SOLAR THERMOBOX: A LOW-COST DEVICE AS THERMAL INSULANT AND SUBSTITUTE FOR OVENS AND DRYERS IN PARTLY CLOUD CONDITIONS

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The global pressure for renewable energy, driven by the need to reduce reliance on fossil fuels and environmental impacts, has elevated the prominence of solar energy. Brazil's geographical location positions it as one of the main candidates for harnessing solar radiation. Practical solar applications, such as solar-powered ovens and dehydrators for cooking, offer an ecological option, especially in underserved communities. However, challenges arise when devices operate under variable solar conditions. To address this, the aim of this study was to develop and validate a versatile Solar Thermobox, using low-cost reused materials such as wood, cardboard, styrofoam, and glass. The design, optimizing space and heat absorption, integrates styrofoam, cardboard, and laminated paper. Tests showed revealed that Thermobox achieved temperatures of 50°C to 60°C even under partly cloudy skies and conditions that effectively dehydrate food. Its insulating properties extend to thermal conservation, retaining beverage temperatures. The impressively low construction cost of <US$8 demonstrates affordability, making it a viable alternative to standard solar dryers and ovens. The device's multifunctionality, combining drying, cooking, and insulation, holds potential for electricity-deprived or resource-limited communities. The innovation's benefits go beyond personal use, offering income generation through food production or resale, aligning with Sustainable Development Goals. Ultimately, the multifunctional Solar Thermobox embodies the application of sustainable energy, addressing various needs and contributing to a greener future.

KEYWORDS: BEVERAGE TEMPERATURES; DEHYDRATED FOOD; SOLAR DRYER; SOLAR OVEN; SOLAR RADIATION.

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1. INTRODUCTION

The search for renewable energy sources has become a global priority, driven by the growing interest in reducing dependence on fossil fuels and mitigating the environmental impacts associated with their use (DOĞAN *et al*., 2022). Solar energy has emerged as a sustainable and abundant alternative in this context. In Brazil, a country with an extensive territory encompassing diverse climates and landscapes, the utilization of solar energy holds enormous potential (SANTOS *et al*., 2020).

Relevant practical applications of solar energy include solar ovens and dryers, which harness sunlight to heat food. These devices are simple and capable of converting solar energy into thermal energy, enabling the dehydration of raw food materials and meal preparation without consuming fossil fuels or electricity (ALMEIDA *et al*., 2022). Furthermore, these appliances contribute to the reduction of greenhouse gas emissions and offer a sustainable alternative for communities without access to electrical power.

However, one of the challenges faced by these devices is maintaining high efficiency under partially cloudy conditions or low levels of solar radiation (HADIBI *et al*., 2022). In regions with significant climatic variations, such as Brazil, ovens and dryers need to operate efficiently even when direct solar radiation is limited. Apart from being efficient, practical, and cost-effective, the versatility of these devices is also crucial to drive the widespread adoption of solar energy in various food-related applications (GOMES *et al*., 2023). For this purpose, these devices must demonstrate multifunctional capacity to meet the diverse needs of communities.

An innovative example of this concept is the integration of thermal insulating properties into solar-powered equipment. Although challenging, the incorporation of thermal insulating properties adds a level of flexibility and utility to solar-powered equipment, making them valuable in a variety of everyday scenarios.

Therefore, the objective of this study was to design and build a multifunctional and low-cost Solar Thermobox, capable of preparing food even in partially cloudy conditions, as well as acting as a thermal insulator when stored indoors.

2. MATERIAL AND METHODS

2.1 Material

For the production of the Thermobox, an analysis of easily accessible and low-cost materials was carried out, aiming to make the apparatus affordable and sustainable for underserved communities. The following materials were used: (reused) wood, (reused) cardboard, Styrofoam, (reused) glass, laminated paper, hot glue, black paint (spray), and adhesive tape.

2.2 Manufacturing process

Considering the space optimization and improved food handling after cooking, the Thermobox (Figure 1) was crafted in a rectangular shape, measuring 70 cm in length, 60 cm in width, and 40 cm in height. The box was spray-painted with matte black paint due to its enhanced heat absorption properties of the black color. Subsequently, the interior was lined using pieces of Styrofoam, which were covered with cardboard and then coated with laminated paper. The use of paper is advantageous for reflecting solar rays and expediting the heating process, while Styrofoam and cardboard assist in maintaining the internal temperature. The Thermobox lid was constructed using wood and transparent glass (3 mm thick), aiming to allow the penetration of solar rays into the box's interior.

