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Research Article

Realization and Experimental Study of a Parabolic Trough Solar Cooker

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Abstract

Cooking food is a necessity for human beings. However, it requires a significant amount of energy. Conventional fossil fuels are the most widely used in cities. This energy is expensive, polluting, and becoming scarce. In rural areas of the Sahel countries, in particular, wood biomass is the most widely used. The use of wood biomass for cooking causes significant deforestation and respiratory diseases. These (Sahelian) countries have significant solar potential. Harnessing this virtually free energy source is essential for cooking. Solar cookers are therefore a solution to reduce fossil fuel needs and deforestation. The objective of this work is to contribute to the development of solar cookers. A solar cooker with a parabolic trough collector is designed and studied in this work. This was an experimental study. We monitored the temperature changes in certain parts of the cooker and the water heated with the device. The cooker's thermal performance was also evaluated. The results show that temperatures at the focus can reach 222 °C. The temperature distribution along the focal line is relatively uniform. The useful power at the focus reaches a value of approximately 225W with a maximum instantaneous thermal efficiency of approximately 0.32. The observed efficiency is acceptable but lower than what was expected with the concentrator user.

Keywords

Solar Cooker, Parabolic Trough Concentrator, Temperature, Performance

1. Introduction

The sun, as a renewable and inexhaustible resource, represents a promising solution to meet current global energy challenges. In a context where dependence on fossil fuels leads to worrying environmental and health consequences such as deforestation, desertification and more than 3.5 million annual deaths worldwide caused by smoke from biomass combustion [1]. Technologies exploiting solar energy, such as solar cookers, are emerging as viable and sustainable alternatives to address household concerns. These devices convert solar rays into heat, thus providing an environmentally friendly cooking method. The popularization of solar cookers mainly helps relieve households in rural (Sahelian) areas

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whose access to energy is limited and the main source of energy for cooking is wood biomass. Solar cookers are mainly of two types: direct solar cookers and indirect solar cookers. The most developed type of cooker is direct where the operator is also in the sun. Direct solar cookers can be classified into three subcategories: box-type solar cookers, panel-type solar cookers, and concentrator solar cookers (parabolic, parabolic trough). Box-type cookers have been extensively studied by researchers [1-7]. Panel-type solar cookers, also due to their simplicity, have been extensively developed and studied [8-10]. Concentrating solar cookers are developed to improve direct solar cookers. Zamani et al. (2015) studied the performance of a cooker designed with three narrow, adjustable flat mirrors mounted on a curved parabolic substrate to concentrate the reflected solar beam onto the absorber plate. They showed that this system generates an increase of 32.07% and 35.5% in effective and overall efficiencies, respectively [11]. Noureddine El Moussaoui et al. (2020) studied a solar concentrator cooker using a vacuum glass tube and the heating of oil circulating in a large tube located inside the tube. They found that when cooking food at high temperatures (fries, etc.), the temperature of the cooking oil rose to 200℃. After 1 hour of heating, cooking was carried out at a temperature of 120℃ for 20 minutes [12]. Indirect solar cookers were then developed to reduce the consequences of operator exposure to the sun [13-15]. This work consists of the experimental design and study of a direct solar cooker with a protected support for the pot. This is a direct solar cooker with a parabolic trough collector.

2. Materials and Methods

2.1. Cooker Elements

1) The reflector

This is the part that reflects the sun's rays to concentrate them at the focus. It is made of an aluminum sheet (length 1.1m and width 1m) folded to take the parabolic trough shape with a depth of 0.18m.

2) concentrator support

The frame is made of 30mm square tubes. It consists of two parts: a parabolic trough section that supports the reflector, and a table section with space for the cooking pot. It is equipped with a lever to allow the user to track the sun.

3) Operating principle

The operating principle of the solar cooker studied is as follows: the captured solar rays are concentrated towards the focus where the pot is located. This concentration of solar rays causes an increase in temperature. The heat thus produced at the focus is transferred to the pot containing the food to be cooked. To achieve an optimal cooking temperature, it requires regular reorientation following the path of the sun.

Figure 1 shows the device.

