BIFOCAL CONCENTRATION SOLAR COOK FOR DIRECT COOKING

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Abstract. A model of concentration solar cook composed of two mirrored parabolic segments is presented obtained using fiber glass applied on a ceramic mold. The mirror surface of the two half parabolas was obtained through the use of multiple plain segments of mirror of 2 mm of thickness. A circular cut tool was developed to cut of the mirrors using professional diamond. The structure of the two half-parabolas is dismountable, and has mobility of movements for the correction of the apparent of the sun. The main characteristic of the present cook is the possibility of cooking two simultaneous foods once are generated two focal regions, consisting of a technological innovation in relation to the cooks with only one focus shown by specialized literature. The area of each half-parabola corresponds to approximately 0, 75 m ². Technician details of the manufacture processes and assembly and an analysis of the thermal, economic and of materials viabilities of such cook will be presented, that also has an important social connotation and a primordial aspect that is to combat the ecological damages for the use, on large scale, of firewood for cooking foods. Preliminary tests had shown the viability of the considered cook for the attainment of temperature levels in the focal region around 500°C. The time for the boiling of 1 liter of water was also tested, reaching the result of 25 minutes. It will be presented the cooking times for some types of foods showing its competitiveness with the cooks that uses conventional gas.

Key words: Solar cook, concentration cook, bifocal cook.

1. INTRODUCTION

About one third of the world-wide population (more than two billion people) depends on the use of the firewood to supply its energy necessities for food firing and heating. This data demonstrate the importance that it can have the alternative renewed energies in this context of minimization of the decurrent ambient problems because the use of pollutant energies, that contribute for the global heating of the planet, bringing irreversible damages to ecosystems of our planet (Bezerra, 2001).

Figure 1 percentile displays the behavior of firewood use of in Brazil, for sectors, showing that its use for food firing is still significant, reaching percentile around 33% (BEN, 2003, Varella, 2004).

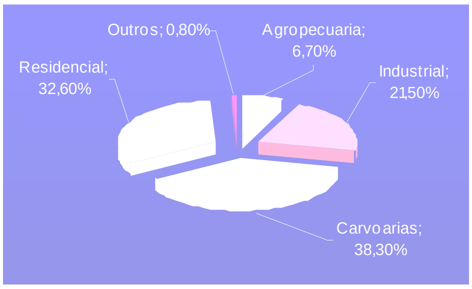

Figure 1. Use of the firewood as combustible for sector in Brazil in 2002.

It is important to extend the use of the solar cook for a bigger number of people as a mean to preserve the nature and also to brighten up the ecological disequilibrium because of the indiscriminate use of firewood, beyond minimizing the emission of pollutant gases to the atmosphere. As we can see, studies that make possible the use of the solar cook, through the improvement of its construction process and the generated levels of temperature, as well as the improvement of comfort for its user, it must have priority and are essential for politics to combat the ecological disequilibrium, that brighten up the energy matrix, contribute for the setting the man in the field and can give an option to them as income generation, through the domain of the construction of solar cooks, for its future commercialization.

For the extreme social importance that the use of solar cook represents the LES of UFRN, has more than one decade of developing, constructing and testing archetypes of solar cook. Solar cook box type of different materials, different lay-outs and solar cook to the concentration of different sizes and with different materials for the material reflecting surfaces had been the main options searched in the attempt for technology as an income generation and comfort for the population excluded layers. The socialization of the energy is essential, for the fact the energy is a good of the humanity and not only of a richest social layer. In this context we cannot help to lament the absence of the Brazilian government in this effort, not possessing any programs that make possible the use of solar kitchens as a politic of combat to the intensive and gradual use of the firewood, generating pollution and ecological disequilibrium.

In Brazil we live in the contra hand of history, once the developing countries already use the solar cooks significantly, many times distributed by its governments. This represents a vision of the reality once such cooks already had been tested and had revealed viable to be used mainly in our country that possess enviable conditions in relation to the available solar potential. The solar cook considered oven is a solar archetype of average concentration that works with the effect of the reflection and concentration of the incident solar rays in a focal region. This cook has as main characteristic the baking possibility for two foods at the same time; therefore it produces two regions focal, what represents a technological advance in relation to the cooks of only one focus. It is destined to domestic use in agricultural and urban zones, on the period from 8am to 4pm.

