

250 years saga of solar box cookers

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Abstract—Europe was the cradle of the solar cooker. Way back in 1767, a Swiss naturalist Horace-de-Saussure, who evolved the very first solar cooker, which is now popularly known as Solar Box Cooker. In the past 250 years, the device has experimented extensively, and many improvements have been made. This review article summarizes major developments made on this design.

Keywords—Solar Box Cookers, Reflectors, Insulation, Vessels, Storing heat, Testing

1. INTRODUCTION

Solar Box cooker, one of the most popular solar cooker, was designed in 1767 by Swiss naturalist, Horace-de-Saussure. He was aware of the ability of glass panes to trap heat, although he did not know the real basis. Just to see how hot it would get inside multiple layers of a box made of glass panes, he experimented with 5 square glass boxes, telescoping into one another. He noted that the temperature in the innermost box reached 87°C (189° F). Encouraged by this finding, Saussure built a small rectangular box of half-an-inch thick pine planks, lined it with black cork sheets, and covered it with three glass panes. The temperature inside was recorded at 108°C (228°F). To prevent heat loss, he insulated it on the sides and bottom with wool and placed it in a large box. Artists have recreated this design at Solar Cooker International (SCI) [1], as in Figure 1. He could record a temperature of 110°C (230°F). Fruits kept inside the box were cooked and became 'juicy.' de-Saussure stated almost self-effacingly, "someday some usefulness might be drawn from this device. . . [for it] is actually quite small, inexpensive, [and] easy to make." (SCI)

For a long time, the box cooker remained dormant, although some scientists were experimenting with

i. Size and Shape of the Box

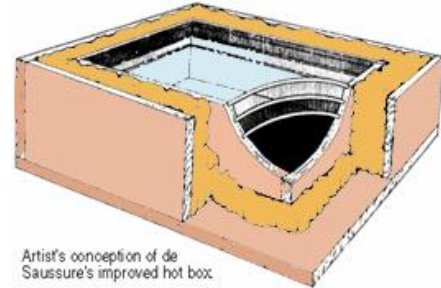


Figure 1. Original box Cooker

such a design. In the year 1881, Samuel Pierpont Langley, the American Astrophysicist, experimented with such a hot box on top of Mt Whitney and reported that water could be boiled on snow-covered fields. Sri John Hershel, during his expeditions in South Africa, used a box cooker to boil eggs and some dishes as well [2].

It was in 1945 that an Indian scientist, improved performance on the de - Saussure's hot box by adding a reflector [3]. Since then, the Box Cooker has gained popularity as 'Gosh Cooker.' Today, thousands are using Gosh type Box cookers in India. Hundreds of scientists are striving to improve the performance of the design by changing the shape of the box, Glazing, adding more reflectors inside and outside the box, trying out different types of insulation, using different paints inside the box as well as on the cooking vessel, and even attempting to store heat through chemicals or to make it more versatile by adding electric booster heaters. This paper delves into the following aspects of the box cooker mentioned above, where work has been done to improve performance.

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|-------------------|--------------------|
| i. Size and shape | v. Paints, |
| ii. Glazing | vi. Vessels, |
| iii. Reflectors, | vii. Storing heat, |
| iv. Insulation, | viii. Testing |



Sun Stove USA



Square horizontal & Inclined top



Dutta's Inclined



Koyoto Box cooker

Figure 2. a-e

Box cooker generally consists of two boxes, and outer and inner with some insulation in between and is covered over with a double-glazed cover. The size of the outer box is generally 625 x 625 mm with a height of about 200 mm, while the inner box would be 590 x 590 mm, and 195 mm deep. If the height of the inner box is maintained at 195 to 250 mm, then the dimension of the box could be of any size or shape. Large cooker boxes are generally rectangular, the width being 780 mm, while the length could be 1980 mm. or more [4]. The space between them filled with fiberglass mats or other such insulation. Material to be used for the outer box could be 15 mm thick wooden planks, and metal sheet for inner box. The height of the inner box is rather critical, and a height of more than 250 mm is not recommended (Cantinawest)[10]. Some designs do not have reflectors (Figure.2a).

