# Comperative Study of two Solar Cookers: Parabolic Reflector and Flate Plate Collector Indirect Heating

Maria Eugênia Vieira da Silva, Lana Ludmila Pinheiro Santana, Régio Davis Barros Alves
Universidade Federal do Ceará, Laboratório de Energia Solar e Gás Natural.
Bloco 718, Campus do Pici s/n, Pici, Fortaleza 60190-080 BRAZIL.
Tel: (85) 3288-9632 ramal 221 Fax: (85) 3288-9636
e-mail: lesgn@les.ufc.br

Klemens Schwarzer
Solar-Institut Jülich, FH-Aachen
Heinrich-Mußmann-Str. 5, D-52428, GERMANY

**Abstract**

Solar cookers are heat exchangers designed to use the solar energy in baking processes. Depending upon the heat transfer to the cooking pot, they can be divided in two types: direct and indirect cookers. The first type uses solar radiation directly in the cooking process. The indirect cookers use solar radiation to heat up a thermal fluid, which transport this heat to the place of food processing. The purpose of this article is to present the measured thermal efficiencies and the fabrication costs of two cookers: a parabolic-concentrating direct cooker and an indirect heating cooker (Schwarzer model) that uses flat plate solar collector. The parabolic cooker is composed for parabolic reflectors with a mobile support and a pan unit. The indirect cooker is made of one or more flat plate collectors and a cooking unit with pots. For the comparative study of the two cookers, experimental testing was carried out at the Solar Energy and Natural Gas Laboratory (LESGN) in Fortaleza, Ceará. The efficiencies, sensible and latent, of the two cookers were determined. Temperatures around 200$^{o}$C were measured in the flat plate collector cooker, reaffirming the possibility of its use in cities and in the countryside. Fabrication cost for the two cookers were made and the results showed a lower price for the parabolic cooker. The flat plate cooker had as advantages: reliability, security in operation, very low maintenance and a longer life time.

**Keywords:** Solar Energy, Solar Cookers**.**

## Introduction

Countries worldwide have invested resources in research and development of alternative energy sources and equipments, although, in many cases, not in the amount that they should have. In Brazil, a country characterized by its natural riches and renewable energy sources, the adequate use of solar energy can help reduce the problems of energy supply. As the world slowly realizes that its reserves of fossil and nuclear fuels are limited and rapidly running out, more attention has been devoted toward the use of renewable energies. Solar energy is by far the most abundant and accessible. Countries like Israel, Austria, Germany and Japan, among others, have a great number of solar systems installed.

Even though wood burning is not the main cause of deforestation, it represents more than 90% of the energy used in some countries. Deforestation is an environmental problem caused by different reasons. In rain forests, deforestation is mainly due to agriculture expansion, cattle rising and wood extraction. In semi-arid regions, the reason is wood burning for fuel.

Solar cookers are heat exchangers designed to absorb solar radiation and convert it into heat for food processing. They can totally or partially replace the use of wood in various regions. Different models of cookers have been tested and the most common ones are the box and the concentrator cookers, both direct cookers. This article presents the experimental results (temperature, global radiation and efficiency) and the cost estimation for two solar cookers: a parabolic-concentrating direct cooker and an indirect heating cooker (Schwarzer model) that uses a flat plate solar collector.

## Systems Descriptions

The flat plate collector cooker operates in indirect heating (Figure 1) and is composed of one or more flat plate collectors, cooking pots, and a storage tank, if energy storage is needed. Side reflectors provide additional solar radiation in the surface of the absorvedor. In its operation, a thermal fluid flow is heat up in the collectors and moves by natural convection to the pots, where it transfers part of the sensible energy to the food. The advantages of the system are: the possibility of cooking in internal rooms, high operation temperatures in a short period of time, allowing baking so as well as frying, and the use of an energy storage tank to keep the food warm longer or allow nocturnal cooking.

Figure 1. Solar cooker with flat plate collector with side reflectors at the LESGN in Fortaleza, Brazil.

The parabolic cooker (Figure 2) is made of parabolic reflectors (point concentration) with a mobile support and a pan unit. In its operation, the incident solar radiation in the aperture area is reflected to the sidewalls of the pan. The support allows a manual tracking of the direct radiation and the cooker can be easily moved. The advantages are the price and easy construction. The disadvantages are the need of solar tracking, outdoor cooking, and its relatively non-safe use for the operator (solar radiation on the eyes and skin, if not correctly used).

