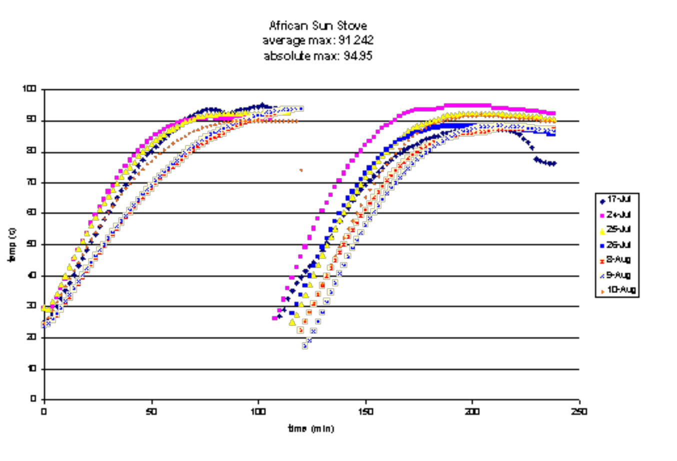
For the quantitative portion of my evaluation I used a TI-83 and TI-CBL with two temperature probes and the program TEMP [11] to record the temperature of 600 mL of water at two minute intervals for two hours at a time. (Two hours is sufficient because the temperature curves of all the cookers tested began to level off in the neighborhood of an hour.) The water was left in flat black cooking vessels in the solar cookers from 11:00 to 1:00 and again from 1:00 to 3:00. In carrying out experiments with a particular cooker I attempted to optimize performance in all cases by doing things like turning the cooker slightly ahead of the sun at the beginning of the two-hour period, covering the vessel with an oven bag or some other type of clear plastic, raising it on a wire stand if the bottom of the cooker was reflective, and only recording results from days which had little or no cloud cover. The results I obtained are valid for Provo, Utah in midsummer and will vary for seasonal changes and latitude; naturally solar cookers are more effective when they are exposed to more intense sunlight. [10]

Results

Note: I consider reasonable cooking temperature to be 85 Celsius degrees or above. (Boiling temperature at Provo's elevation is approximately 97.) For pasteurization of water, a temperature of 66 degrees is sufficient. [8] The prices I give are for materials purchased within the US and do not include labor or shipping costs.

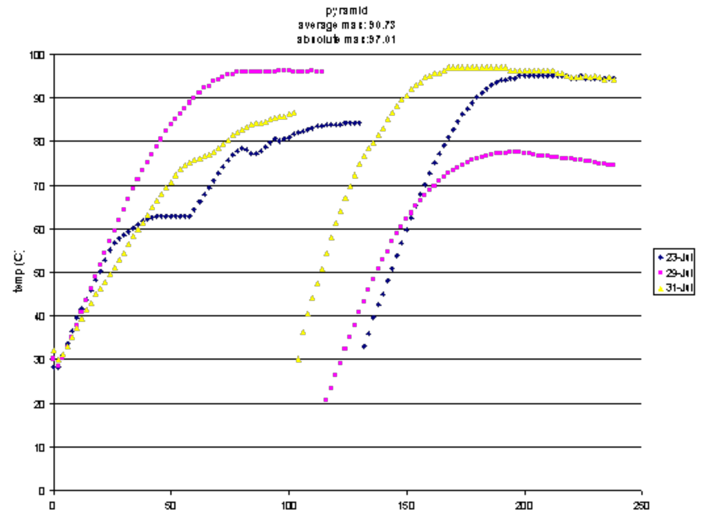
African Sunstove – ~ $18 - Girl Guides of South Africa

The basic shape of the reflector in the African Sunstove is a funnel, which is made from aluminum sheet metal from a lithograph printing press, a material that is cheap and available worldwide. [10] The reflector is surrounded by fiberglass insulation and contained in a plastic housing, however, which raises its price and limits its availability. It is not affected by wind and is not susceptible to water damage if the lid is on, but its portability is poor. The performance of the African Sunstove is the best overall for reliability and average temperature, and it has a decent cooking capacity. The bottom is aluminum painted flat black, and the solid data points on the graph represent trials where the pot rested directly on this. The crosses, x's, and asterisks represent trials where the bottom was covered with aluminum foil and the pot was raised on a wire stand. It is unfortunate that this model has been discontinued due to the difficulty of manufacturing it in developing countries.