2. STATE OF THE ART

Is told to follow it one little of relative history to the use of solar stoves in everybody, emphasizing main studious in the this field of use of the solar energy that has as main characteristic, socialization of the use of the clean alternative energy, ecological correct and that it propitiates a sustainable development (Censolar, 2001).

Since the most remote antiquity people use the energy of the sun to heat water, to dry fruits and to cook vegetables. The first solar kitchen with modern technology is attributed to the French Horace de Suassure, who constructed a small solar box, among others inventions related to this power plant.

The solar kitchen of Horace consisted of two boxes of pine wood, one inside of the other, isolated with wool and had three glass covers. The British astronomer John Herschel used a solar kitchen of its invention during its trip to the south of Africa, in 1830. Also in century XIX, Adams tried in India diverse solar devices with sufficient success. Until the year of 1860, Mouchot, in Algeria, cooked with a bending reflector, concentrating the solar rays on a small pan. In 1881 Samuel P.Langley used a solar kitchen during the ascent to the Mount Whitney in the United States. Charles Abbot drew a concentrative mirror that got temperatures around 200°C. It heated oil, holding back part of the heat for some hours after for of the sun, obtaining some cooked foods during the night.

With the arrival of century XX the progressive use of fossils fuels, as well as the possibility of attainment of abundant and relatively cheap energy in almost all the layers of the population, the industrialized world forgot the old ones and simple natural techniques and only in the three final decades of this century when started to appear the resultant problems of the distribution of the petroliferous products and for the increasing contamination of its derivatives, the solar energy came back to be used despite of incipient form.

In 1960 a study of the ONU was published to evaluate the real possibilities of implantation and development of the solar kitchens in the countries in development. The conclusion of this publication was that the kitchens were viable and that only one change in the customs for an adaptation was necessary its large-scale use. In this search to make the solar cook a real option for a progressive use for the food firing if it cannot leave to cite the efforts of the engineer Maria Telkes who created innumerable drawings of solar kitchens, that are characterized for the easy construction and low cost, viable, therefore, to be used in poor countries. China and India already had made enormous efforts to distribute a high number of solar kitchens for the population.

In 1970 Sherry Cole and Barbara Kerr had developed in Arizona some models of solar cooks that had received great acceptance in function of its low prices. Simultaneously, Dan Halacy, a pioneer in the field of the solar energy, manufactured solar kitchen 30-60, called thus because its construction if based on angles whose measured in degrees were these.

In the 80's we had a great knowledge of the solar chef Sam Erwin. It was the most efficient domestic solar oven. It was the Sunspot of Bud Clevette, together with the Sun Oven, that reached a bigger diffusion.

In 1992 the International Solar Association Cookers promoted the First World-wide Conference on the Solar Kitchen, a historical event that congregated enthusiastic researchers of 18 countries. This Conference happened again in 1995, 1997 and recently in 2006, Spain. In Brazil the study of solar cooks had origin in the Laboratory of Solar Energy of the Federal University of the Paraíba, in the decade of 80, with Arnaldo Moura Bezerra, who constructed some types of concentration solar cook, using diverse materials for the reflecting surface. In the LES/UFRN this line of research has deserved prominence already being object of some scientific works. Already they had been constructed to some versions of cooks the concentration and the type box.