Figure 2. Parabolic solar cooker at the LESGN in Fortaleza, Brazil.

## Approach

To study the cooker performance, experimental measurements were made. The measured variables were global solar radiation, ambient temperature and the temperature of the water in three positions in the cooking pots. Using these measurements, the sensible and the latent efficiencies were calculated.
Two cookers were selected for the fabrication cost study. The flat plate collector cooker had two pots (8L), a 1,97 m² high quality collector, and three side reflectors, allowing the preparation of 30 to 40 meals per day. The parabolic cooker had an aperture area of 1,26 m² and one pot.

*Experiments*

In both cookers, 3 liters of water were used for the sensible efficiency tests. Three thermocouples (type J) were placed in each pot. A solar radiation sensor was installed in the same inclination as the collector, in one case, and in the horizontal for the parabolic cooker. The sensors were scanned each two seconds and the average values for each minute were stored. The water temperature was initially the ambient temperature and the end temperature near 95°C, to avoid the uncertainty in the start of boiling.
For the parabolic cookers, the focal point was adjusted every 5 minutes in the east-west direction, by moving the side reflectors.
The rate of sensible heat transfer was estimated using Eq.(1), as presented by Schwarzer and Silva, 2003. The sensible efficiency was calculated as the ratio of the sensible heat of the water divided by the amount of solar radiation incident. The rate of latent heat was determined using the amount of water evaporated multiplied by its heat of vaporization. The latent efficiency was calculated using Eq.(2).

$$\dot{Q}_h = \frac{m_W . c_P . \Delta T_{95-Tamb}}{\Delta t} \tag{1}$$

$$\hbar = \frac{m_W . h}{A_{ab} \int_0^t \dot{E}_{dir} . d.t} \tag{2}$$

*Materials*

To estimate the cooker prices, material and labor costs were considered. The flat plate collector cooker had a $2m^2$ flat plate collector, side reflectors, two 8 liter pots, and a cooking unit. Connecting the collector to the cooking unit, a copper circuit was installed. The parabolic cooker had to side reflectors that were manually moved to maintain the focus on the cooking pot, a central structure to support the pot, and two wheels and a stop.
The materials used in the flat plate cooker were: selective absorber fins, glass, stainless steal pots, polished aluminum sheets, copper tubing, insulation and support structures. In the parabolic cooker, the materials were: polished aluminum sheets, stainless steal tubes, 2 wheel moving mechanism, and a manual reflector adjustment mechanism.

## Results and Discussion

The values presented for the sensible and latent efficiencies are the average values for various tested performed. The plots are for the specific days of measurements.
Figure 3 shows the experimentally measured data (global solar radiation flux and temperature in the water) for the solar cooker with flat plate collector. This experiment was made on October 8, 2004. Water temperature data are the average values of the three thermocouples in the pots. The experiment took place in a 19 minute period, that is, 13 minutes were necessary for the temperature increase from ambient to 95°C, and 6 minutes for the increase from 95°C to about 100°C.   The average global solar radiation was 1000 W/m$^2$.

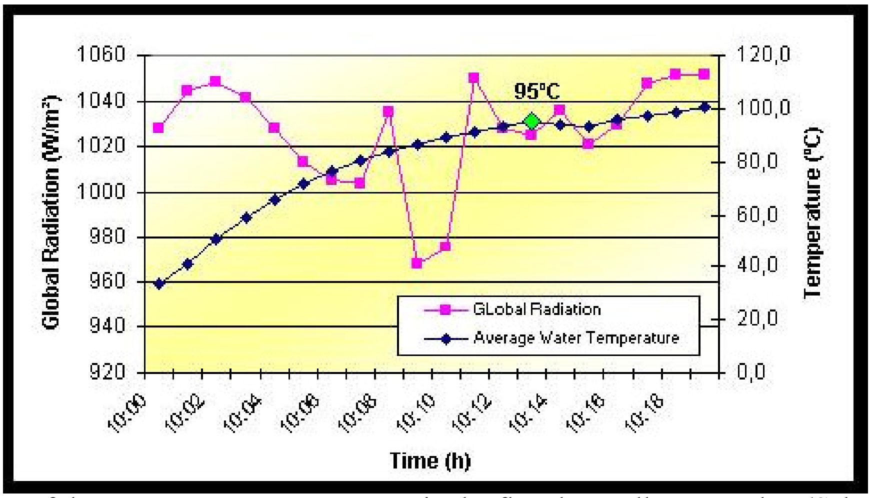

Figure 3. Plot of the average water temperature in the flat plate collector cooker (Schwarzer model).