The upper surface of the box is generally horizontal and covered with a double-glazed door. A plain glass mirror with frame and protective back forms the outermost cover for the entire box. This reflector can be opened and suitably inclined to direct maximum sunlight into the box. A metal stay is generally provided to hold the reflector at the best possible angle. (Figure. 2b) However, researchers of latitude beyond 20° , prefer to have a box with an inclined top (Figure 2c). Trapezoidal box has been used with good results [5]. Many different shapes of boxes have been experimented with, and it was found that square box with inclined walls performed best [6]. Inclined box design has been tried successfully [7] (Figure 2d). Boxes made of Cardboard also work well, and many low-cost box cookers, like the Kyoto Box, are made with two cardboard boxes telescoping into one another

(Figure 2e). If the space between boxes is suitably insulated, such low-cost cookers work well.

Bureau of Indian Standards (BIS, 2000) had specified the use of 0.7 mm (22 gz) Cold Rolled (CR) Iron sheets for inner box [8]. In the recent past, however, 0.5 mm, Aluminum sheets have been used successfully. This change from Steel to Aluminium renders the cooker lighter, enabling easier maneuverability. Outer box can also be of 0.7 mm CR

sheets or Aluminum sheets. Many solar cookers available in the Indian market use thinner Aluminum sheets for inner as well as outer boxes. While many manufacturers are using molded plastic outer boxes.

ii. Glazing

The size of the glazing cover matches the size and dimension of the box. Usually, double glass glazing is recommended. A gap of 10 mm between glass panes is suggested, and they are held in place with a wooden or metal frame. A good quality beading has to be used between the box and glazing door to prevent leakage of hot air from the box. BSI recommends Neoprene beading. 2 mm thick felt mat also works well.

3 mm thick toughened sheet glass is the recommended glazing material. Iron-free sheet glass, which has better clarity, is usually preferred. But 2 mm glass has also been used as an outer sheet with success. A transparent plastic sheet or a combination of clear plastic sheet and glass also works well. As to plastic, transparent Polycarbonate sheets are recommended [9].

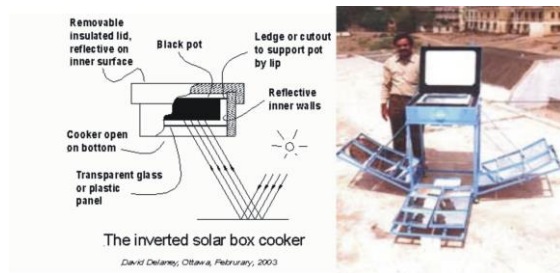
iii. Reflectors.

Gosh (1945) was probably the first to use a reflector to boost the performance of box-type solar cookers. Innovators of the later years have tried two, three, four, five, and 4 + 4 reflectors (Figure 3, a-e). However, box cookers without the reflectors like 'Sun Stove,' are still in vogue, especially in the USA. (Figure 2 a).

A standard mirror is commonly used. BIS recommended a good quality glass mirror with a minimum of 65% reflectivity. In the recent past, good quality plastic reflector sheets with higher reflectance have been used. Such plastic reflector materials are being used even with parabolic cookers. The stagnant temperature of a single reflector box is in the range of 120 to 130°C, and that of 4 + 4 reflectors of Telkes type may reach 200°C. Tracking the sun improves performance, and many simple, low-cost tracking systems suggested by innovators have been summarized in the Treatise [10].



Delane's [11] inverted Box cooker needs a special mention here (Figure 4a). Although this design did not gain popularity, many different variations on these lines have been presented. [12] (Figure 4 b)

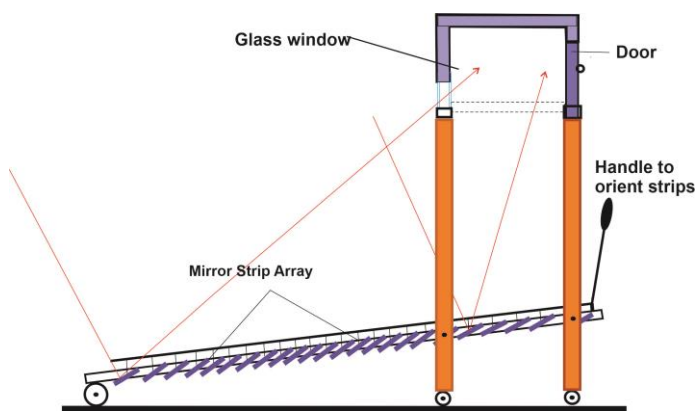


Delaney's Inverted Box Ajay's Model
Figure 4. (a & b)