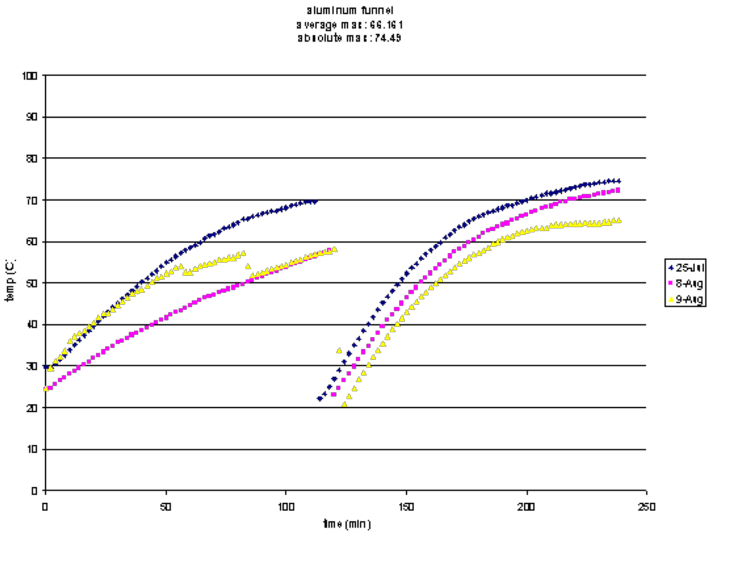
Fabricated Sunstove – ~ $40 - Sunstove Organization (South Africa)

This cooker is similar in design to the African Sunstove, with the main difference being that the reflectors are flat instead of round. They are made from aluminum sheet metal from a lithograph printing press and are surrounded by fiberglass insulation. The cooking performance is similar to that of the African Sunstove, although not as reliable and with a slightly lower capacity, but it is more portable with its lighter, sturdier wood frame and a carrying handle.



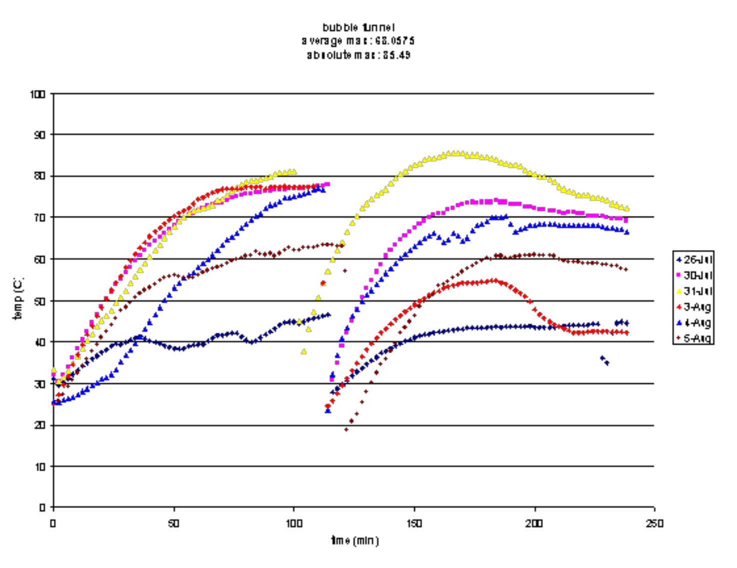
Aluminum funnel – $0

This is called the aluminum funnel to distinguish it from an earlier funnel cooker Dr. Jones built from aluminized Mylar. It is made from lithograph aluminum. Fairly early on we could see that the African Sunstove was successful so we wanted to find out if we could make a design that would give similar performance but without the added cost of the insulation and plastic housing. Our attempt was not successful, mainly because the aluminum used was not reflective enough (it would heat up considerably, indicating that it was absorbing radiation rather than reflecting it). This implies that not all lithograph aluminum is created equal and that its reflectivity varies from source to source.