The average value for the sensible efficiency was 0,36. The average values measured in previous experiments varied from 0,30 to 0,34 and this difference can be associated with the use of different thermal oil in the thermal siphon circuit. The average value for the latent efficiency was 0,49 – approximately the same value found in previous measurements (Schwarzer and Krings, 1996). This higher value for the latent efficiency was expected as the latent efficiency tests always took place after the sensible heating tests, when energy was used to heat up the mass of metals and storage tank that make the cooker.
Figure 4 shows the same experimental data for the parabolic reflector cooker. The experiment was made on October 19, 2004. Water temperature data are also the average values of the three thermocouples in the pots. The experiment took place in a 28 minute period, that is, 21

minutes were necessary for the temperature increase from ambient to 95°C, and 7 minutes for the increase from 95°C to about 100°C. The average global solar radiation was 947 W/m$^2$.

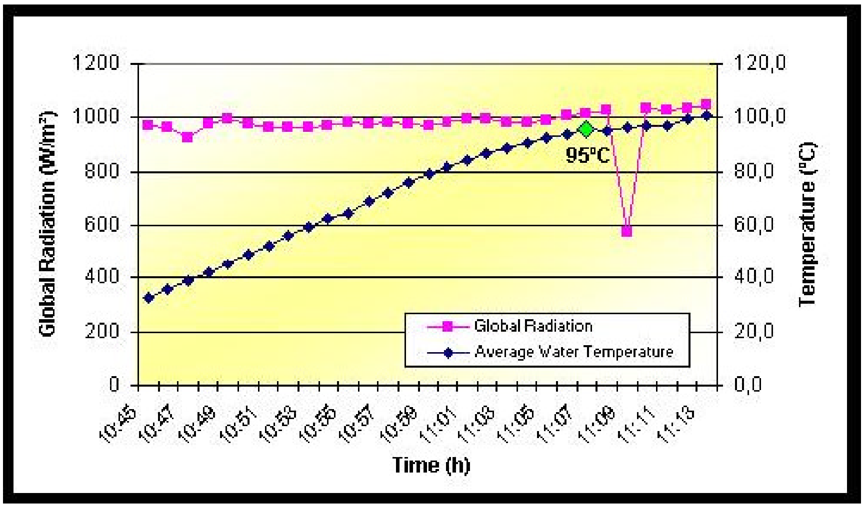


Figure 4. Plot of the average water temperature in the parabolic reflector cooker.

The average value for the sensible efficiency was 0,26. This values agrees well with the measurements made at Solar-Institut Jüelich, where a value of 0,27 was also experimentally measured. The average value for the latent efficiency was practically the same as in the flat plate collector cooker.

The estimated price for the flat plate collector cooker was about R$ 4.000, equivalent to US$ 1.417, or Euro 1.099, at the current exchange rate. The estimated price for the parabolic cooker tested was about R$ 1.300, equivalent to US$ 461, or Euro 358.

It is also important to notice that the flat plate collector cooker had two 8 liter pots, which allowed for, at least, the preparation of twice as many meals as for the parabolic cooker with one pot. Also, the safe-operation costs were not quantified. The flat plate collector cooker allows the cooking process to be done indoors, avoiding exposure of the cook to the sun, particularly near the focal point. This repeated exposure can cause skin burning and eye damage.

Life-time expectancy of the flat plate cooker is greater than 10 years. These cookers are made with quality materials and require very simple maintenance; the first cookers made more than 10 years ago are still working in very good conditions.

## Conclusion

In this research, two models of solar cookers were compared: a flat plate collector that operates in indirect heating mode and a parabolic reflector cooker that operates in direct heating mode.

The experimental results showed the good thermal performance of the two solar cookers. The sensible or heating-up efficiency was 0,35 on the solar cooker with flat plate indirect heating and 0,24 on the solar cooker with parabolic reflector. (Schwarzer and Krings, 1996) measured values between 0,30 and 0,34 for the sensible efficiency in the solar cooker with flat plate. The average value for the latent efficiency was about 0,50 for both cookers.