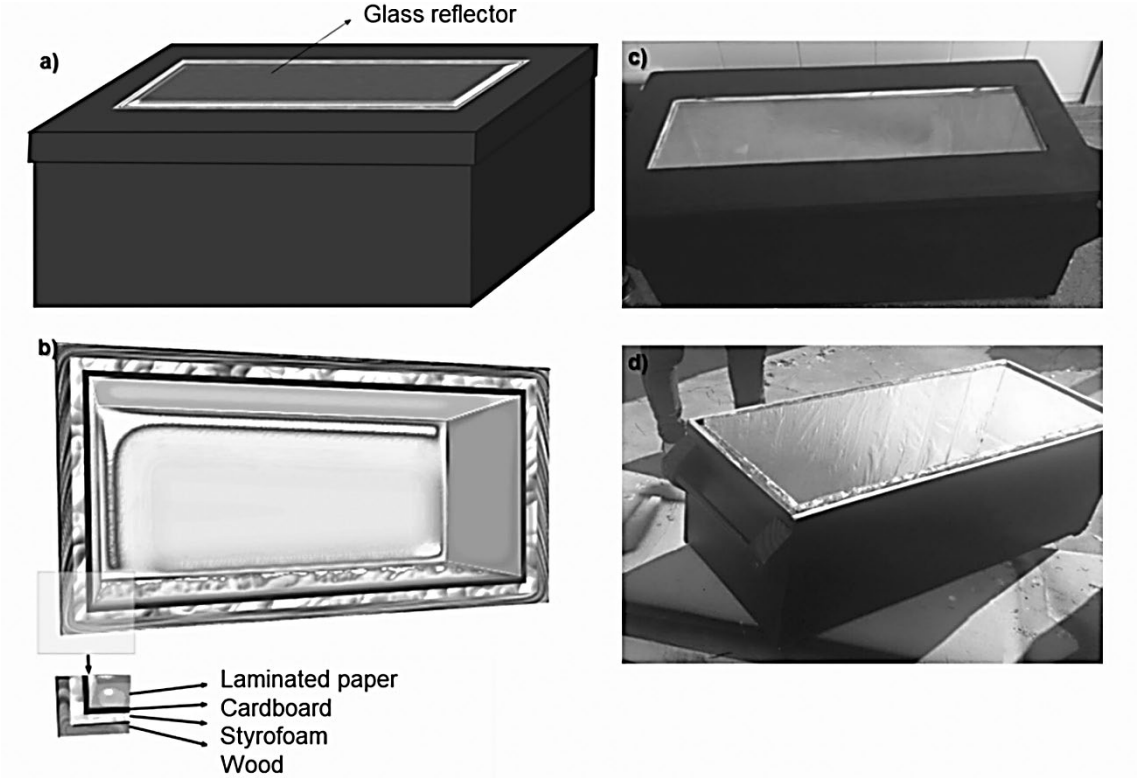

FIGURE 1 - PRODUCTION OF THE THERMOBOX, A) AND B) - SKETCH OF THE IDEA/COATING MATERIALS, C) AND D) - EXECUTED PROJECT.

Once completed, the Thermobox underwent temperature range tests under partly cloudy conditions, aiming for potential applications in food preparation. Additionally, the thermal insulation capability of the device was assessed through a closed environment water test. A conventional thermometer was used to measure temperatures. The tests took place in the city of Barreiras, Bahia, Brazil.

3. RESULTS AND DISCUSSION

3.1 Potential application of Solar Thermobox as dryer and oven for food

During the three days of experimental testing, the Thermobox (Figure 2a) maintained an interior temperature ranging from 50°C to 60°C, with an average of 53.3 ± 5.8°C. In comparison, the average ambient temperature at the testing site was 25.7 ± 1.1°C. In other words, even under cloudy conditions, the apparatus was able to convert the limited available solar energy into thermal energy, raising its internal temperature by 107.4% (or 27.6°C).

An average temperature exceeding 50°C implies that the Thermobox can be used under partly cloudy skies for the dehydration of fruits and vegetables, considering that the thermal range resembles the performance of traditional solar dryers, which typically achieve temperatures between 30°C and 70°C (SINGH; MALL, 2020). The ideal average drying temperature for fruits and vegetables ranges from 45°C to 60°C, as drying at average temperatures above 60°C can be detrimental to agricultural products (MARULANDA-MEZA; BURBANO-JARAMILLO, 2021). Thus, under conditions of low solar incidence, the device can ensure the quality of drying, preventing excessive dehydration of the surface of fruits and vegetables.