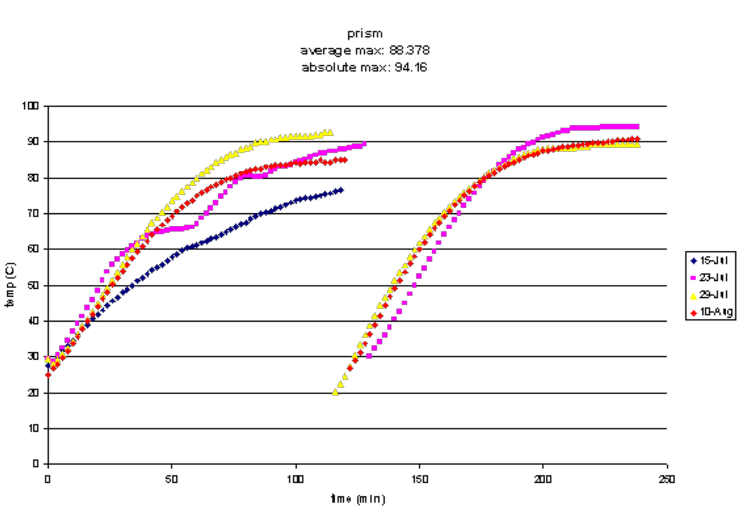
Bubble funnel – $5

This was another attempt to emulate the performance of the African Sunstove with a different type of insulation. The funnel is constructed out of a sunshade for a car windshield, which has air-filled bubbles sandwiched between two reflective layers. This model was unsuccessful mainly because it was too flimsy to support its own weight, and the variation in its performance is a result of its poor wind stability and the fact that it wouldn't stand up the same way twice.



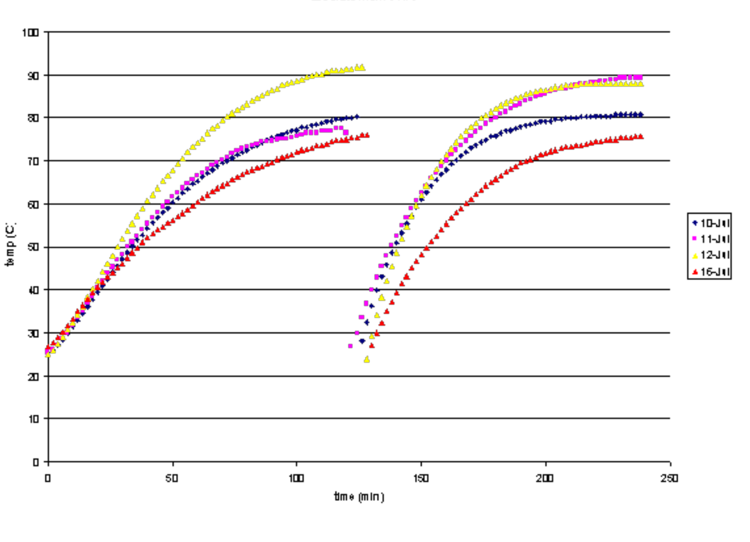
Dakota Sunstove – $56 – Rotary International

This model has decent portability and cooking ability, and has the largest cooking capacity of any of the models included in this report. It is light but sturdy and not affected by wind or water. The Rotary organization currently has about 1000 of these deployed in Haiti where they consistently reach temperatures around 270 degrees Farenheit. Its performance in Utah is not quite as impressive, but still suitable for cooking. Its sides are highly reflective and the bottom is flat black.



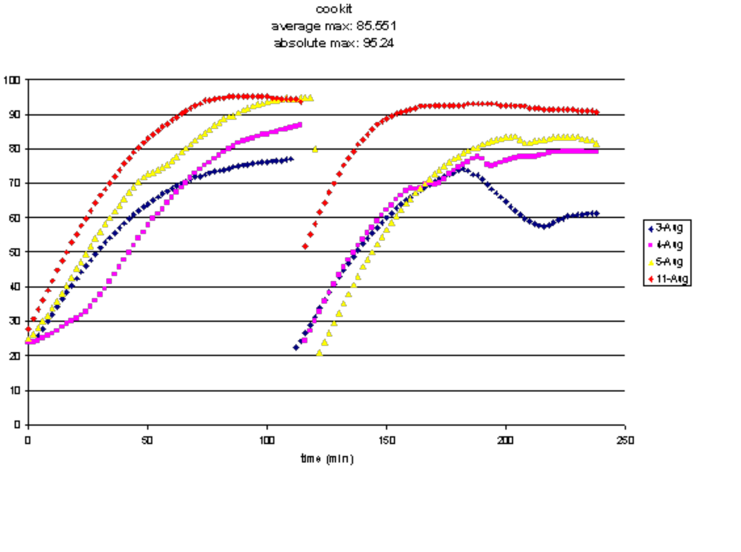
Wedge – $35 – built by Dr. Jones, design by Sunstove Organization (South Africa)

The wedge cooker is heavy and cumbersome to carry around, so its portability rating is very low. Its cooking performance is poor as well, probably because it focuses very little sunlight onto the cooking vessel (only the back of the wedge is reflective) and because the double wall polycarbonate from which it is constructed is not very transparent. In Utah's climate it is not quite adequate for cooking.



