Open Journal of Applied Sciences, 2026, 16(9), 3302-3322
https://www.scirp.org/journal/ojapps
ISSN Online: 2165-3925
ISSN Print: 2165-3917

Experimental Study of a Rotary Kiln Using Organic Charcoal Briquettes and Wood Coal as Fuel Suitable for the Local Context

Dabilgou Téré[1,2], Tubreoumya Guy Christian[2], Nebie Jacques[2,3], Nombre Yssouf[2], Tiendrebeogo Eloi Salmwende[2,4], Daho Tizane[2], Nyongesa Francis Wanjala[5], Sanogo Oumar[6], Dissa Alfa Oumar[2]

[1]Centre Universitaire de Ziniaré (CUZ), Ziniaré, Burkina Faso
[2]Université Joseph KI-ZERBO (UJKZ), Laboratoire de Physique et Chimie de l'Environnement (LPCE), Ouagadougou, Burkina Faso
[3]Université Thomas SANKARA (UTS), Saaba, Burkina Faso
[4]Ecole Normale Supérieure de Koudougou (ENSK), Koudougou, Burkina Faso
[5]Université de Nairobi, Nairobi, Kenya
[6]Centre National de Recherches Scientifiques et Technologie (CNRST), Ouagadougou, Burkina Faso
Email: terejdabilgou@yahoo.fr

How to cite this paper: Téré, D., Christian, T.G., Jacques, N., Yssouf, N., Salmwende, T.E., Tizane, D., Wanjala, N.F., Oumar, S. and Oumar, D.A. (2026) Experimental Study of a Rotary Kiln Using Organic Charcoal Briquettes and Wood Coal as Fuel Suitable for the Local Context. *Open Journal of Applied Sciences*, **16**, 3302-3322.
https://doi.org/10.4236/ojapps.2026.169181

Received: April 12, 2026
Accepted: September 14, 2026
Published: September 17, 2026

Abstract

In Burkina Faso, domestic cooking relies mainly on the use of solid fuels, particularly charcoal, with devices that are often inefficient. This study aims to test and analyze the thermal behavior of a rotary oven using organic charcoal briquettes and charcoal. The oven developed comprises an insulated combustion chamber made of compressed earth bricks (CEB), a cooking chamber equipped with a rotating bar and a grate, and a storage system that can be filled with sand. A series of thermal tests was conducted with fuel loads ranging from 1 to 3 kg. Temperatures were recorded using K-type thermocouples connected to a data logger. The results showed that charcoal causes a rapid rise in temperature, while organic charcoal offers more stable and prolonged combustion. The entire device has potential for optimization to improve the energy efficiency of rural cooking systems.

Keywords

Rotary Oven, Organic Charcoal, Energy Efficiency, Combustion

1. Introduction

The cooking of food is an essential activity in all households, and the oven is a central element in this process. There are different types of ovens, powered by gas, electricity, solar radiation, wood, or charcoal. In developing countries, biomass remains the most widely used energy source for cooking [1]-[5]. Globally, more than 2.7 billion people use biomass or animal waste to prepare meals [4].

In Burkina Faso, approximately 85% of domestic energy comes from biomass [6]. In this context, excessive logging is a major threat, particularly in rural areas, but also in urban centers [7]. This pressure on forest resources contributes to deforestation, exacerbated by the lack of sustainable alternatives for cooking.

In meat processing activities, grilling dominates with an estimated share of 74% [4]. However, this activity generally uses artisanal ovens or grills, often designed without appropriate technical knowledge [4] [8] [9]. This not only leads to significant energy losses, but also to health risks related to the exposure of food to dust and unsuitable materials.

The traditional ovens used for grilling in Burkina Faso are mostly rudimentary, energy-intensive, poorly insulated, and leave food exposed to the open air [4]. This equipment has low thermal efficiency and contributes significantly to the consumption of wood or charcoal, with harmful consequences for the environment.

Energy waste is particularly significant among grillers who use charcoal. This raises a key issue: how can we design a more efficient oven that limits energy loss, is more hygienic and environmentally friendly, while still meeting local needs?

Given the environmental emergency and the limitations of current artisanal ovens, it is essential to develop more efficient cooking solutions. The introduction of organic charcoal, produced from organic residues, offers a sustainable alternative to traditional charcoal.

The project presented in this study aims to combine thermal performance, reduced energy losses, and the use of renewable energy sources.