The Thermobox can also be employed in the processing of foods that require gentler preparation temperatures, such as blanched vegetables and boiled eggs using a water bath; roasted fish, utilizing laminated paper to maximize product heating; and longer-duration cooking of other foods, such as cakes (Figure 2b) and meats.

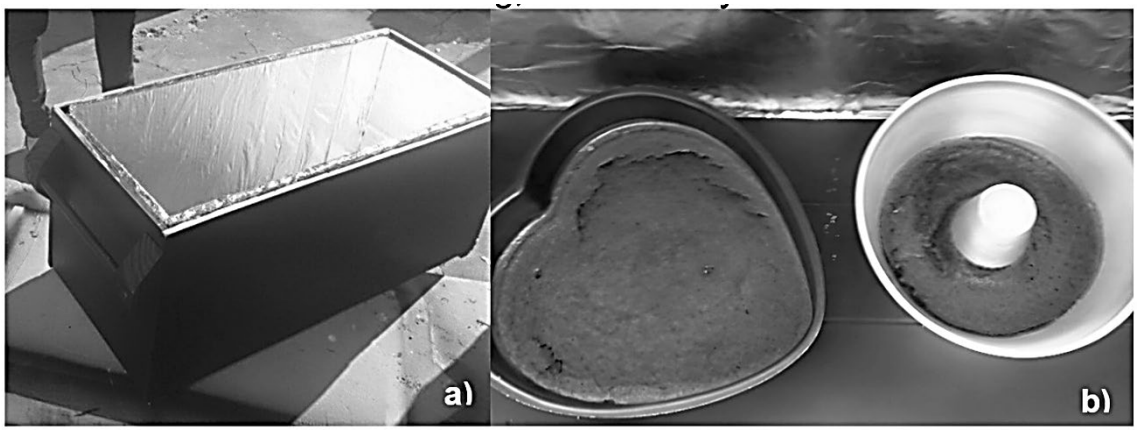

FIGURE 2 - A) THERMOBOX. B) CAKE BAKED IN THE THERMOBOX AFTER 12 HOURS OF COOKING, INTERMITTENTLY.

3.2 Potential application of the Solar Thermobox as a thermal insulator for beverages

The Thermobox acted as an effective thermal insulator for water, as the temperature of the liquid stored inside the apparatus remained between 26.3% and 31.4% lower than water exposed to ambient storage conditions (Figure 3). In other words, the apparatus exhibited an average performance 28.3 ± 2.2% better than conventional storage. This outcome suggests that the equipment is

a potential alternative for maintaining the temperature of beverages and food items that predominantly contain water as a component.

