

DESCRIPTION

"A SOLAR COOKER CONCENTRATOR OF THE BOX TYPE, USING CPC-TYPE OPTICS"

1 - OBJECT OF THE PRESENT INVENTION

The goal of the present invention is a solar cooker, simultaneously of the box type and concentrator, by the explicit use of Non-Imaging Type Optics, also referred to as Ideal or of the Compound Parabolic Concentrator Type (CPC), to cook food in temperature and power conditions higher than the ones used in conventional box cookers, but conserving and even improving the working characteristics of those cookers, in particular in what pertains to stationarity and control of cooking time. Another fundamental aspect of this invention is the achievement of great sophistication for the optics used together with low fabrication cost, from a materials point of view and from the point of view of the fabrication process, given the choice of plastic for both the external envelope and the inner cooker structure. The solution established by the present invention is the first one to allow the fabrication of solar cookers in large series production, with a thermal behaviour in the limits of what is possible for this type of cookers (more than double the efficiency achieved by conventional box types), and with a lower cost.

This goal is achieved by the specific development of an optical solution which starts with an entrance aperture area and an interior volume optimised, with the curvature of the inner reflecting walls defined in an integrated manner with the curvature of the augmenting exterior reflector, concentrating in an ideal fashion the incident solar radiation during the maximum

number of working hours compatible with the cooking of food. All necessary curved walls are achieved in moulded plastic, moulded in moulds specially developed to this effect, with the reflector obtained from thin aluminium reflecting sheet (0,4 to 0,5 mm in a specific embodiment of the present invention), pre-roll-bended and glued on the plastic.

The present invention has still other applications, for instance in the pasteurisation of water or of other foodstuffs, like milk, and as a dryer.

2 - BACKGROUND OF THE INVENTION

The use of solar energy to cook food is an old idea that has a variety of specific embodiments, many of which have been the object of patents.

They can be placed in two main categories:

- 1) Box type cookers, with or without augmenting reflectors and
- 2) Concentrator type cookers.

The first ones include a large set of different forms, variations on the idea of having a box with or without reflecting flat walls, a black bottom where the cooking vessels are placed, a transparent cover, single or double, to let solar radiation through and, at the same time, providing the necessary heat barrier to promote a temperature rise in the box. There are an enormous variety of solutions for the box geometry (rectangular or square in cross section, cylindrical, spherical, etc.) and ways to combine it with flat reflectors, fixed or with

movement, always with a concern for symmetry with respect to the cooker's meridian plane.

The second ones usually correspond to the use of parabolic reflectors in whose focal zone the cooking pot is directly placed, with or without a transparent envelope to improve the thermal performance of the concentrator. Within this category there are the so called focusing concentrators, concentrating solar radiation in a very substantial way onto the cooking vessel, requiring permanent tracking of the sun's position in the sky following its daily apparent motion, conserving the vessel permanently on the focal plane and concentrators of lesser concentration factor, requiring less tracking accuracy, surrounding the vessel in such a way that the focal spot moves on its surface during the cooking process.

The ones in the first category can be truly stationary, but have the inconvenience of presenting a low global efficiency, a less efficient and lower power delivery of energy to the cooking vessel. The best on the market are produced with expensive materials and with characteristics designed to alleviate at least some of the referred deficiencies, but, as they are "hand produced" or, at best, in small series production, they remain an expensive product, thus with little value for the very large number of potential users in third world countries, presently and daily using wood, an ever scarcer resource, whose use is one of the main causes for the amazing and dangerous deforestation taking place on a world wide scale.

The ones in the second category are less practical, demanding the presence of the cooker for the tracking of the concentrator, are usually more expensive and have serious inconveniences associated with the risks of concentrated radiation on the eyes of the user if they come inadvertently into the focal zone.

There are also a large number of solutions in which the oven itself is independent from the solar energy collector, with the energy transferred to the first by means of a heating fluid or by optical means. Sometimes thermal losses reduction is also achieved by the use of vacuum at some point of the system.

