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A Solar Cooking Workshop for Low-Income Communities: A Social and Environmental Initiative

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A B S T R A C T

Brazil is a tropical country which has an average of 250 sunny days per year. Unfortunately, very little solar energy is used for both heating water and for food cooking with solar cookers. Traditional cooking process demands fuel consumption while solar cooking takes advantage of the abundant, free solar energy. This article proposes the use of affordable panel solar cookers, with a sustainable design, based on waste materials, such as cardboard and potato chips metallized plastic bags as alternative materials to commercial reflective aluminum foil or reflective plastic films. Our work is an example of the feasibility of simple, fast and low-cost solar cooking apparatus and techniques dissemination among underprivileged communities.

Keywords: Solar Energy; Affordable Solar Cookers; Sustainability, Waste Materials

Oficina de Fogões Solares para Comunidades de Baixa Renda: Uma Iniciativa Socioambiental.

Resumo

O Brasil é um país tropical que tem em média 250 dias de sol por ano. Infelizmente, muito pouca energia solar é usada para aquecer água e para cozinhar alimentos com fogões solares. O processo de cozimento tradicional exige consumo de combustível, enquanto o cozimento solar aproveita a abundante energia solar gratuita. Este artigo propõe a utilização de fogões solares de painel de baixo custo, com design sustentável, a partir de resíduos, como sacolas plásticas metalizadas de papelão e batata frita, como materiais alternativos às folhas de alumínio reflexivas comerciais ou filmes plásticos reflexivos. Nosso trabalho é um exemplo da viabilidade da disseminação de aparelhos e técnicas de cozimento solar simples, rápido e de baixo custo entre comunidades carentes.

Palavras-chave: Energia Solar; Fogões Solares Acessíveis; Sustentabilidade; Resíduos.

Introduction

About two-thirds of the world's population (more than 4 billion people) depends on firewood to satisfy their needs, which are energetic daily and this represents the annual deforestation of the tropical forest in the order of 30,000 to 40,000 km^2 (WHO, 2016). On the other hand, natural forest exploitation occurs more frequently in tropical regions, which are the most favorable regions for the use of solar energy, where an incidence of sunlight can reach, in some cases, a potential of 1 kW · m^{-2} (Arshad, 2017). Because of this, the use of solar cookers becomes an ecologically important and correct alternative to the use of fossil fuel or firewood in cooking food because it is considered one of the most simple, viable, and attractive thermal applications of solar energy (Asif, 2017; Herez et al., 2018; Sabiha et al., 2020; Padonou et al., 2022).

In developing countries, cooking remains a dominant end-use of energy demand (Nahar, 2014). For this reason, the widespread use of solar cooking brings environmental, social, and economic benefits, with a positive impact especially for low-income families living in rural or suburban areas (Otte, 2013; Aquilanti et al., 2023). Predatory deforestation generated by firewood collection could be mitigated, contributing to the preservation of fauna and flora, while the cost of energy for cooking purposes would be drastically reduced worldwide (Gallagher, 2011; Panwar et al., 2012; Otte, 2013). Besides, it is important to note that slow cooking with solar energy helps to retain nutritional content and these foods rarely burn during solar cooking (Gupta et al., 2021; Mawire et al., 2021).

Despite these benefits, solar cookers cannot yet be seen as a final solution to problems related to cooking. Therefore, there has been an increasing attempt to promote solar cooking as part of an integrated solution to these problems. Thus, solar cookers are being promoted as a complementary kitchen device with specific advantages and offering greater flexibility to consumers who are usually forced to use fossil fuels or combinations of appliances for reasons of price and affordability (Wentzel et al., 2007).

Types of solar cookers

The main feature of a solar cooker is that it uses solar energy to heat or cook food, producing an effective work output during sunny hours and minimizing it during twilight or cloudy days.

To solve this problem and increase the productivity of solar cookers, thermal storage systems are added to provide off-peak heat. This method is already well discussed in the previous literature both for storage of latent heat of fusion and also for sensible heat (Thirugnanam et al., 2020; Gokul et al., 2021; Vengadesan et al., 2021; Verma et al., 2022; Kumar et al., 2023; Wazeer et al., 2023).

In addition, many solar cooker configurations have been developed and tested in the literature. However, all of these configurations can be broadly divided into four categories: (1) solar panel cooker, (2) box-type solar cooker, (3) parabolic solar cooker, and (4) vacuum tube solar cookers (Arunachala et al., 2020; Gupta et al., 2021; Ruivo et al., 2021; Saxena et al., 2022).