3. MATERIALS AND METHODS

An aspect that deserved attention for the manufacture of the parabolic surface of solar cook in study was the drawing in real size of the parabolic curve, main tool for the reproduction of this curve in a metallic part to be used for the confection of the mold. For this stage, its necessary the construction of a device similar to a compass, that made possible the molding and necessary finishing, of the parabolic surface, in concrete. This represented an important stage in the manufacture of this surface. Another factor that differentiates the present project of excessively is the area of each mirror used for the composition of the reflecting surface and its geometry. It used mirrors with lesser areas than the shown ones for literature. It looked to give simplicity to the mechanism of accompaniment of the direct radiation of the sun. For the construction of the considered solar cook it was used the following procedures:

1. Project of the dimensions of the parabolic surface - the dimensions of the cook had been defined with the purpose to get a parabola with area with equal reflection to 1,5 m^2: equal diameter to 1,5 m and equal focal distance to 0,75 m, later divided in two equal parts.
2. Drawing of the reflecting parabola using the AutoCAD tool
3. Manufacture of the profile standard for the construction of the mold - the profile of the parabola reproduced in a steel plate for the construction of the mold aiming an improvement of its process of attainment.
4. Confection of the structure of setting of the profile standard - standard was constructed to a structure for the setting of the profile, in steel 1020, that allowed its turn in 360°.
5. Construction of the Mold - the mold was confectioned in concrete and received covering from mass race and waterproof ink. The structure of the profile fixed the mold through an orifice in the center of the same.
6. Construction of the parabolic surface using resin and fiber glass - placing a fiber fabric layer on the mold; locating the structure of the parabola; placing another fiber layer re-covering the structure and after that applying resin on the fiber fabric, got a part in fiber with raised perfection degree, after the necessary time for a perfect drying of the resin. Before initiating the process of confection of the parabola the mold was re-covered with wax to facilitate the withdrawal of the constructed fiber structure. After this phase, cut parabola in two equal parts.
7. Cut of the parabolic surface – the parabolic surface of 1,5m ^{2} was cut to the way, getting itself two parts of 0,75m ^{2} of area.
8. Confection of the structure of setting for each part of the parabolic surface - the structure of setting for the two parts of the parabolic surface was constructed using bar steel boat.
9. Cut of the mirrors - the pieces of mirrors had been obtained through the cut of a thickness blade measuring 2 mm, using diamond tool of cut. To facilitate the uniformity of the used mirrors, it was established a mirror surface, in a total of 12 buds. These buds had been divided and constituted by 41 segments.
10. Setting of the mirrors - contact glue for wood and other materials was used (wood glue), for the setting of pieces of mirror in the surface of the parabola.
11. Confection of the structure - the structure of the projected solar cook was confectioned from of a table scrap iron, which it consists of the central part, steel pipes and bars boats. It has movements that they allow the accompaniment of the apparent movement of the sun and has as main characteristic the easiness of construction and assembly.
12. Painting of the structure - All the structure of the solar cook received a painting to protect it of climatic variations and in such a way to minimize the effect of the degradation by its exposition to the natural phenomena.

The solar cook was tested for the determination of the reached maximum temperature in the focus; where the pans were situate, after to adjust it with regard to the apparent movement of the sun. The temperature data had been measured for six days of assay, with low indices of cloudiness, in intervals of fifteen minutes. Such data had been measured through the use of a thermocouple connected to a digital thermometer.

The first test to survey the baking capacity of the solar cook in study consisted of determining the necessary time for the boiling of 1,0 liter of water. In this test was measured evolution of temperature in the water to each five minutes, until reaching the boiling point. An important characteristic of the cook is relationed to the operational positioning of the pans which remain static the time all due to a project detail whose adopted criterion is that the center of rotation of the parabolic surface coincides with the illuminated surface of the deep absorber “of the pan” while this is located perpendicularly to the solar rays.

The thermal losses of the absorber pan for the environment had been evaluated through the measurement of temperature of its external surface and of the ambient temperature, both measures used thermo electrical pair for the measure of the temperature on the focus. Also the intervals of baking time had been determined for some types of foods, comparing them in relation with the time obtained with the conventional cook (Gil,2001, Bezerra, 2001, Souza, 2005, Souza, 2006). The Figure has shown the bifocal solar cook in test of the food cooking.

Figure 2. Bifocal solar cook in test.