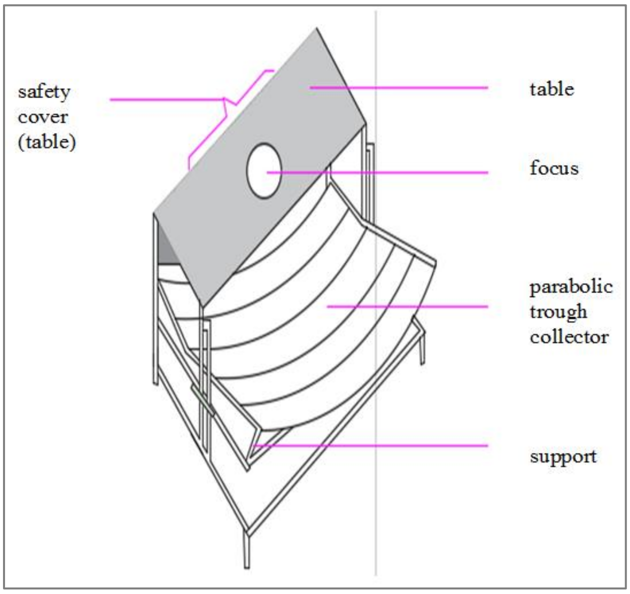

Figure 1. *Parabolic trough solar cooker device in place.*

2.2. Measuring Devices

To conduct our experiments, we used the following measuring devices:

1. a midi LOGGERGL220 digital data logger connected to type K thermocouples for temperature measurement. Temperatures were recorded at 5-minute intervals.
2. a solarimeter for measuring solar irradiation with a sensitivity of 72 mV/1000 W/m^2.

Figure 2 shows the measuring devices.

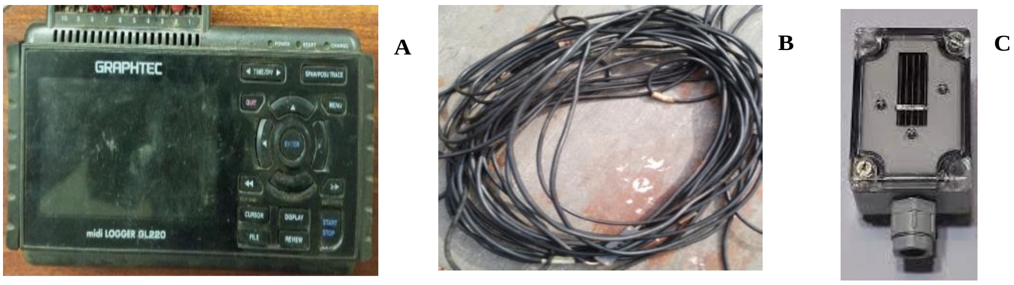

Figure 2. *Measuring devices; A: datalogger B: thermocouples C: solarimeter.*

Figure 3: shows the location of the different devices on the device where T denotes a thermocouple.

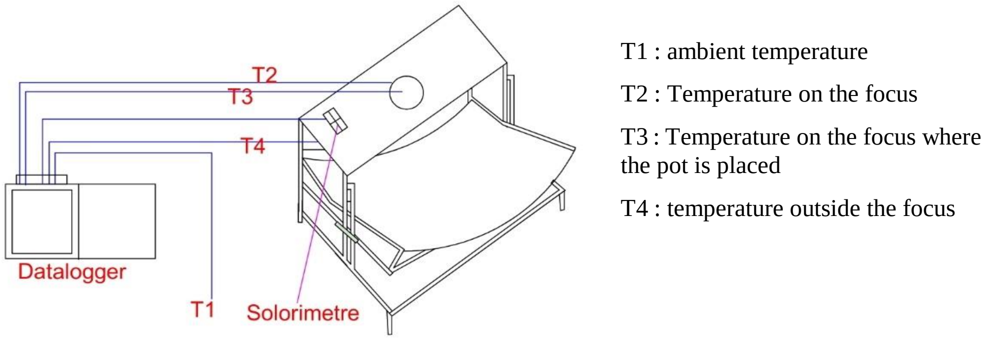

Figure 3. *location of the different devices on the device.*

2.3. Thermal Performance Evaluation Theory

Equation (1) allows us to calculate the useful power.