These different concepts strive to achieve improvements in the most common and classic box type solution, through specific solutions, which may end up becoming very complex (and expensive!). None of these, however, considers the possibility of direct improvement of the box type cooker, by incorporating in the box itself the necessary concentrating optics able to solve the problem in an ideal fashion, i.e. in the limits fixed by First Principles in Physics.

3 - DETAILED DESCRIPTION OF THE PRESENT INVENTION

The present invention introduces improvements in the state of the art of past technology, through a new product combining for the first time in an ideal way (ideal in the sense of Non-Imaging or CPC type Optics) the two basic approaches described above, being of the box type but also of the concentrator type with Non-Imaging Optics integrated in the box itself with an exterior augmenting reflector. This optics, in contrast with the focusing one referred above, allows for solar radiation concentration without the need to track the sun in its apparent daily motion, resolving one of the inconveniences referred, at the same time allowing for more power and temperature into a box type cooker, as it is typical of the concentrating focusing types. The use of augmenting reflectors (on the back of the lid and lateral ones) is also made in an integrated fashion with the inside optics, sharing in this way the Non-Imaging optics

characteristics referred above. The side reflector, only one and that can be placed on one side or on the other, is also a novelty, as usually solutions with reflectors on both sides are considered. Concentration is thus augmented and, above all, automatic control sunshine exposure duration is achieved, as the solar cooker is oriented such that the side reflector can cast a shadow once cooking time is exceeded.

On the other hand, the outside structure, the box itself, and the inside one, the material substrate for the reflectors and bottom absorbing plate, are made out of very low cost materials like plastic, with the outer one made to resist solar UV radiation, and the inner one in plastic made to resist temperatures in excess of 200°C. The verification that it was possible to produce this plastic has no precedent and constitutes also a relevant aspect of this invention. This characteristic allows:

- large series production at low cost,
- inner wall curvature without serious repercussion in overall costs,
- excellent mechanical resistance and durability,
- special aesthetics both in terms of shape and colour.

For a better understanding of the invention some figures will be presented and described next, illustrating preferred embodiments of the cooker of the present invention but in no way with the intention of limiting with them the scope of the invention defined in the annexed claims.

Figure 1 shows a longitudinal cut of the box cooker of the present invention with a plastic envelope 1, exhibiting the lateral walls of the internal structure in plastic 3 with reflectors 2' left and right 2'', with the typical curvature of

a symmetrical CPC. It shows the existence of thermal insulation 2 between the interior and the exterior box for the control and significant reduction of thermal losses. It shows the existence of a double glass 4 (with upper glass 4' and lower glass 4'', being this last one laid on and glued through a silicon cord 6 which insulates it from the plastic 3 guaranteeing adhesion and tightness to the internal box volume. It also shows a flat bottom reflecting surface 12, as well as the bottom black absorbing plate, the heating of which is responsible for the functioning of the cooker. It also shows the peripheral plastic cover frame 7 that also ensures the fixation in place of the double glass cover.

Figure 2 shows a transversal cross section of the cooker, exhibiting, beyond the characteristics already referred, the curvature of the front 5'' and back 5' walls, the curvature of another symmetric CPC. It also shows the lid 9 on which the augmenting/concentrating reflector 8 is fixed. These surfaces are defined according to criteria of optimisation of the solar energy collected in each day and the cooker's stationarity. Thus in a specific embodiment of the present invention the lateral CPC corresponds to an angle of $48^{\circ} \pm 5^{\circ}$ truncated to an height h (140 mm in a specific embodiment of this invention), for a concentration of $1.15 \pm 0.000500.1$, and the asymmetrical frontal/bottom CPC corresponds to an acceptance angle from $60 \pm 5^{\circ}$ to $65,5^{\circ} \pm 5^{\circ}$, truncated at the same height h (140 mm in an embodiment of the present invention), for a concentration of 1.12. Global concentration, internal to the box is, in this case, 1.29. In this embodiment, the augmenting reflector 8 on the internal lid surface 9 is flat and hinges on an axis (signalled by the letter A) in order to take the appropriate tilt to accommodate solar height each day and during the day.