In accordance with Figure 3, the process of conversion of the solar energy in thermal energy, to materialize itself, passes for some periods of training, (Queirós, 2005), as follows: 1. In the first one I serve as apprentice the solar radiation is caught through a collection surface and reflected until it I serve as apprentice of absorption and conversion of the solar radiation in thermal energy. 2. In as I serve as apprentice the solar radiation is absorbed and transferred to the work fluid that can be water, oil, you leave etc. that circulates through appropriate tubing, or simply an absorber element whose thermal efficiency will depend on the format and the properties of the employed material as, for example, the emissivity (ε) and the absortivity (α) that are project parameters that assume limitant role.

The cycle of global conversion of the system can be represented for the diagram of Figure 4.

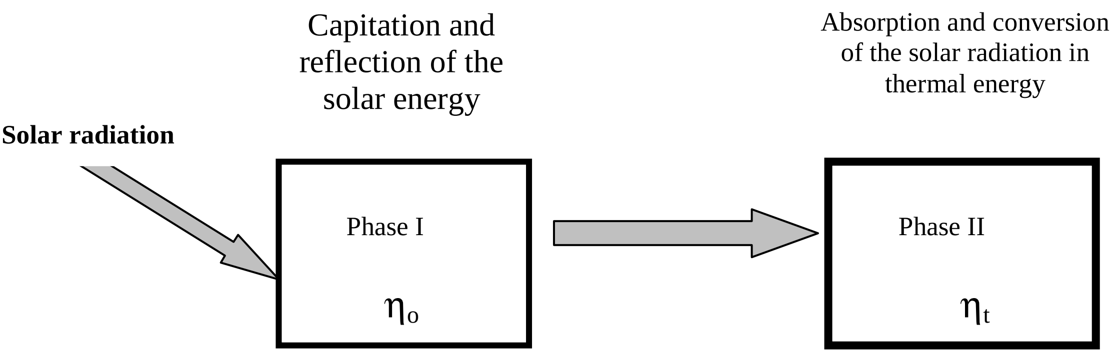

Figure 3. Global process of conversion of the solar energy in thermal energy.

As indicated in the diagram above, the first phase of the process depends on an important factor, the optical efficiency **(η_o)**.. Depending on the material and the degree of precision that is constructed the surface of capitation of the system the optical efficiency represents a variable with limiter characteristics in the global result of the system together with the thermal efficiency, (in the second phase of the process). Another important factor must be considered in any project of conversion of radiating energy in another form of energy says respect to the variation of the intensity of radiation in function of the geographic localization and of other factors associates the climate, time of the year and atmospheric pollution. However the useful efficiency of the cycle can be represented through the relation, equation (1):

$$\eta_u = \eta_o \times \eta_t \quad (1)$$

The useful power of the system, in (w), is given by the difference between the absorbed power and lost power, in accordance with the equation:

$$P_{útil} = P_{abs} - P_{perdas} \quad (2)$$

The absorbed power for the system can be calculated for the equation (2).

$$I_c.A_u\rho.k_{rd}.\alpha_p = P_{abs} \quad (3)$$

Where:
Ic - Instantaneous radiation collected by the system of capitation of solar energy W/m2
Au - useful Area of the concentrator. (m2)
r - Reflectivity of the concentrator (%)
krd - Fraction of the reflected radiation that is absorbed by the pan (%)
AP - Absortivity of the pan (%)
Pabs - maximum Power absorbed by the pan (w)

Considering itself that loss for the radiation of the pan for the way is worthless, the total loss is convective, given equation (4):

$$P_{perdas} = h_{ce} \cdot A_{lp} \cdot (T_{ep} - T_a) \quad (4)$$

Where:
hce- convection coefficient enters the external surface of the pan and surrounding air. (W/m². °C)
Alp - lateral Area of the pan (m²)
Tip - external Temperature of the pan (°C)
Tep - Ambient temperature (°C)

