SOLAR COOKING BUILT IN COMPOSITE MATERIAL

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Abstract. *. It is a solar oven/cooker for the operations of solar cooking of food for meals in a residence, especially for the country area. The use of this prototype can contribute decisively to a policy of economy of conventional fuels, minimizing the harmful effects of pollution caused by the use of firewood as a source of energy. Brings as benefit a reduction in the level of desertification in our region, which is increasing and causing ecological imbalance. Its massive use can mean a policy of using clean energy, environmentally correct, contributing to sustainable development. Will be shown the process of manufacture and assembly of the oven / stove built from a composite of ceramic matrix formed of plaster, grounded EPS and water. Its main feature is its low cost. Works by solar rays concentration and greenhouse effect. The concentration of solar rays is obtained and directed to the interior of the oven/cooker through a mirrored cylindrical surface placed at the top of the solar oven / cooker. Will be presented results of the tests that demonstrate the thermal, economic and material viability of the oven / stove built. It will also be determined the time of cooking for various types of foods and their results will be compared with other types of oven / stove solar and conventional ovens.*
Keywords*: solar oven; solar cooker; composite material; low cost; sustainable development*

1. INTRODUCTION

The wood is probably the oldest energy used by man and still has great importance in the Brazilian energy matrix, participating with about 10% of the production of primary energy (Balanço Energético Nacional, 2006).

About 40% of wood produced in Brazil is transformed into charcoal. The residential sector is the one that consumes more fuel (29%). Usually it is for cooking food in rural areas. A family of eight people requires approximately 2,0 m^3 of wood per month to prepare their meals. The industrial sector is then about 23% of consumption. The main consumers of wood industries in the country are food and beverages, ceramics and pulp and paper.

These data show that the massive use of wood, putting at risk the health of the planet, suggest the need for a politic of mass use of solar cooker for cooking of food as a way to preserve nature and to mitigate the ecological imbalance the indiscriminate use of firewood, and minimize the emission of greenhouse gases into the atmosphere.

The use of solar energy for cooking and roasting of food is one of the oldest and most widespread applications of this energy source, and its main characteristic social function. It is wonderful to note that people in Africa use massively the stove and / or solar furnace, contributing to a policy of non-use of wood, which contribute decisively to the environmental imbalance of our planet.

In northeastern backlands affected by drought, the swing is suffering from hunger and thirst due to the severity of the sun on their land arid. The use of *solar oven/cooker* in the drylands promises to reverse or at least soften it possible to swing a better condition of life.

This paper presents a model of solar oven/cooker for the baking sun and cook food, built from the use of a composite material, which presents in its composition the EPS ground, a recycled material. Will determine which operation to the prototype is more efficient, whether for baking or roasting food.

The proposed *solar oven/cooker* is an average concentration solar prototype intended for domestic use in rural and urban areas in the period from 9:00 am to 14:00 pm. It is primarily the operation of roasting food, such as breads, cakes, pizzas and more.

The main innovation of this work was the use of a composite material-based gypsum, EPS ground, cement, sand and water for the construction of *solar oven/cooker*. The use of this material has an additional advantage, besides its low cost and easy workability, which is its low coefficient of thermal conductivity, which gives the furnace a good thermal insulation capacity.

Another innovation was the design and construction of a reflector to direct sunlight into the *solar oven/cooker.* This system presents a profile that approximates a parabola, increasing the concentration of solar rays inside of the *solar oven/cooker*.

2. BIBLIOGRAPHIC REVIEW

Solar cookers are designed for cooking of food and are classified into three basic types; type box, concentrators and heated by flat plate collectors.

The box type cooker can have different numbers of external reflectors, flat or slightly concave. It is characterized by allowing the taking of temperatures below 200° C. It takes the heat and its operation is very simple. It has the advantage of being able to operate virtually without user intervention, keeping the food warm for a long time. It does not produce harmful effects to the user or by a contemplation or reflection. The box type cooker are stable and do not present risks for the production of flames, generating not therefore susceptible to burns (Lion, 2007).

Are constructed with materials of low cost, although it is unlikely their use for every day of the year. It's possible to build models for easy transport, lightweight and foldable.

This type of *solar oven/cooker* has wide application around the world, mainly in Asia and Africa, especially India and China, as countries that have invested more in social programs that enable the construction of low cost solar cookers for a significant use by its people (Souza, 2005, 2007, Melo, 2008).

Then in Fig (1) are presented different models of *solar oven/cooker* in use worldwide.

Figure 1. S*olar oven/cooker* box type in use worldwide as India, the first, second and third picture; USA second line and Brasil the latest pictures (Gomes, 2009).