Panel solar cookers

The panels are folded in a way to focus sun heat towards the cooking pan spot. This type of cooker presents lower yield temperatures (up to 150°C). Nevertheless, they are efficient to promote food cooking, as this process demands minimum temperatures around 82°C (Wassie et al., 2022). For improved efficiency, the pan used in Panel solar cookers must be wrapped with a plastic oven bag capable of standing at 300°C or covered with a clear glass dome (Pyrex type, Figure 1) (Kerr, 1991; Diassana, 2020).

Figure 1. A panel solar cooker showing a pan covered with a clear glass dome. Source: Conner, 2011.

The cover acts as a greenhouse trap and retains the heat, significantly increasing thermal cooking efficiency (Arunachala et al., 2020). Solar cookers make the cooking process slower than conventional cookers, they also use little to no water, since the food cooks in its own water or steam. In addition, slow cooking is a healthier way of food preparation, as it preserves nutrients. Panel solar cookers are not suitable for frying. On the other hand, they can bake breads, cakes, and other baked goods with virtually no carbon footprint (Indora, 2018).

Box solar cookers

The box solar cooker is the most common type of solar cooker produced for personal use (Kimambo, 2018; Vishwakarma and Sinha., 2022). It can be built from cardboard, wood, or plastic boxes, as shown in Figure 2 (Vengadesan et al., 2021). The solar radiation passes through a glass (or plastic) cover that provides an adequate greenhouse effect, while the side flap or reflector concentrates the solar thermal energy inside the box. For this, it is necessary to paint the inside of the box and the pans with black paint to maximize this greenhouse effect during heating (Herez et al., 2018).

Figure 2. A panel solar cooker.

Solar box cookers have moderate thermal yields when compared to solar panel and solar parabolic cookers, reaching up to 150 ° C, making them suitable for roasting, but not for frying (Aramesh et al., 2019; Vengadesan et al., 2021). In general, construction is more time consuming and requires reorientation throughout the day to ensure optimal sun exposure, making it difficult to use on a large scale. However, some studies have improved the free tracking system, finding experimental results in which the system tracks the Sun for up to 6 hours (Farooqui, 2015; Herez et al., 2018).

Parabolic solar cookers

Parabolic solar cookers are the most powerful and most versatile solar cookers, they can cook, boil, fry, and roast all types of food very quickly, compared to box or panel cookers (Arunachala et al., 2020; Sahu et al., 2021) and feature yields equal to or greater than the thermal energy of a conventional gas stove.

The shape of the parabolic solar cookers provides precise convergent focus, allowing cooking temperatures above 150 ° C and shorter cooking times (Kedar et al., 2017; Theu and Kimambo, 2023). However, they are directional, requiring angle adjustments every 15 - 20 minutes (Arunachala et al., 2020).

They can be built with different materials: fiberglass, molded plastic, cardboard, polished aluminum in a support structure, etc. However, they are more expensive and more difficult to build, when compared to previous solar cookers, which brings some difficulties in their introduction in day-to-day use in low-income communities or in solar cooking workshops. Figure 3 shows a ready-to-use parabolic solar cooker.

Figure 3. A parabolic solar cooker. Source: The authors.

Vacuum tubes solar cookers

A new generation of high performance solar cookers is being developed based on solar cookers that use sunlight indirectly through vacuum tubes, as shown in Figure 4. This type of solar cooker maintains and retains heat better than any other type due to a double glass tube wall present in the cooking chamber. In this way, a vacuum form is created in the space between the glasses that provides excellent heat retention (Bazile, 2018).

Although vacuum tubes are more effective, the use of glass limits the size of the tube opening in addition to increasing costs for its production (Daghestani, 2020). As such, they are not suitable options for extensive use among underprivileged populations.

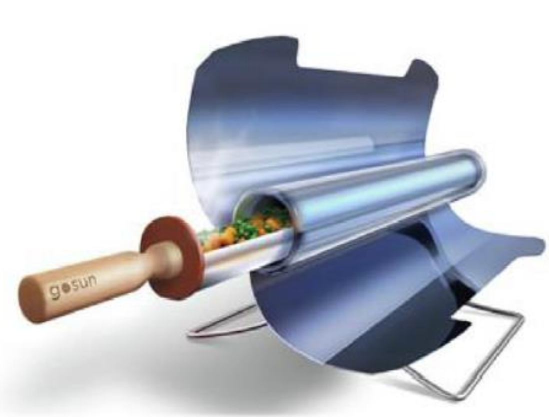

Figure 4. A vacuum tube solar cooker. Source: Ashok, 2018.