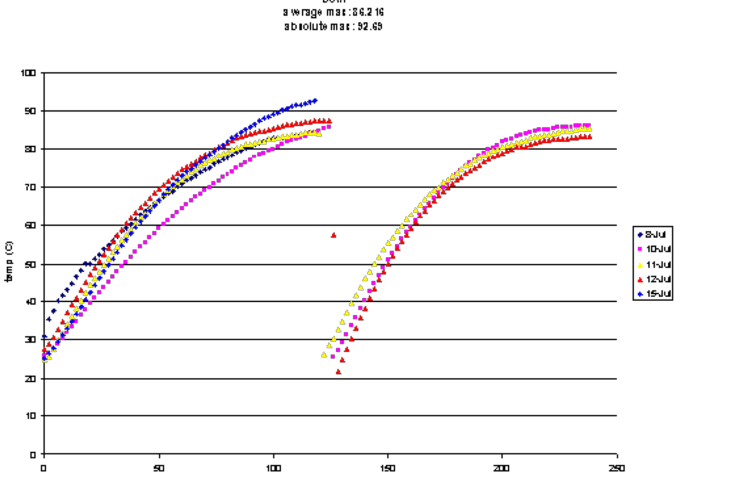
Cookit – $20 – Solar Cookers International

This is a highly portable model made from cardboard with a highly reflective foil coating that folds up into a convenient size. Its high portability makes it useable in situations where a sturdier but less portable model won't suffice but makes it unsuitable for regular use as being repeatedly folded and unfolded weakens it and water can ruin it completely. Despite these weaknesses it has a decent cooking capacity and performance, although poor reliability. (The first funnel designed by Dr. Jones has similar portability and performance, but has better durability and reliability and lower cooking capacity.)



Bowl – $12

Dr. Jones made this cooker out of a plastic planter, but any suitable hemisphere which can be purchased or constructed will work. Because of its symmetrical shape, it gives very consistent results, and it also has a decent cooking capacity. It is not too heavy and multiple bowls can be nested for storage and transportation. If it is left upright then it is absolutely unnecessary to follow the sun with it, but its performance could be improved by tilting it towards the sun. Its simple design is an additional advantage.



Conclusions

The evidence I gathered seems to indicate that insulation does help a small amount, but is not absolutely necessary (compare the average maximum temperatures of the insulated African, Fabricated, and Dakota Sunstoves to those of the uninsulated cookit and bowl cookers), and may not be worth the added expense and labor in a poor country with plenty of sunlight. It is likely to be desirable for cookers marketed for middle-class buyers in temperate regions. Also, cookers with round reflectors seem to be more consistent in the temperatures they reach than cookers with flat reflective surfaces (compare the consistency of results for the round African Sunstove and bowl cooker with the more spread out data for the flat Fabricated and Dakota Sunstoves and the cookit). A possible explanation for this is that cookers with round surfaces are more symmetrical and therefore their foci are not as dependent on the position of the sun, whereas cookers with flat surfaces have to be pointed directly at the sun to achieve maximum effectiveness. This is an important consideration, because one of the drawbacks of solar cookers is that they have to be turned occasionally during long periods of use, and anything that diminishes the amount of tending necessary is a good thing. Also, solar cookers already don't work when it is overcast and don't work as well during times of day or seasons with little sun exposure, so they should work as often and as consistently as possible when the sun is shining.

Suggestions

My work suggests some directions for further research. Whether or not it is better, in general, to have a cooker with a reflective or absorptive (black) floor is still an open question. My results for the African Sunstove seem to indicate that an absorptive floor is marginally better, but broader tests, with different designs, are needed to confirm this. More tests could be done to see if my result that round reflectors give more consistent results than flat ones holds for different designs, as well as to determine the maximum length of time various models of cookers can stay in one position without being turned and still maintain optimum cooking temperatures. Comparing round and flat reflectors in such a way could determine whether or not my explanation for the difference in results is correct. And finally, previous tests have shown that Dr. Jones's funnel design works well [5]; so a larger model that can accommodate an average sized cooking pot should be equally successful, if sufficiently reflective material is found.

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