The convection coefficient can be given by the equation (5), shown to

$$h_{ce} = \frac{K_{ar}}{L} \cdot C_k \cdot R_{a_L}^n \quad (5)$$

Where:
Kar - Thermal conductivity of air (W/m^2. °C).
L - Height of the pan - m
R_a - number of Rayleigh
C_k - coefficient and the exponent n, depends on the interval of number of Rayleigh, being that: for n = ¼ the draining is laminar and for 1/3 n = the draining is turbulent. To find the values of efficiencies thermal, useful optics and (total), the below described equations are used:

$$P_u = A_c \cdot I_c \cdot \eta_o - h_{ce} \cdot A_p (T_p - T_a) \quad (6)$$

The optic efficiency (η_o) of the system is given by the following equation:

$$\eta_o = \rho.k_{rd}.\alpha_p \quad (7)$$

The thermal efficiency (ηt) of the system, is given by the relationη {between the useful energy (Qu) and the liquid flow of collected energy, (Ac Ic)}. Thus:

$$\eta_t = \frac{Q_u}{I_c \cdot A_c \cdot \eta_o} \quad (8)$$

The factor of concentration (c) is defined as being the relation between (Ac) - area of the surface of collection of solar energy e (Air) - absorber illuminated area:

$$C = \frac{A_c}{A_r} \quad (09)$$

It is possible to establish a relation between the concentration, the temperature and the energy wasted for the radiation in the focus of a concentrator, for values of (c) that varies in a band of 1: n. The temperature of a situated body in the focus of a concentrator depends on the density of flow in the image of Gauss being, therefore governed for the law of Stefan-Boltzmann (Incropera, 2003). Once (c) represents the concentration factor then the energy in function of (c) can be given by the equation (12), as follows:

$$E = C.P_{abs} = \varepsilon.\sigma.T^4 \quad (10)$$

Where: σ - Constant of Stefan-Boltzmann, (5,67 x 10-8 W/m2. K^{-4})
ε - Emissivity of the absorber
T - Absolute temperature in the focus (°K)
C - Factor of solar concentration

The theoretical value of the temperature can be calculated by means of the equation (11), as follows:

$$T = \left(\frac{C \cdot P_{abs}}{\varepsilon \cdot \sigma}\right)^{1/4} \tag{11}$$

4. RESULTS AND DISCUSSIONS

Using the described equations in the previous chapter one calculated the parameters that diagnosis the efficiency of a solar cook, as the procedure below.

1. **Calculation of the maximum thermal power absorbed by the pan**

For intermediary of eq. (3) it's shown maximum power that is absorbed by the pan from the following data:

- $\mathbf{I_c}$ = 600 W/m^2
- $\boldsymbol{A_u}$ = 0,75 m^2
- $\boldsymbol{\rho}$ = 0.95 %
- $\boldsymbol{K_{rd}}$ = 0.90 %
- $\boldsymbol{\alpha_p}$=0.9 %
-

Substituting the values in the equation (3), below, it's shown that:

$\boldsymbol{P_{abs}}$ **= 346,27 W**

2. **Calculation of the useful power**

The lost power is calculated by eq. (4), presenting corresponding value the P_{loss} = 28,67 Watts.

The calculated useful power through eq. (2), has corresponding value the P_{useful} = 346,27 W-28,67 W = 317,6 Watts

3. ***Calculation of the concentration factor***

Through eq. (10) the concentration factor using itself Ac is calculated = 0,75 m² and A focus = 0,011m², resulting in C = 68,18.

Calculation of the optical efficiency.

$$\eta_o = \rho k.\alpha_p = 0{,}95.0{,}9.0{,}9 = 0{,}77$$

4. **Calculation of the thermal efficiency**

$$\eta_t = \frac{P_u}{I_c \cdot A_c \cdot \eta_o} = \frac{317{,}6}{346{,}27} = 0{,}92$$

5. **Calculation of the useful efficiency**

$$\eta_u = \eta_o \times \eta_t = 0{,}77.0{,}92 = 0{,}71$$

The calculated values shows a good efficiency; a raised optical thermal efficiency and a significant global efficiency, of the segments of small area mirror that had produced a uniform reflective surface, adapting themselves to the parabolic profile, exactly being plain and of the use of the thermal isolation in the absorber pan. 4. Calculation of the theoretical temperature in the focus of the concentrator.