Bowman's FIT design (1978) could also be regarded as inverted box cooker. In this design, the sun rays are reflected into the cooking box by 14 to 20 strips of mirrors linearly fixed under the box as shown in the figure 5. The arrangement is such that all the strips can be easily turned to track the altitude angle, while the wheels at the base of the frame can follow the azimuth angles of the sun (Figure 5). Probably, with some modification such a design can be adopted to be fixed to south facing window of a house. The advantage of this variation is that the cooking can be done from inside the kitchen.

However, if one needs to extend the length of the mirror strip array, then the reflection from farthest reflector would not reach interior of the box. Hence, the author thought of an additional glazed

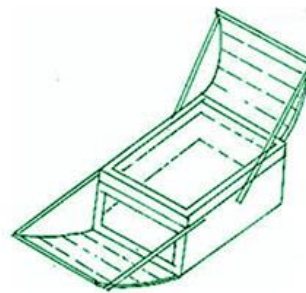
transparent window at the back. Thus, the insulated cooking box would have an opening at the front side as well as at the bottom, to receive reflections from all the mirror strips.



Bowman's design modified
Figure 5. Bowman's FIT Design Modified

Cheema [14] had designed a double exposure box cooker and had recorded a temperature of 200°C. The insulated cooking box has glazed 'windows' on top as well as on front side, facing another reflector. Recently Yasin Khan et al. [5] have presented another

impressive double exposure design, dubbed as 'K 5,' (Figure 6 a & b). A Stagnant temperature of over 200°C has been attained in such cookers. Recently, Khan has further modified the design by making the stand shorter



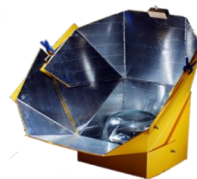
Cheema's Design



Yasin Khan's K5

Figure 6 a & b

There have been some attempts to combine the best aspects of Box and panels. For example, the 'All Season Solar Cookers' of Jim la Joie,[16] or 'Box Panel cooker' Paul Hedrick of SCI,[7] but more development is needed to improve and perfect the designs. (Fig 7 & 8)



All Season Cooker



Box-Panel cooker

Figure 7. a & b

vi. Insulation

Insulation plays a significant role in the box-cookers; it prevents heat loss. de-Saussure seems to have used sheep wool, but in the recent past, the most popular insulation has been Fiberglass or Rock wool mats of 40 to 50 mm thick. Low-cost insulations like rice husk or compressed sawdust have been used successfully. In emergencies, newspaper balls work well, as suggested by a

stalwart, Barbara Kerr (1991) [18]. Composite materials have been suggested, but no concrete example exists. Some researchers have tried transparent insulating material, made of polycarbonate sheets, find it very useful for temperature under 85°C [19]. Recently vacuum tubes have entered the scene and have proved to be very effective, but their use in the box type cooker is not known. Besides, it would be costly, if not impossible, to use a vacuum glass box as a solar cooker. Thermocole (Polystyrene) is an excellent insulator can be formed into a box of any size, but it gets deformed in contact with a hot surface, thus reducing the performance. Polyurethane foam sheet is

considered a better option, but this too is not stable at a higher temperature. The only advantage of this type of insulation is that it does not absorb moisture like fiber mats. Recently, the entire box has been fabricated using thick panels of wood, with green fiber insulation (made up of ground cardboard newspaper and the like). As early as 1975, Bowman had recommended the use of Foam Glass, for it is rigid, black as well as light, but it is not readily available in the market, hence not popular.

v. Paints

It may be remembered that de-Saussure had kept fruits on black tabletop in his initial experiment. Ever since then, black paint has become part of Solar cooking technology. Blackboard paint, which is readily available in the market, is still prevalent. Maria Telkis (1978) [20] had suggested a mixture of Zinc Copper sulfate and Sodium hydroxide to get black paint. Of late, powder-coated matt black vessels have become popular, as the coating does not peel off easily like black paint. Chromium-based commercial paints, too, are recommended. Mauricio Gonzalez-Aviles [21] worked with black soot mixture as paint for cooking vessels and recommends it as a low-cost option to coat vessels used for solar cooking.