$$P_u = \frac{m_e \times C_{Pe} \times (Te_f - Te_i)}{\Delta t} \quad (1)$$

Equation (2) allows us to calculate the thermal efficiency.

$$\eta = \frac{P_u}{I_s(S_c \times C_g + \frac{1}{2} S_r)} \quad (2)$$

With me: the mass of the water, Cpe: the specific heat of the water, Tei: initial water temperature, Tef: final water temperature, Sc: the surface of the collector, Sr: the surface of the receiver, Is: the solar flux, Cg: the geometric concentration factor, Δt: the time step.

3. Results and Discussion

3.1. Empty Cooker Experimentation

The experimental study was carried out from October 6 to 10, 2024. During these experiments, we were able to monitor the evolution of temperatures and sunshine. The results obtained are represented in the form of curves.

Figure 4 shows T1, T2 and T3 respectively the ambient and linear focus temperatures.

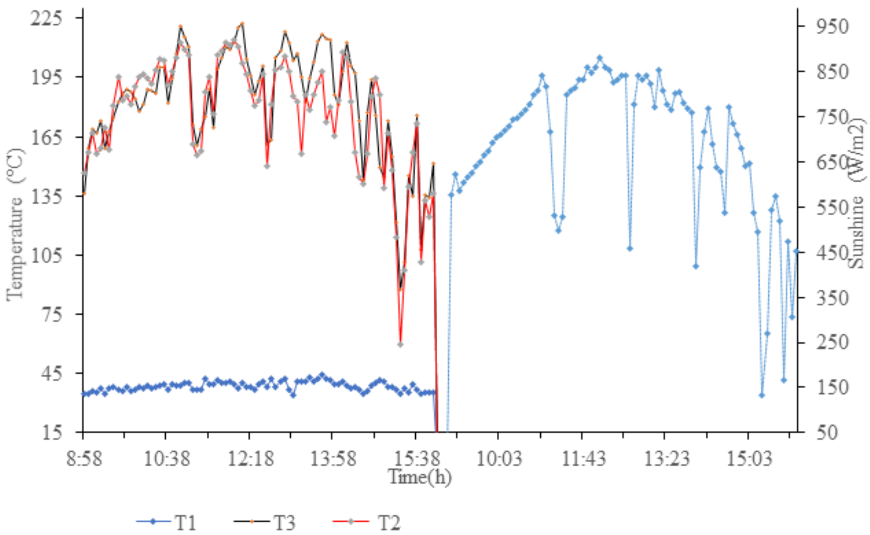

Figure 4. *Temporal evolution of the temperatures of the different parts of the cooker and the sunlight.*

There is a fluctuation of solar radiation during the day. Its maximum value reached is approximately 880 W/m^2. At the level of the focus, the temperatures T2 and T3 have the same appearance and are similar to that of the sunshine. These temperatures are then influenced by the solar flux. The values of these two temperatures are practically close. This is explained by the fact that they are all placed on the line of the focus. This observation also proves that the concentration is indeed done on a line and the pot can be placed anywhere on the concentration line. Their maximum values vary between 212.6 ℃ and 222.2 ℃. These values are close to those obtained in the literature, notably Thierry et al. (2024) [16].

3.2. Experimentation with Cooker Load

The load used is water. This involved water heating.

Figure 5 shows the ambient, on focus and water temperatures, as well as the solar flux.