The calculation of the theoretical temperature in the focus of the concentrator is obtained through eq. (11), as follows.

$$T = \left(\frac{C.P_{util}}{\varepsilon.\sigma}\right)^{1/4} = \left(\frac{68{,}18.346{,}27}{0{,}9.5{,}67.10^{-8}}\right)^{1/4} = 824{,}73K = 551{,}73°C$$

The obtained maximum theoretical temperature for each parabola composes the considered bifocal solar cook was practically equal the measured real maximum temperature in focus 1, around 550°C and a little superior the maximum temperature reached by focus 2, around 518°C, as they will show the data of presented assays to follow. In relation to the data average temperatures with the two focus of the considered cook, its perceivable that they are inferior the foreseen maximum theoretical temperature. The first experience carried through with the considered cook was to measure the necessary time for the boiling of one liter of water placed in a pan without thermal isolation. It measured evolution in the temperature of the water placed in the pan to each five minutes for the two focuses. This test was carried through in some days for changeable solar conditions. Table 1 shows the gotten average data in the assay.

Table 1. Time of boiling of the water in function of the average

DAY	TEBULITION (minutes)	DIRECT AVERAGE RADIATION (W/m²)
DAY 1	25	614
DAY 2	30	604
DAY 3	30	598
DAY 4	30	571

The data shown in the tables point with to an average time of boiling, for both the pans around 25 minutes, if the water is placed in the pan after a time of the same one in the focus and of 30 minutes if the pan will be placed in the focus together with the water. Another parameter that brings basic influence in relation to the time of boiling is the direct solar radiation, that stops the first day of assay presents superior average index than the other days. With regard to the comparison of the times of boiling presented by other cooks, literature always points times around 15 - 20 minutes with respect to parabolic surface of 1,0m².

For the cook in study an area of corresponding capitation of 75% of the area of the cook above cited, so it's expected to wait an extra time around 25%, if kept the same degree of perfection of the parabola constructed in the cited work. This would lead to a time of boiling around 20 minutes what it did not occur in function of the imperfections in the some stages of construction of the archetype that had generated dispersion in the focal zone.

One another factor that must be considered is the fact of pans not to possess thermal isolation, in contrast of the test with the cook comparison base. It is possible, therefore, to diminish the boiling time using thermal isolation in the pan. At last, the main advantage of the cook in study is the possibility of the boiling of two liters of water simultaneously.

The General Table to follow presents the average values of temperature in the two focus, direct solar radiation and gotten maximum temperatures in the tests carried through with the bifocal cook.

Table 2. General average data of every day of test.

DAY	$T_{focus 1}$ (°C)	$T_{focus 2}$ (°C)	I_G (W/m²)	I_D (W/m²)	$T_{MAX.}$ (F1)	$T_{MAX.}$ (F2)
DAY 1	400	351	660	528	550	518
DAY 2	381	354	660	528	492	463
DAY 3	391	361	671	536,8	494	480
DAY 4	425,6	362,7	711,4	569,1	515	450
DAY 5	406,1	353,6	697,1	557,7	500	440
DAY 6	369,3	332,9	661,4	529,1	500	441
AVERAGE	395,5	352,5	676,8	541,5	508,5	465,3

The behavior assumed for the average values of temperature for the two focus meets shown in the Figure 3.

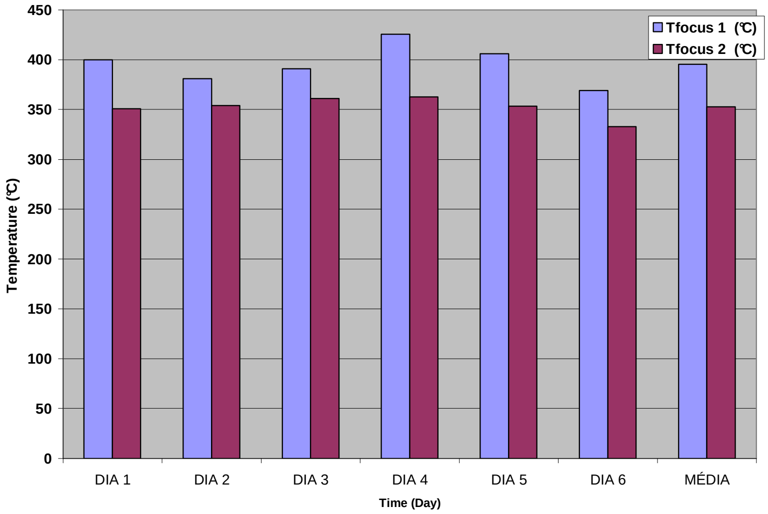

Figura 3. Behavior of the average temperatures in the two focuses in every day of test.