vi. Vessels

Aluminum or Hindalium vessels painted black are most popular in solar cooking. Box cookers generally use 4 nos of flatter 200 mm diameter boxes with a lid. Recently some researchers have

tried out such vessels with fins. It has been suggested that such boxes should be fitted with 'ears' on the side and a knob on the lid for more comfortable handling when the vessels get hot in the cooker [22] (Figure 8)



Figure 8. Types of cooking vessels

vii. Storing Heat

It is difficult to trace the history of storing heat in solar cooking. The procedure was popular with the conventional forms of cooking on fire for ages. Once the food being cooked reaches the desired temperature, it would be removed from open fire (or cooker box) and placed in an insulated box. Popularly known as Hay boxes, they had been popularized in India, and later Stainless Steel sheet boxes lined internally by suitable insulating materials became popular, especially in areas using boiled or para boiled

rice. Recently such devices popularly known as Fireless cookers, Wonder bags of Sarah Collins, and Witches Box of Pedro Serrano are in vogue [10]. (Figure 9 a & b).



Fireless Cookers



Sarah Collin's with her Wonder Bag

Figure 9. Low-cost Heat storing devices

To enable cooking or at least to heat the food after the sun sets, attempts are being made to store solar heat using a variety of materials. A list of such materials can be found in recent review papers of [23 & 24]. Much work needs to be done on low-cost materials like pebbles or sand, which is readily available to low-income groups to store heat.

Whatever type of heat-storing material is used, once it absorbs heat, it is bound to lose it slowly. Even if heat loss is minimized by using better insulation

materials, it would be challenging to cook a full meal in the evening. At best, food can be warmed. This failure led many scientists and inventors to explore the possibility of storing solar energy in the form of electric power. Many Photovoltaic installations do use batteries. Puttaraj [32], an inventor from India, collects solar power using small PV panels of about 250 Ws and stores it in a set of batteries. The power thus collected is used to power a slightly modified Induction cooker, which is then used for cooking meals even during night-time. The power thus collected can also be used for light and fan if need be. Right now, the cost of his entire system is around \$ 300 net, which is less than

some popular types of cookers.

viii. Testing.

Several scientists, as well as many NGOs like GATE of Germany (1979) [26], have paid serious attention to test solar cookers. Some of the recent publications summarize these aspects (Ashok & Sudhir, 2009) [27]. At present, however, ASAE S 580.1 of 2013 formulated by Funk has become a standard test procedure [28]. Recently scientists at Solar Cooker International have evolved a simple, low-cost device to test two solar cookers simultaneously and plot suitable graphs to evaluate them Allen Begalov, [28]. Apart from these thermodynamic tests measuring energy and exergy efficiencies, it is essential to express the efficiency in percentage, which is more comfortable for the users to select the design suitable for them [27]). A recent paper has summarized progress in the testing cooker (Sagade et al. 2018) [29]. Besides, attention should also be paid to the Cost per Watt ratio (Shaw 2002) [30, 27], especially to

substantiate improvement by way of adding reflectors or other products. Any further improvement would only result in extra cost, and it should be gaged if it is worth the additional cost through this Cost vs. Watt ratio.

2. CONCLUSION

About 250 years ago, the very first Solar Cooker invented by Horace-de-Saussure, in the year 1767, was a box-type cooker, without a reflector booster. For over 175 years, the design had not caught the attention of researchers or even users. Even now, although much work is being done on the design to improve its performance by altering shape, adding single or multiple reflectors inside or outside the box, providing better insulating materials, electric booster heaters, and also by augmenting heat-storing chemicals or materials, these box cookers have not become as popular as envisioned. In terms of stability and safety, solar box cookers are better over panel and funnel cookers. But panels cookers have fared better in popularity, on account of its simplicity and low cost.

Solar box cookers would be more useful and popular for commercial applications, especially in tropics and subtropics, as in the case of Kothara School cooker in India [10]. In conclusion, it can be stated that the Solar Box cooker has a bright future, and these and other Solar Cookers have to be made popular to mitigate pollution caused by cooking and to improve the health of users.

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