As we can see, there are many designs for solar cookers, and each one of them may be useful, depending on the application intended (Atmane et al., 2021; Kimambo, 2018; Ruivo et al., 2021; Sabiha et al., 2020; Vengadesan et al., 2021). In our evaluation, Panel solar cookers present the best set of characteristics to be presented for a Do-It-Yourself project using affordable materials. Therefore, we chose the Bernhard Müller pattern to introduce Panel solar cooking to the Community of Morro da Cruz, Porto Alegre, Rio Grande do Sul State-Brazil. Our findings suggest that this type of solar cooking apparatus can pave the way to further development of solar cooking techniques in low-income communities.

Methodology

This article proposes to disclose a Panel solar cooker model, which is affordable and simple to assemble and use. These solar cookers are usually made from cardboard panels, which can be recycled from used cardboard boxes. Reflective surface coatings can be made of aluminum foil, metalized plastic films used in gift bags, potato chip bags, among others. They are fixed to the cardboard with homemade or white glue.

Subjects

Eight residents (three male and 5 female) of Morro da Cruz low-income community, Porto Alegre City, Rio Grande do Sul State, south Brazil, accepted an invitation to learn how to make their own inexpensive cardboard solar cooker. They received all material necessary to make a solar cooker by donation. All instructions on how to make and use the solar cooker were given to the subjects, either in written and by oral presentation. All subjects accepted to participate on the workshop from the beginning to the end.

Materials and methods to build a Fun Panel solar cooker

Originally proposed by Teong Tan (Tan, 2008), Fun Panel solar cooker is the model of choice when it comes to make powerful panel solar cookers. This model was further improved and scaled up for better results. In this study we chose Bernhard Müller pattern (Figure 5) to build a Panel solar cooker suitable to be implemented as an eco-friendly, affordable cooking option for needful communities (Müller, 2016). The model consists of two rectangles, which can be fold to make two L-shaped parts joined by adhesive tape. Main parts of the apparatus are: two folded tabs; a pan area to hold the pan, and a support made with a shoes box.

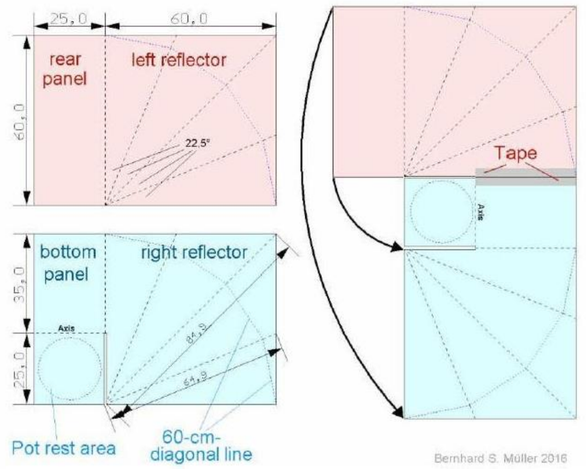

Figure 5. Fun Panel solar cooker pattern. Source: Müller, 2016.

The cardboard used in the Panel solar cooker can be waste material. For example, LCD TV packages usually have adequate dimensions to make a good Panel solar cooker. Large cardboard boxes, in sizes superior to 60 x 60 cm, are also good alternatives.

The reflexive material can be made out of waste potato chip bags, metallized biaxially-oriented polypropylene (BOPP) sheets used in gift bags, or aluminum foil, but with less reflexibility and poorer mechanical resistance.

Reflexive material can be glued to the cardboard with homemade glue or white glue. However, best results are achieved with double-sided tape, as the reflexive cover presents less wrinkles and better reflexivity.

The instructions provided to the subjects were:

a) Cut two cardboard rectangles, in dimensions showed in the pattern (Figure 6).
b) Cut the two reflexive sheets, in the same size of cardboard rectangles. For best results, apply double sided tape in the edges of cardboard, with vertical glue lines, as shown in Figure 7.
c) Apply double-sided adhesive tape in the cardboard sheets.
d) Stretch reflexive film over the cardboard sheets.
e) Fold and join the two "L" sheets to make the Panel solar cooker, as shown in Figure 8.

Figure 6. Cardboard sheets and metallized BOPP plastic reflexive sheets. Source: The authors.

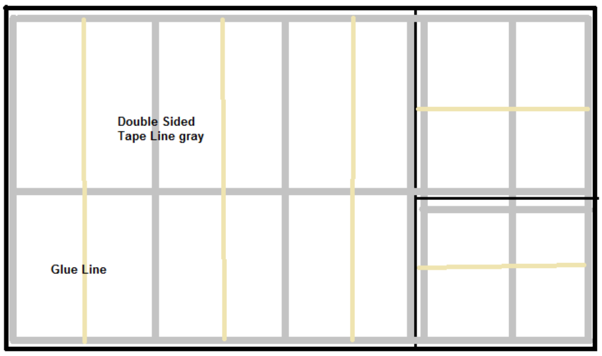

Figure 7. Schematics on double sided tape and glue line to glue reflexive the sheet on the cardboard. Source: The authors.