Considering for days of intense global solar radiation a corresponding diffuse radiation of 20%, m gets to an interval of direct solar radiation between 528 and 569,1 W/m ², with equivalent average of 541,5 W/m ², with corresponding maximum variation of 7%. These data of direct solar radiation demonstrates the viability of using the solar cook in our region, because of our great magnitude potential found in few world regions. The shunting line standard in relation to the gotten averages was of 17, 7 W/m2, demonstrating that the assays had happened for days with similar solar metrical conditions.

The average data of temperature in the measured focus of the cook had varied in foco1 from 381ºC to 425,6ºC with average of 395,5ºC and standard shunting line of 19,77 W/m ² and corresponding maximum variation of 10.5% and in focus 2 from 332,9ºC to 362,7ºC with average of 352,5ºC and standard shunting line of 10,64 W/m ² and maximum variation of 8,2%. The values of maximum temperature obtained in both focus had been significant, being 550°C for the focus 1 and 518°C for focus 2, values that make possible a fast baking of foods and that corresponds to something around 75% obtained with cook comparison base. With respect to the gotten maximum temperatures with the cook in study, the gotten maximum variation was around 11% in focus 1 and 15% in focus 2. Between the two focuses this value corresponded 6%.

It's perceivable that in focus 1 a bigger temperature was generated that in focus 2, with maximum variation enters the two focuses around 11%. This difference presented are because of the imperfections caused in the constructive process, causing a difference between the geometry in the two halves of the parabola, after the cut of the surface of 1,5m ². This caused a bigger focal dispersion in focus 2. Although these problems, the generated average temperatures in focus 2 are enough for the considered end, which are the foods baking.

To finish the tests with the considered bifocal cook were made essays with baking food that constitute a typical basic meal of Brazilian northeast. The following foods had been: beans, rice, pasta, potato candy, inhame and macaxeira. The obtained baking times are shown in the Table, together with the relative time gotten with the gas cook, the cook studied for Souza and Queirós, in Christmas and the cook studied for Arnaldo Moura in João Pessoa - Pb.

Table 4.7. Food baking time in function of the type of solar cook.

Aliments		**Baking Time (min)**			
Type	**Quantities (kg)**	**Gas Cook gas**	**Solar Cook Arnaldo Moura**	**Solar Cook Souza and Queirós**	**Solar cook in study**
Beans	0,50	90	95	120	150
Potatoe	0,50	27	30	30	39
Candy potatoes	0,45	26	30	30	38
Rice	0,25	30	35	30	40
Inhame	1,00	30	34	32	41
Pasta	0,50	28	35	30	37
Macaxeira	0,50	30	40	30	38

It can be perceived that the results obtained with the bifocal cook are competitive if compared with the gotten ones with the already studied cooks. The cooking times of the bifocal cook are always superior to the cooks with which it was compared, once the area of each parabola of the bifocal cook is 25% minor. However the bifocal cook allows the cooking of two foods at the same time and this is a differential of speed in the preparation of a meal, what it brings to a conclusion that such cook presents advantage in relation to the other developed unifocal cooks already.

This affirmation can be clearer if the processes of construction and assembly of the bifocal cook was optimized, diminishing the focal dispersion. It is important to stand out that the baking times shown by literature for solar cooks always are overestimated; making it difficult sufficiently the comparison enters the cooking times.