3. MATERIALS AND METHODS

For the construction of the *solar oven/cooker* used a mold made of wood. The proportions by volume of composite material in the mixture were: 1.0 part gypsum, part of 1.0 EPS ground, 0.33 parts of cement and 0.3 parts of water in relation to the total volume of the mixture.

The *solar oven/cooker* proposed presented the following dimensions: external - length: 0.69 m, width: 0.47 and height 0.18; internal - length: 0.58, width: 0.37, height: 0,13. The external area was 0.32 meters and the volume external to 0.0584 m³; the internal area was 0.215 meters and the internal volume of 0.028 m³. The external surface reflector provides a an area of exposure to solar radiation corresponding to 0,6 m².

All the internal volume of the furnace was covered with sheets of zinc painted black to a greater absorption of solar radiation incident.

The collector was covered with a transparent glass 3mm thick. The glass is placed in the composite and presented slide motion to provide the placement and removal of food cooking made.

The structure of the furnace was made using the angles and spin sets to facilitate the handling of the *solar oven/cooker*.

Tests were performed to determine the absorber temperatures and the interior of the *solar oven/cooker* box type studied. It also measured the direct incident solar radiation on the prototype built. The tests were performed for the period from 10:00 to 14:00 hours (Melo, 2008, Gomes, 2009). The internal temperature and of the absorber in the *solar oven/cooker* was measured with cromel-alumel thermocouples attached to a digital thermometer and measures in the solar radiation were obtained with a pyranometer. These measures were realized for the interval of ten minutes.

Even under solar conditions not ideal there was a test for roast a pizza, 460 grams, providing the necessary time to this. Temperatures were measured in the absorber and the air inside the *solar oven/cooker*. Measurements were realized at intervals of five minutes.

Was to conduct further tests to produce the assamento cake, pizza, bread and cheese bread in addition to tests for cooking of food, but the solar conditions in our city presented great instability in the period which it finished the construction of the *solar oven/cooker* proposed. It is expected that in the correction for final work may be performed such tests and submit their results. Figure (2) shows the alternative *solar oven/cooker* proposed in test.

Figure 2. *Solar oven/cooker* in solar test.

4. RESULTS AND DISCUSSIONS

Table 1 present results of the internal and of the absorber surface temperature of the *solar oven/cooker* studied and the graph of Figure 3 shows the behavior assumed by these parameters. The s*olar oven/cooker* was exposed to the sun from ten o'clock

Table1. Results of the internal and of the absorber surface temperature of the solar oven/cooker studied

Time (hour)	$\mathbf{T}_{absorber}$ **(°C)**	$\mathbf{T}_{internal}$ **(°C)**	Global solar radiation **(W/m²)**
10:10	125,0	55,2	710

10:20	133,5	60,5	710
10:30	140,2	65,3	720
10:40	148,6	67,1	720
10:50	151,4	69,7	730
11:00	154,5	76,0	730
11:10	157,3	77,1	740
11:20	158,6	81,3	740
11:30	160,2	81,6	750
11:40	161,2	83,8	750
11;50	163,2	87,2	750
12:00	163,1	89,0	750
12:10	161,8	91,6	750
12:20	156,3	86,7	750
12:30	153,7	88,3	750
12:40	154,3	87,0	750
12:50	153,7	90,6	750
13:00	154,9	90,1	750
13:10	151,2	91,2	740
13:20	150,6	90,4	730
13:30	148,3	90,1	720
13:40	145,3	89,8	576
13:50	144,1	89,1	568
14:00	140,3	88,8	568

Table 2. Hourly average data of the *internal and absorber* temperature and global solar radiation.

TIME (hour)	**$T_{absorber}$ (°C)**	**$T_{internal}$ (°C)**	**Global solar radiation (W/m²)**
10:00 – 11:00	142,2	65,6	720
11:00 – 12:00	159,7	82,3	744,3
12:00 – 13:00	156,8	89,0	750
13:00 – 14:00	147,8	89,9	725,8
AVERAGE	**151,2**	**81,7**	**735**

The maximum temperature of the absorber and inside of the s*olar oven/cooker* corresponding to 163.1 ° C and 91.2 ° C, respectively, were significant, and suitable to provide the roasting of food. The average temperature for these parameters during the duration of the test, around 151 ° C and 82 ° C, respectively, are also suitable for the obtaining purposes. The test was conducted to solar appropriate conditions, with maximum direct radiation of the order of 750W / m² and a minimum of 720W / m², with a variation of only 4.1%, which indicates nearly constant levels of radiation.