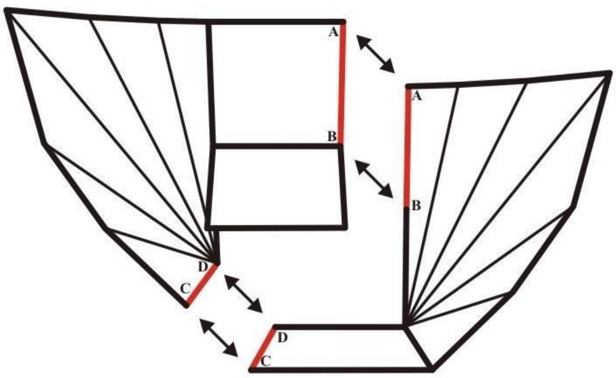

Figure 8. Schematics on how to join the two “L” sheets makes the solar cooker. Source: The authors.

Results and discussion

Subjects were able to follow Procedure “a” without further assistance from the instructors. Figures 9 to 11 show photographs of the subjects following the constructing instructions for the Panel solar cooker manufacturing. Figure 8 shows the execution of Procedure “b”. The special double-sided tape is attached to a paper that acts as protective coating, in order to avoid tape adherence loss due to the contact with air. This paper must be removed before applying reflexive plastic material, to expose the glued surface for an effective adherence. Subjects were encouraged to perform this procedure in pairs.

Figure 9. Applying double-sided adhesive tape in cardboard sheets. Source: The authors.

Figure 10 shows the execution of Procedure “c” and ‘d’. Special care must be taken in stretching the reflexive sheets to avoid wrinkles, which may decrease reflexivity. Resulting good quality panels are shown in Figure 11.

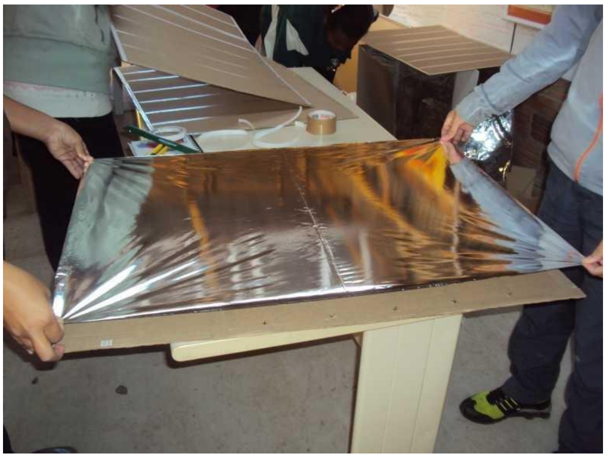

Figure 10. Stretching reflexive film to glue in the cardboard sheets. Source: The authors.

Figure 11. Two cardboard sheets covered with reflexive films. Source: The authors.

After following Procedure “e”, the subjects were able to assembly their own Fun Panel solar cooker (Figure 12). A shoes box was used as pan support. A 1 m long, 4 mm in diameter metallic bolt was used to keep the cooker open.

Figure 12. An assembled, ready-to-use Fun Panel solar cooker manufactured in the Morro da Cruz Workshop. Notice the shoes box used as pan support. Source: The authors.

Figure 13 shows the final results of the Morro da Cruz Workshop. In two hours, the pairs of residents easily built their own Panel solar cooker and were oriented on how to use them. However, further efforts must be done in order to implement the effective use of solar cookers on a daily basis. Additional instructions must be passed on to the community members regarding solar cooking techniques applied to simple recipes, such as cooked white rice, chicken breast, or pasta; and baked goods.

Solar cooking demands black pans to improve heat absorption and achieve better Greenhouse effect. Thus, community members might be instructed to paint common aluminum pans or glass preserve jars in black, and use plastic oven bags to cover their pans.

Another important aspect to be considered is the need to recruit sponsors to provide the basic materials needed, adequate working space and appropriate workshop furniture, e.g. large size sturdy tables. Such facilities are not readily available in most low-income communities.

Figure 13. Workshop in Morro da Cruz poor community – Porto Alegre - RS. Source: The authors.

Conclusions

Our findings revealed that the Fun Panel solar cooker could be fastly and easily manufactured by a group of eight members from the Morro da Cruz low-income community, suggesting that this pattern might be a good starting point to disseminate the use of thermal solar energy for cooking and baking as an alternative to fossil-fuel-based conventional cooking.

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