5. CONCLUSIONS AND SUGGESTIONS

As already said the great objective of the present work was to construct a solar cook with two absorbers constituted of two half-parabolas with compatible performance with the existing cooks of only one focus presented simultaneously allowing the baking of two distinct meals. To follow, in accord with these goals, it is started to discourse about the conclusions of general character that infers of the analysis of the harvested data in the assays carried through with the archetype in study.

1. The considered solar cook is viable for the food baking end, being able to bring substantial economy and to minimize problems of attack to the ecology, mainly in what it says respect to the deforestation for firewood use;
2. Its manuscript is simple in function of its easy mechanism of accompaniment of the apparent movement of the sun;
3. The processes of assembly and dismount of the considered cook are simple, needing only a previous training;
4. The size of the some segments of mirrors that compose the reflecting half-parabolas was basic for the attainment of a significant temperature of focus, for the reduction of the dispersion in the reflection of the rays for the half-parabolas;
5. The considered cook has baking capacity in the period from 8am to 3pm, inside of good solar metrical conditions, being able to cook two distinct meals for a family of up to four people;
6. The variations of position of the cook so that the pans were always in the focus of the system, with area of shade in the center of the parabolic, 1 hour was given generally to each;
7. The baking times of foods had been sufficiently competitive with the conventional cook the gas and the studied and constructed solar similar already in everybody;
8. The obtained levels of temperature had been superior to the gotten ones with cooks shown for literature, between 300°C and 400°C and inferior to the values obtained with the cook base of comparison constructed for Souza and Queirós, however fully viable for the considered use;
9. The cost of manufacture of the considered cook is around R$ 300,00, being inside of the average band for such archetypes between R$150.00 and R$300.00, for ends that do not aim at profit;
10. The baking times for the some types of tested foods are competitive with pointed for literature and the cook the base of comparison previously studied;
11. The bifocal cook requires a bigger perfection in its processes of construction and assembly, a time that errors committed in these stages go if adding, leading to a bigger dispersion of focus;
12. The tool that was developed it circular cut of the mirrors provided the attainment of a reflecting surface of better aesthetic;
13. A difficulty found in the bifocal cook is the alignment of the two parabolas when mounted in the setting structure, for the attainment of the two focus in the daily pay-established regions;
14. The structure of sustentation of the necessary cook to be optimized, to allow a bigger stability in the operation of movement of the same for the pursuing of the apparent movement of the sun;
15. To try to manufacture the parabola with a new type of material with vegetal staple fibers or being used a composite with plaster, cement and sand base;
16. To make the set of parts that compose the structure of the cook with threading rabbets, modulable, to facilitate the assembly, disassembly and the transport;
17. To construct a new structure to grant to the considered cook a bigger stability to the wind;
18. To construct a multifocal cook that has the baking capacity for four foods at the same time;

6. REFERENCES

BEZERRA, A.M. Aplicações térmicas da energia solar,Editora Universitária – UFPB, 221 p. João Pessoa, 2001.
GIL, M. C.; SANTOS, A.C., Energía solar térmica de baja temperatura, CENSOLAR(Centro de Estudios de la Energia Solar), PROGENSA, Sevilla, 2001.
CENSOLAR, Cocinas Solares, CENSOLAR(Centro de Estudios de la Energia Solar), PROGENSA, Sevilla, 2001.
SOUZA, L.G.M, MELO, A.V., Fogão solar alternativo tipo caixa a baixo custo**,** V CONEM – Congresso Nacional de Engenharia Mecânica, Recife-Pe,2006.

SOUZA, L.G.M, QUEIRÓS, W.F., Optimization project of the construction and efficiency analysis of a solar cook for food cooking, 18 COBEM, International Congress of Mechanical Engineering, Ouro Prteo, MG, 2005.
INCROPERA, F.P., Dewitt, D.P., Fundamentos de Transferência de Calor e de Massa, Guanabara Koogan, 4ª edição, Rio de Janeiro, 2003.
VARELLA, F.K.O.M., Tecnologia solar residencial: inserção de aquecedores solares de água no Distrito de Barão Geraldo – Campinas, Dissertação de Mestrado da Faculdade de Engenharia Mecânica da UNICAMP, Campinas-São Paulo, 2004.

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