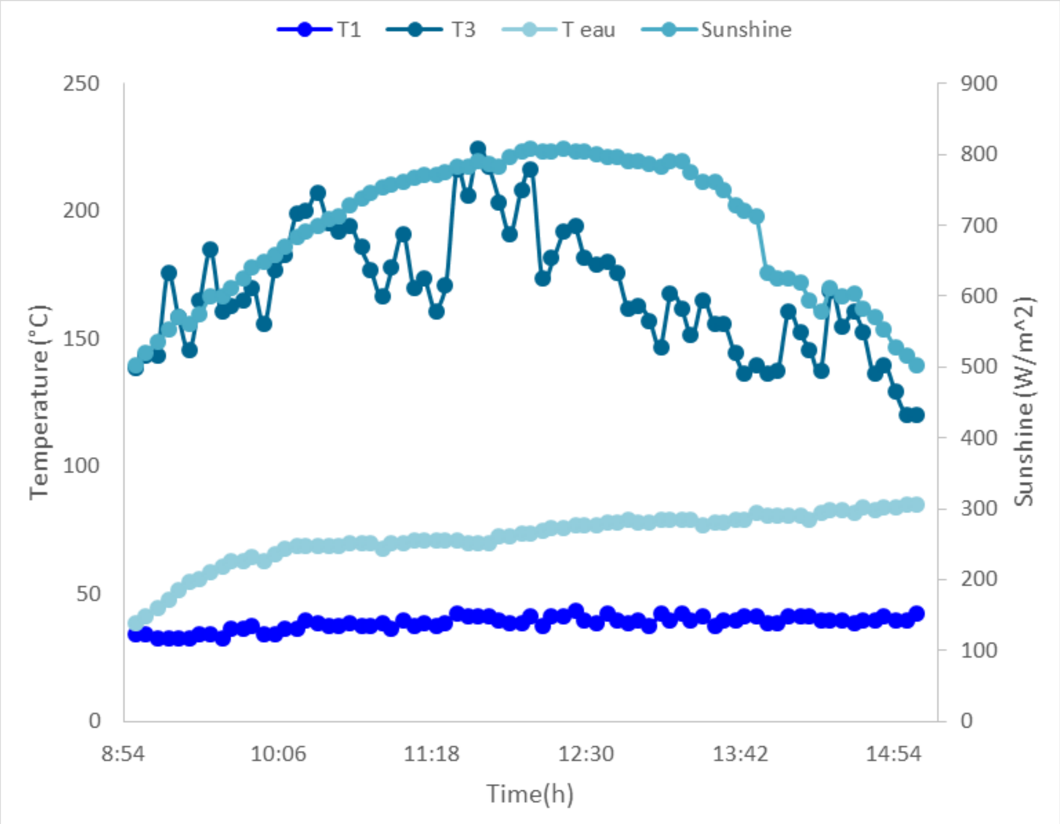

Figure 5. Time evolution of the temperature of the water and the different parts of the cooker.

The changes in sunshine levels show that there was not enough disruption today. The maximum value of approximately 805 W/m^2 around 12 p. m indicates good sunshine but not strong sunshine. The temperature in the focus generally follows the changes in sunshine. The multiple fluctuations are due to the delay in reorienting the device.

The water temperature gradually increases to a maximum value of approximately 85 ℃, reached around 3 p. m., when the sunshine level is 500 W/m^2.

The water temperature is not high enough, but it is still suitable for cooking food.

In fact, we boiled 1 kg of potatoes in 2 hours and 30 minutes (10 a. m. to 12:30 p. m).

3.3. Thermal Performance of the Cooker

Figure 6 shows the curve of useful power as a function of time.

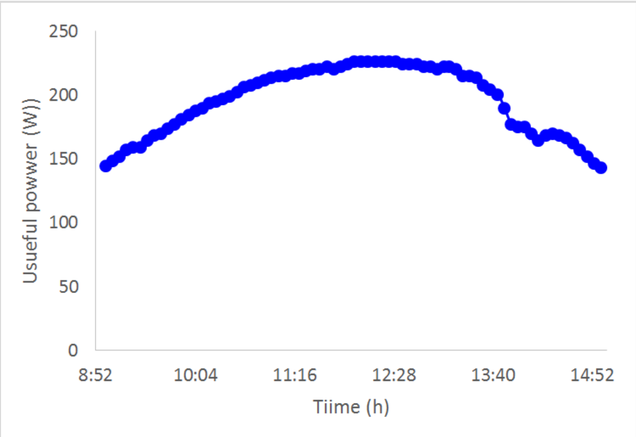

Figure 6. Useful power curve.

The useful power has the same shape as that of the sunlight because it is a function of the latter. The maximum power reached is approximately 230W. This power is quite low compared to what was expected.

Figure 7 shows the evolution of the thermal efficiency as a function of time during the experiment.