An optimisation of the cooker optics in terms of collected energy shows that the curvature of the inner walls and of the lid must be optimised together and taking into consideration the transmissivity of the glass covers, the final result being, neither an exactly flat lid nor a curved inner wall shaped as part of an exact CPC. However the gain thus obtained in comparison with that of the above embodiment is very small and the simplicity of fabrication of a flat reflector justifies this choice. However the more general optimised ideal geometry of the CPC type is also an aspect of the present invention.

An important aspect is the rectangular shape of the cooker, with its largest dimension running longitudinally (a and a' , for instance, in Figure 1) and the smaller transversal dimension (b and b' , for instance in Figure 2). These dimensions are in a relation $a'/b' = 2 \pm 0.2$ and $a/b = 1.8 \pm 0.2$. In the case of a specific embodiment of the present invention the dimensions are: external box $axb = 850 \times 475 \text{ mm}^2$ and inner box $a'xb' = 702.3 \times 344.2 \text{ mm}^2$. The height (h and h' for instance in Figure 1) of the outer and inner boxes is optimised by optical and thermal considerations. Thus we have $h/h' = 1.45 \pm 0.2$ and also $a'/h' = 5 \pm 0.5$. In the specific embodiment of the present invention referred above, h' as the value of $140 \pm 10 \text{ mm}$.

Practical considerations may dictate a more square geometry. In this case the optimisation of solar energy collection referred above dictates an interior volume with a larger height. In this case the optimisation would yield for the dimensions a , a' , h , h' in Figure 1, b and b' in Figure 2, values satisfying the following relations: $a'/b' = 1 \pm 0.2$; $a/b = 0.9 \pm 0.2$; $a'/h' = 3 \pm 0.5$; $h/h' = 1.45 \pm 0.2$. Thus, in one specific embodiment of the present invention the lateral CPC corresponds to an angle of $45^\circ \pm 5^\circ$ truncated to an height h ($180 \pm 20 \text{ mm}$ in a specific

embodiment of this invention), for a concentration of 1.16. Global concentration, internal to the box is, in this case, 1.32. In this embodiment the augmenting reflector 8 on the internal lid surface 9 is flat and hinges on an axis (signalled by the letter A) in order to take the appropriate tilt to accommodate solar height each day and during the day. There is still the possibility, in this embodiment of a more square geometry, to increase the lid reflecting area through the addition of a flat mirror that extends said reflecting area.

Figure 3 shows the augmenting/shadow casting side reflector 11, placed on one side of the cooker, while the concept being proposed allows for the possibility of placing that reflector 11 on one side or the other of the cooker, depending on the time of the day and at the user's convenience. The asymmetry thus created, beyond the effect of augmenting solar radiation collection in case of full stationarity, is a relevant aspect of this invention.

Figures 1, 2, 3 show the double glass transparent cover 4 and still the flat and reflecting bottom of the box 12 with the black absorber plate placed at a certain distance from that bottom. Over that reflecting sheet 12 the black aluminium absorber plate 10 is placed (with a thickness preferably between 2 and 3 mm); that is the surface where the cooking vessels/food will be placed. This absorber plate is placed at a distance on the order of 1 cm above the bottom reflector 12, as a way to reduce thermal losses but also as a way to obtain a temperature difference essential to the survival of the plastic 3. In case of temperature stagnation of the cooker (a situation in which, without any load, the cooker is unintentionally exposed to solar radiation of maximal intensity in a day of high ambient temperature). This is another specific aspect of the present invention.

Figure 4 shows another possible embodiment of the present invention, in which the glass cover 4 is tilted, with front 2'''' and back 2''' inner walls corresponding to an asymmetric CPC whenever the exterior lid reflector 9 is flat 8', or in general with a curvature corresponding to the optimised solution for the curvature of the exterior reflector that is chosen.

Figure 5 shows a general view of another embodiment of the cooker of the present invention with the lid 9 open, exhibiting the inner structure 8' for the fixation of the reflecting sheet onto the inner surface of the lid, and the double transparent glass cover 4, with this specific embodiment showing a frontal door 14 for access to the inside of the cooker. In Figure 5 the door 14 is also open and shows a curvature of the CPC type 5'', which defines it. This embodiment also has telescopic arms 13' and 13'', which serve to establish the adequate tilt for the lid reflector and for each day or instant during the day.