Despite absorber and internal temperatures of the s*olar oven/cooker* built are well below that of the conventional gas oven with internal temperatures of up to 250 ° C, s*olar oven/cooker* made and tested previously reached levels similar those achieved by the s*olar oven/cooker* in studies for cooking foods such as cakes, pizzas, cheese bread, pasta, rice, meat (Souza, 2005, 2006, 2007, 2008, Gomes, 2009, Melo, 2008).

According with the experiences of several other stoves, design a viable use of this s*olar oven/cooker* designed for obtaining the desired end, which is the cooking of food for a family of low-income, minimizing the harmful effects of the use of firewood for the environment and life.

Another test performed was the roasting a pizza. The results of measured parameters are presented in Table 3. The roasting full of pizza was obtained in 25 minutes. The test began at 10:30 hours, with $T_{internal}$ = 60,5°C and $T_{absorber}$ = 97,3°C. The ambient temperature during the test was on average 32 ° C.

Table 3. Results of parameters measured in the test to roast a pizza.

Time (hour)	**$T_{internal}$ (°C)**	**$T_{absorber}$ (°C)**	**Global solar radiation (W/m²)**
10:35	61,8	51,4	650

10:40	64,1	56,4	650
10:45	65,1	65,2	650
10:50	66,5	68,2	650
10:55	67,2	71,3	650

This test again demonstrated the thermal viability of s*olar oven/cooker* proposed for obtaining the roasting of the pizza in 25 minutes, although this time is well above the time needed for the same purpose in a s*olar oven/cooker* conventional. This time of 25 minutes can be greatly reduced if the roasting operation if occur under ideal solar conditions with sky with low cloud cover.

Other s*olar oven/cooker* already tested under appropriate solar conditions solar had roasting for the same pizza around 15 minutes to an average global solar radiation around 750 W/m². For this test the average global solar radiation was 650 W/m².

Figure 4 shows the behavior by the temperature inside the furnace and of the absorber temperature during roasting the pizza. Figure 5 shows the pizza in roasting in the s*olar oven/cooker* built.

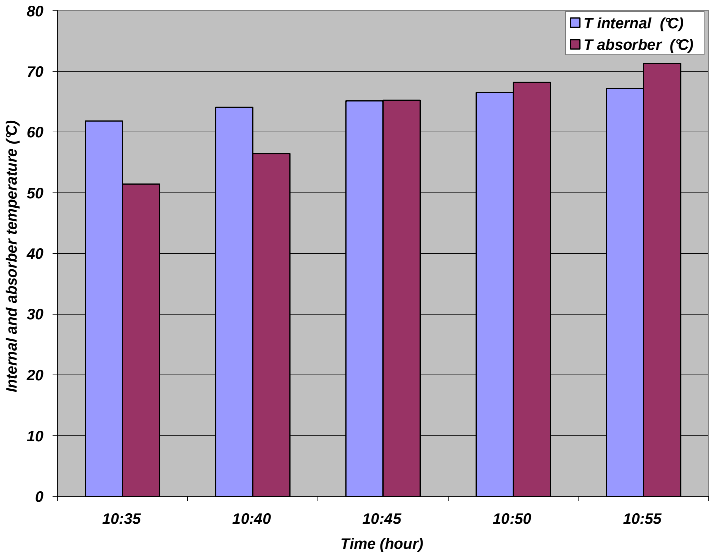

Figure 5. Pizza in roasting in the solar oven/cooker tested.

Figure 6. Solar oven/coker in test of pizza roasting.

Was informed that the work should be completed with the cooking of other foods, as has been done for other already constructed and tested at the Laboratory of Hydraulic Machines and the Solar Energy UFRN, where four mastering dissertations were development in cooking food using s*olar oven/cooker* solar.

The time of the pizza roasting, corresponding to 25 minutes is far above what is obtained by conventional *oven/cooker* solar, with time around 10 minutes. In another version of box type cooker studied got time to roasting up to fifteen minutes. The times of cooking for box type solar cookers are always higher than those obtained with conventional *oven/cooker* solar, but its good cost benefit and social contribution that its use brings, main to the health of the planet, are essential factors for a policy social quality of life for the most poor. O Brazilian government should have a state policy of massive use of *oven/cooker* solar in poor communities, especially in rural areas as a contribution to the decrease in the emission of pollutants and desertification by using firewood and the dignity of life to his people.

But the conditions in our city meteorological continued inappropriate and took up the time to promote some changes in the proposed *oven/cooker* solar. The main one was the introduction of the enclosure within the furnace of a parabola reflector, obtained through the use of a grade of scrap fan covered with composite material and then mirrored. This modification will increase the temperature of the absorber surface, reducing therefore the time for cooking food. Besides the introduction of the parabola reflector, cover up the side walls of the oven with mirrors. The area of the oven / stove solar trambém was going for a modified area of 0,14 m² and internal volume of 0,025 m³. The main changes made in the solar oven/cooker proposed can be seen in Figure 7.