This value, higher than the sensible efficiency, was found because, at the start of the measurements, the whole system was already warm.

As expected, the price for the parabolic cooker was lower than for the flat plate collector cooker. The first cooker is easier and cheaper to make, but it presents some disadvantages:

non-safe operation, exposure of the cook to intense solar radiation, and lower life-time. The flat plate cooker has as advantages: reliability, safety operation, and a longer life time.

**Acknowledgements**

The authors would like to thank the SECITECE (Secretaria de Ciência e Tecnologia do Estado do Ceará, Brazil) and the firma IBEU (Ingenieurbüro für Energie- und Umwelttechnik, Germany) for financing the cookers used in the experiments, and the Brazilian institutions: CNPq (Conselho Nacional de Pesquisa, Brazil) for research fellowships, and the firma Petrobrás (Petróleo Brasileiro S.A., Brazil) for presently supporting a solar cooker project.

**References**

Schwarzer, K., Krings, T., 1996. Demonstrations- und Feldtest von Solarkochern mit Temporäre Speicher in Indien und Mali. Shaker Verlag, Aachen.

Schwarzer, K., Silva, M. E. V., 2003. Solar Cooking Systems with or without Heat Storage for Families and Institutions". Solar Energy, vol.75, pp. 35-41.

Silva, M. E. V., Schwarzer, K., Medeiros, M. R. Q., 2002. Experimental Results of a Solar Cooker with Heat Storage. Krauter, S.C.W. (Ed.), Proceedings of Rio 02 World Climate and Energy Event, Rio de Janeiro, Brazil, pp. 89–93.

Telkes, M., 1959. Solar Cooking Ovens. Solar Energy 3, 1–10.

Vieira, M.E., Gomes, C. A. S., and Teixeira, R. N. P., 1997. Thermal Efficiency of a Solar Cooking System with Heat Storage, COBEM-448, São Paulo, Brazil.

# Solar Cooking in Nigeria

F.T. Sheyin
Centre for Energy Research and Training,
Ahmadu Bello University,
Zaria, Nigeria

## Abstract

Nigeria has abundant country-wide availability of solar energy of total average 3.5-7.00kwh/m$^2$.day. The solar radiation levels for Nigeria indicate that solar cooking is applicable through out the country.

Since 1969, various sizes of prototypes of solar box cookers and ovens and the parabolic or concentrator types have been developed and tested. Their performances were found to be satisfactory especially for rural applications. Solar cookers are not yet finding widespread utilization for cooking in Nigeria. There is however increasing use of solar cookers by some communities in Nigeria. New plans are also under way to improve the state of the use of solar cookers for cooking in the country.

Solar cookers may not replace the use of wood, kerosine and liquified natural gas(LNG) fuels and also electricity from hydro-power and fossil fuels mainly used for cooking in Nigeria. Solar cooking in Nigeria is however promising because it will help to save and reduce air pollution from the carbon containing fuels, protect the environment, improve health and nutrition and reduce certain burdens of life caused by the use of the main cooking fuels.

**Keywords:** Main Cooking Fuels, Solar Energy Resources, Status and Barriers to Solar Cooking.

## 1. Introduction.

The main cooking fuels in the rural areas in Nigeria are wood fuel, agricultural wastes and animal dung. In the urban and suburban cities, the main cooking fuels are kerosine, liquified natural gas(LNG), electricity from hydro-power and fossil fuels such as coal and natural gas.The use of kerosine for cooking is presently more common in the urban and suburban cities because of the declining production, poor management and distribution of electricity and also the increasing cost of LNG due to the bad economic situation in the country. The use of wood fuel and other biomass, kerosine and LNG for cooking introduces $CO_2$ and other greenhouse gases in the household environments which contribute to global warming and climate change. The persistent use of wood fuel for cooking in addition leads to soil erosion, deafforestation, desert encroachment and the shortage of wood fuel.

Solar energy is a good alternative source of energy for cooking in Nigeria. Fortunately, Nigeria is endowed with abundant sunshine of not less than 11 hours per day through out the year. Solar cooking may not replace the main cooking fuels in Nigeria. However, the use of solar energy for cooking in Nigeria has the following advantages:- Solar energy is inexhaustible, universal, abundant and free. Solar cookers can therefore be used for cooking at needed sites in areas that include the most remote rural areas in Nigeria without fuel cost and