The inner thermal plastic structure 3 has curvature adequate to the direct placement of the reflecting surfaces which will constitute the inner reflecting walls of the cooker 2, 5 as well as its bottom, also resulting from a flat reflecting sheet 12 placed over the thermal plastic.

Another important aspect is the possibility of including in the cooker backup electrical energy, in particular for those days without sunshine or with intermittent sunshine, in places where the electrical grid is available, as it is typical in industrialized countries, where the cooker will be utilized in the leisure market (camping, weekend house, vacations, etc.) or in other cases (schools, factories, building construction, etc.). The electrical backup is realized in two distinct ways:

1) In the first and more conventional way it comes from a resistance, placed under the black plate (10), fixed to it, with a control including a safety thermostat.

2) In the second an optical procedure is used to transfer energy radiated by an incandescent resistance to the bottom plate, with a set of reflectors of the CPC type, which, in an ideal fashion, with minimal losses, allow for perfect illumination of the bottom plate with the infrared radiation emitted by the resistance.

This second way is profoundly innovative, separating the electrical resistance from the absorbing plate, and constitutes a substantial advantage in terms of durability, cleanliness and safety of the cooker.

Figure 6 shows a specific embodiment of the present invention where CPC type optics is used for the electrical back up.

The optical backup system has dimensions that minimize the blocking of incident solar radiation, accommodating the ideal CPC type optics to transversal dimensions m and longitudinal n that are on the order of $m \cong a'/7$ and, in the perpendicular, $n \cong b'$. The optical system is designed to accommodate in an ideal way cylindrical electrical emitting resistances 18, with a diameter $d = 15 \pm 10$ mm. It is formed by the curved reflectors 16 and 17 corresponding to involutes of a virtual cylindrical emitter, tangent to their intersection point and by the curves 16' and 17' which continue them, respectively, and whose definition results from their ability to reflect tangentially emitted rays from the virtual absorber already referred, to the edges of the absorbing plate.

The optical system thus described may be placed on either the left or the right side of the cooker, depending on which side is predominantly coming the solar radiation, since it is most conveniently placed where there will be more shadows, cast by the less active curved walls or by the cooking vessels.

In another specific embodiment of this optical system the area of the absorbing plate it illuminates may be smaller than the one covered above and which includes the whole plate. In the limit of the least possible optics, curves 16' and 17' may not exist.

The existence of backup energy conceived to provide the same energy as it is to be expected from the sun under normal operating conditions, in order not to alter the cooking conditions if and when brought into use, coming from an electrical resistance placed under the plate, with its associated control system, also constitutes a novelty of the present invention.

The lower face of the box 1 has feet that sustain the oven on a horizontal plane. There is a central foot slightly shorter than the others and which only serves to avoid too much deformation of the bottom due to excess load inside the cooker. In the present embodiment of the present invention the feet are cylindrical.

It is also a characteristic of the present invention the fact that the feet are conceived in such a way that removable tubes can be fit to them, with or without telescopic capabilities (for instance plastic tubes in the case of the present invention) placing the cooker at any desired height from the ground, avoiding the need of a table or any other support to that effect.

The solar cooker of the present invention may still have a solar clock, with its dial engraved on the glass (or otherwise) and with a shadow-casting gnome, designed for the local latitude.

The solar cooker of the present invention with its lid closed has the appearance of a suitcase inside which one can easily transport cooking vessels, side reflector solar clock gnome, etc.

References related to the present invention:

- Nandwani S. (1993) "La Cocina/Horno Solar", Editorial Fundación.
- Biermann, E., Grupp, M., Palmer, R., "Solar Cooker Acceptance in South Africa: Results of a Comparative Field Test", Solar Energy, Vol. 66, N°6, págs. 401-407, 1999.