Figure 7. Constructive details of the changes made in solar oven / cooker.

Although few tests have been done with the proposed solar oven / cooker, it is believed that it may be viable, having the characteristics of low cost and easy manufacturing process, since the composite used for its construction is obtained by accessible, low cost and recyclable materials. A mastering thesis on the use of the solar *oven/cooker* is in development and as soon as solar conditions return to normal, an intense sun, few clouds and long hours of visible sun, characteristic of our town (Natal), the tests will be conducted with other foods, including those suggested by reviewers of the work. Experiences with several concentration solar cooker and box type constructed and studied, allows preview its success, and competitiveness in relation to other alternative solar oven / cooker box type in use around the world.

Although the solar conditions have not been the most appropriate it was performed a test with the solar oven / cooker to bake a cake of 600 grams. The Table 4 shows the results of parameters measured, oven internal temperature, absorber temperature and global solar radiation. The test began at 11:00 am, with $T_{internal}$ = 58,0°C and $T_{absorber}$ = 40,5°C. The ambient temperature during the test corresponded to an average of 32.0°C. The complete roasting of the cake was obtained in 50 minutes.

Table 4 Data of the parameters measured in test of roasting cake.

Time (Hour)	**$T_{oven\ internal}$ (°C)**	$T_{absorber}$ (°C)	**Global solar radiation (W/m²)**
0	58,0	40,5	620,0
5	58,8	53,6	620,0
10	60,5	61,6	620,0
15	61,7	68,9	620,0
20	64,1	73,8	650,0
25	68,0	79,4	650,0
30	72,1	84,5	650,0
35	73,5	87,5	650,0
40	73,5	91,1	650,0
45	73,5	93,7	650,0
50	73,5	94,7	650,0
Average	67,0	75,4	639,1

Considering that the time to bake a cake in conventional oven gas would be around 30 to 40 minutes, the solar *oven/cooker* built has proved itself efficient for obtaining a time of 50 minutes, considering that the solar *oven/cooker* was made using low cost and recyclable materials, and using energy without cost. It's emphasized that the average solar radiation was below the historical average for our city at the time of the test.

The test demonstrated the viability of using the studied solar *oven/cooker* and its massive use can be of great importance in social policy to generate job and income for poor communities, which could produce cakes at a lower cost and using a clean energy, contributing to decrease the use of firewood as a source of energy. Figure 8 shows the cake roasting in the studied solar oven / cooker.

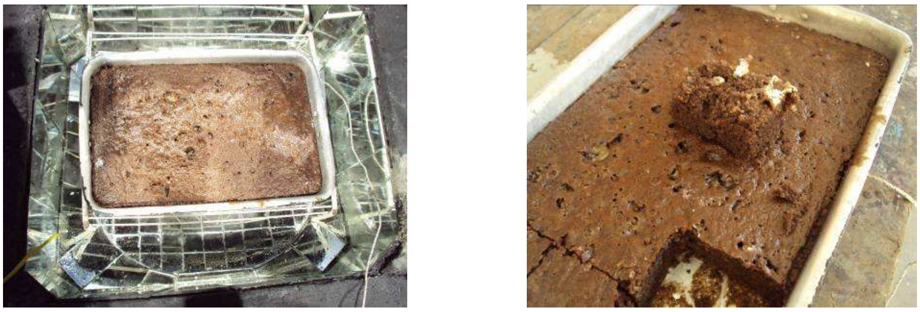

Figure 8. Cake in roasting and roast in solar *oven/cooker* constructed.

5. CONCLUSIONS AND SUGGESTIONS

1. The proposed so*lar oven/cooker* is viable for the cooking of food, can bring substantial economic and minimize problems in attack on ecology, especially as regards the use of deforestation for firewood;
2. The s*olar oven/cooker* is able to produce the food roasting;
3. It is easy to build, so the composite used in its manufacture is easy to work;
4. The processes of assembly and disassembly of the proposed s*olar oven/cooker* is simple, requiring only a previous training;
5. The s*olar oven/cooker* proposed is capable of cooking in the period from 9 to 14 hours, in good solar condition;
6. The cost of manufacture of the s*olar oven/cooker* in study is around 50 dollars, is below the average range for such prototypes between 100 and 150 dollars, not intended for profit;
7. Despite the necessity of conducting further tests, for various types of food, it can be stated that the proposed modifications in the prototype helped to increase their efficiency.
8. Testing for various types of foods in all seasons of the year for a more realistic assessment of the performance of the solar oven / cooker proposed.

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