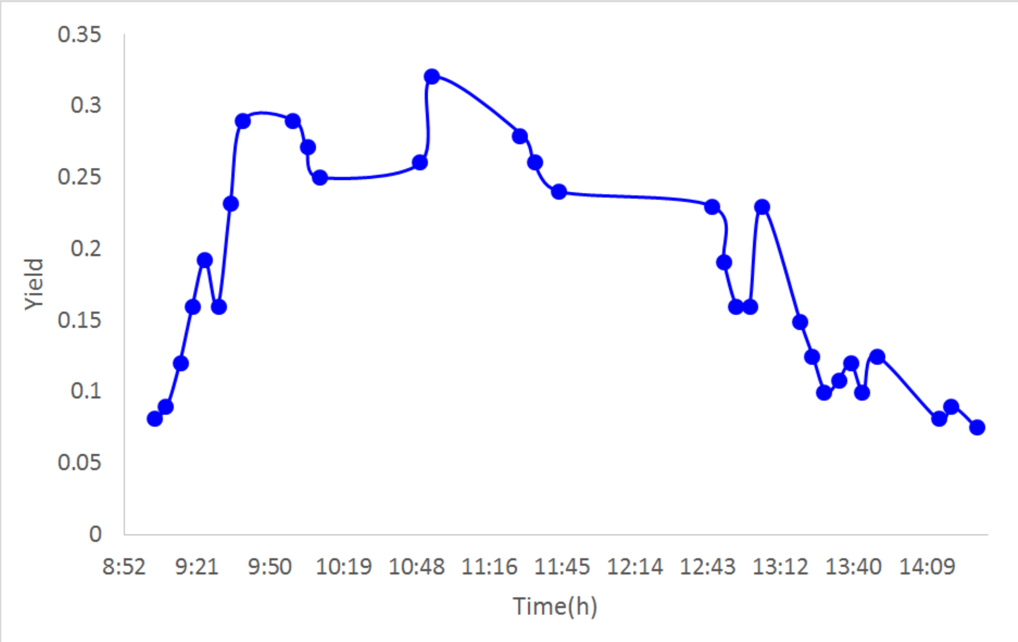

Figure 7. *Evolution of the thermal efficiency of the cooker.*

The thermal efficiency curve gradually increases to its maximum of 0.32 and then decreases until the end of the test. The average efficiency is 0.18 (18%). This result is slightly higher than that obtained by Masoud Adavi et al. (2025), with their indirect Fresnel lens solar cooker with thermal oil storage tank [17]. Indeed, they obtained an average efficiency of 16.92%. However, this result is very low compared to that obtained by Ravi Kumar Goyal et al. (2023). They obtained a thermal efficiency of 34% with their integrated box-type solar cooker with parabolic concentrator [18]. The efficiency value obtained with our cooker is still within the range of values obtained by Ashmore Mawire et al. (2024), which is 0.11–0.42 [19]. The efficiency of the solar cooker depends on solar irradiation and wind, which have a strong impact on heat exchange.

4. Conclusion

This work consisted of experimentally producing and determining the performance of a solar cooker with a parabolic trough collector. At the focus, we obtained a maximum temperature of approximately 222 ℃. The temperature of the heated water reached a maximum value of 85 ℃ under a maximum sunshine of approximately 805W/m^2. The instantaneous thermal efficiency reached a maximum of approximately 0.32. The observed efficiency is acceptable but lower than what was expected with the concentrator user.

Abbreviations

Cg	The Geometric Concentration Factor,
Cpe	The Specific Heat of the Water (J/kg ℃)
Is	The Solar Flux (W/m^2)
me	The Mass of the Water (kg)
Pu	Useful Power (W)
Sr	The surface of the Receiver (m^2)
Tei	Initial Water Temperature,
Tef	Final Water Temperature
Sc	The Surface of the Collector (m^2)
Δt	The Time Step (s)

Author Contributions

Dianda Boureima: Conceptualization, Validation

Belem Abdoulaye Aziz: Data curation, Funding acquisition

Compaore Aboubakar: Methodology

Bathiebo Dieudonné Joseph: Validation

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Conflicts of Interest

The authors declare no conflicts of interest.

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