CLAIMS

1. A solar cooker, concentrator, of the box type, incorporating "Non-Imaging Optics" of the "Compound Parabolic Concentrator" type in its interior and integrating an augmenting and exterior reflector, generically curved, and characterized by including:

- An envelope box (1),
- An internal structure (3), with reflectors, left (2') and right (2'') with the typical curvature of a symmetrical "Compound Parabolic Concentrator",
- A zone of thermal insulation (2) defined between the interior (3) structure and the enveloping box (1) for the control and significant reduction of thermal losses,
- A double glass (4) including an upper glass (4') and a lower glass (4''), with this last one glued by a silicon cord (6) which insulates it from the inner internal structure (3), guaranteeing the tightness of the internal box volume,
- A flat bottom reflecting surface (12),
- A bottom flat black plate (10) whose heating is responsible for the functioning of the cooker,
- A peripheral cover frame (7) insuring the fixation of the double glass,
- And finally a plastic lid (9) articulated with the back wall of the cooker box and on which the augmenting/concentrating reflector is placed.

2. A solar cooker according to claim 1, characterized by the solar energy absorbing plate (10) being placed at a distance preferably between 10 and 15 mm from the reflecting box bottom.

3. A solar cooker according to claim 1, characterized by the exterior and interior box dimensions corresponding to the ratios $a/b = 1.8 \pm 0.2$, $a'/b' = 2 \pm 0.2$, $h/h' = 1.45 \pm 0.2$.

4. A solar cooker according to claim 1, characterized by the exterior and interior box dimensions corresponding to ratios $a/b = 0.9 \pm 0.2$, $a'/b' = 1 \pm 0.2$, $a'/h' = 3 \pm 0.5$ and $h/h' = 1.45$.
5. A solar cooker according to claim 4, characterized by the lid reflecting area being extendable with a flat mirror which is located beneath it.
6. A solar cooker according to claim 1, characterized by including backup energy consisting in an electrical resistance of the cylindrical type placed in an optical system of the "Compound Parabolic Concentrator" type with a transversal dimension on the order of $1/7$ (or smaller) of the longitudinal dimension of the cooker box and stretching over all of its transversal internal dimension, able to transfer in an ideal way the energy emitted by the electrical resistance to the whole plate or to a smaller part of it.
7. A solar cooker according to claim 6, characterized by the backup energy being produced from an electrical resistance placed and fixed against and under the black absorber plate (10), with a control and safety thermostat.
8. A solar cooker according to any one of the previous claims, characterized by the exterior box (1) being made of plastic resistant to the solar UV radiation.
9. A solar cooker according to any one of the previous claims, characterized by the inner structure (3) and the peripheral cover frame (7) being made of plastic, of the thermal type, resisting to temperatures up to 200°C .

10. A solar cooker according to any one of the previous claims, characterized by having an access front door (14) with a curved reflecting wall of the "Compound Parabolic Concentrator" type.

11. A solar cooker according to any one of the previous claims, characterized by the tilt of the lid (9) and its augmenting/concentrator reflecting face (8) being obtained by telescopic arms (13', 13'') allowing for a continuous or large number of tilt angles.

12. A solar cooker according to any one of the above previous, characterized by possessing a lateral augmenting/concentrating reflector (11), to be placed on one side or the other of the box (1), as means to guarantee the stationarity of the cooker and controlling cooking time.

13. A solar cooker according to claim 1, characterized by the glass cover (4) being inclined, the inner front (2''') and back (2'') walls corresponding to an asymmetric "Compound Parabolic Concentrator" whenever the outer lid (9) reflector is flat.

14. A solar cooker according to any one of the previous claims, characterized by being ready to accept a solar clock, which, combined with the lateral augmenting/shadow casting reflector (11) allows for an automatic control of the cooking time.

15. A solar cooker according to any one of the previous claims, characterized by possessing short support feet on the lower face of the outside box, with a shorter central foot, as means to compensate eventual excess weight inside the cooker, if necessary, without cooker deformation.

16. A solar cooker according to claims 12 and 13, characterized by the referred feet being prepared to receive removable tubes, telescopic or not, fitting them, resulting in a way to raise the

cooker to a convenient cooking height, avoiding the need to place it, for that effect, on any other surface.

17. The use of the solar cooker according to any one of the previous claims, characterized by being applied to cook foodstuffs.

18. The use of the solar cooker according to any one of the previous claims, characterized by being applied to the pasteurisation of foodstuffs, in particular water or milk.

19. The use of the solar cooker according to any one of the previous claims, characterized by being applied to drying products of any nature.