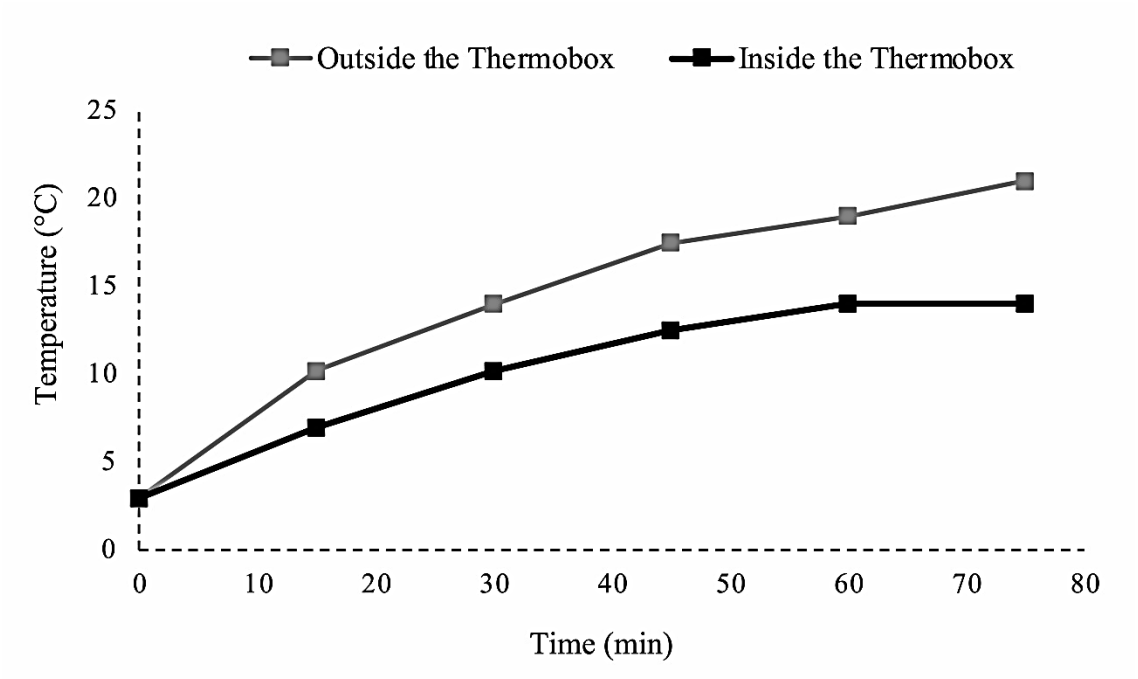

FIGURE 3 - WATER TEMPERATURE INSIDE AND OUTSIDE THE THERMOBOX OVER TIME.

3.3 Cost to build the Thermobox

The main materials for building the Thermobox were reused wood and discarded glassware, which allowed for a drastic reduction in the apparatus' production costs. The other materials, except cardboard, were purchased (Table 1), totaling an expense of US$ 7.81. It is worth mentioning that the purchased materials can be reused for other purposes, in addition to being able to build more Thermoboxes. The production value of less than US$ 8.00 demonstrates the cost-effectiveness of the device, considering that the expense represents a maximum of 4.85% of the value of a conventional solar dryer, which can cost between US$ 161.00 and US$ 300.00 (MELONI, 2023). Compared to traditional solar ovens, the solar Thermobox represents savings of 96.6% to 98.4%, as prices range from US$ 230.00 to US$ 500.00 (GOOGLE, 2023).

TABELA 1 – ACQUISITION COST OF THE MATERIALS USED IN THE CONSTRUCTION OF THE THERMOBOX.

MATERIAL	AMOUNT	UNIT PRICE (US$)
Glue (refill for gun)	3	0.23
Laminated paper	2	0.52
Spray paint	1	3.28
Adhesive tape	1	0.78
Styrofoam board (20 mm)	2	1.01
Total Amount (US$)		**7.81**

4. CONCLUSION

By combining the functionalities of a dryer, an oven, and a thermal insulator for temperature conservation, the equipment, which relies solely on solar energy through natural convection and boasts a low construction cost, proves to be a promising alternative for communities without access to electricity or financial means to acquire more sophisticated devices. Furthermore, the Thermobox can generate revenue either through its production and sale or by being utilized in the preparation of food products for resale. In any case, the equipment can democratize access to hard-to-obtain technologies and contribute to the achievement of the Sustainable Development Goals (SDGs).

SOLAR THERMOBOX: UM DISPOSITIVO DE BAIXO CUSTO COMO ISOLANTE TÉRMICO E SUBSTITUTO PARA FORNOS E SECADORAS EM CONDIÇÕES DE CÉU PARCIALMENTE NUBLADO

A pressão global por energia renovável, impulsionada pela necessidade de reduzir a dependência de combustíveis fósseis e os impactos ambientais, elevou a proeminência da energia solar. A localização geográfica do Brasil o posiciona como um dos principais candidatos ao aproveitamento da radiação solar. Aplicações solares práticas, como fornos e desidratadores movidos a energia solar para cozinhar, oferecem uma opção ecológica, especialmente em comunidades carentes. No entanto, surgem desafios quando os dispositivos operam em condições solares variáveis. Para resolver isso, o objetivo deste estudo foi desenvolver e validar uma caixa térmica solar versátil, usando materiais reutilizados de baixo custo, como madeira, papelão, isopor e vidro. O projeto, que otimiza o espaço e a absorção de calor, integra isopor, papelão e papel laminado. Testes revelaram que a Thermobox alcançou temperaturas de 50°C a 60°C mesmo sob céu parcialmente nublado e em condições que desidratam efetivamente os alimentos. Suas propriedades de isolamento se estendem à conservação térmica, retendo a temperatura das bebidas. O custo de construção impressionantemente baixo, de <US$ 8, demonstra a acessibilidade, tornando-o uma alternativa viável aos secadores e fornos solares padrão. A multifuncionalidade do dispositivo, combinando secagem, cozimento e isolamento, tem potencial para comunidades carentes de eletricidade ou com recursos limitados. Os benefícios da inovação vão além do uso pessoal, oferecendo geração de renda por meio da produção ou revenda de alimentos, alinhando-se aos Objetivos de Desenvolvimento Sustentável. Em última análise, a Solar Thermobox multifuncional incorpora a aplicação da energia sustentável, atendendo a várias necessidades e contribuindo para um futuro mais verde.

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