The overall objective of this study is to test a rotary oven that uses organic charcoal as its main heat source, has an energy storage system, and uses solar power to power the oven's rotation system.

The specific objectives are:

- to experimentally measure the thermal properties of the rotary kiln;
- to evaluate the temperatures of the kiln's internal walls for the different fuels used and for different masses;
- to determine the temperatures of the kiln's external walls for the different fuels used and for different masses;
- to identify the temperatures in the combustion chamber.

The approach adopted includes the design of the furnace (choice of materials, sizing), the construction of a prototype, an experimental phase to evaluate its thermal and energy performance, and an analysis of the results to identify the gains compared to traditional models.

2. Materials and Methods

2.1. Methodology of the Study

In this study of the rotary kiln, a methodical approach was adopted in order to organize the entire project. It covers the various stages, from the sizing and design of the kiln to the interpretation of the results.

The precise description of the device, as well as the choice of materials and measuring instruments, enable a study of thermal and energy performance. These methodological foundations are essential for understanding the behavior of the kiln during tests with or without a storage system, paving the way for future improvements for cooking operations efficient and sustainable firing.

This approach is summarized and illustrated in Figure 1.

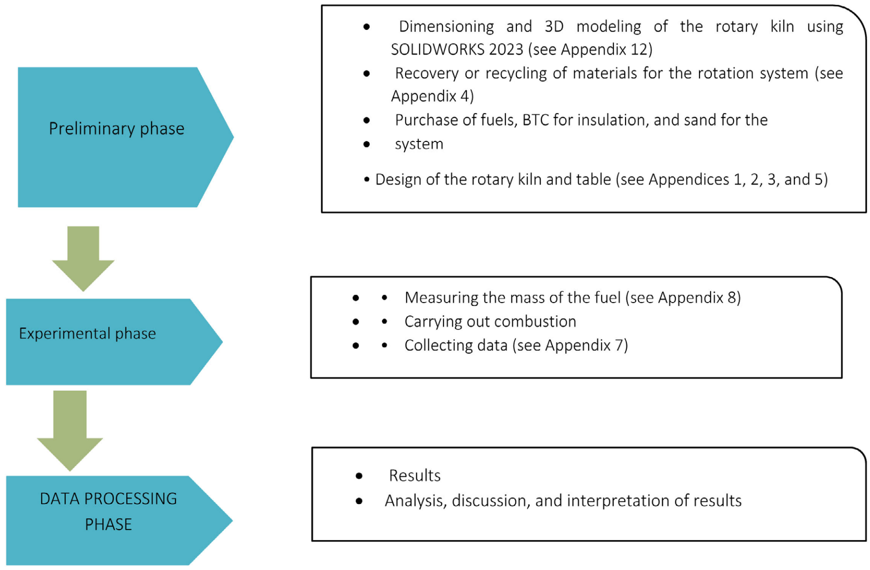


Figure 1. Method of the study.

2.2. Materials Used

The materials used depend on the parameters we want to measure. The parameters measured include:

- Fuel mass before and after combustion
- External furnace temperatures
- Internal furnace temperatures

A set of experimental equipment was used to carry out the experimental study:

- An SBS-LW-10000A precision balance with a measurement uncertainty of ±0.1 g, which was used to weigh the final masses of charcoal and ash at the end of the experiments. Figure 2 shows the SBS-LW-10000A scale.
- A CAMRY scale with an accuracy of ±50 g, used to measure fuels before combustion. This scale is also used to measure the mass of sand in the storage system. It has a mass range of 1 kg to 150 kg (see Figure 3).
- A FLUKE Ti480 PRO thermal camera with an accuracy of ±1.5˚C is used to visualize the heat distribution on the outer walls of the furnace. It is shown in Figure 4.

Class 1 K-type thermocouples with a temperature range of −40˚C to 1200˚C and an accuracy of ±1.5˚C were placed on the various components of the rotary kiln. The thermocouples used were connected to a Keithley DAQ6510 data logger with 24 connection terminals and an accuracy of ±0.08˚C. The assembly is used to measure the internal and external temperatures of the rotary furnace. Figure 5 shows the data logger and thermocouples assembly.

Figure 2. Balance model SBS-LW-10000A.

Figure 3. Balance CAMERY.

Figure 4. Thermal camera FLUKE Ti480 PRO.

Figure 5. Data Logger Keithley DAQ6510.

In Table 1 below, we have summarized the technical characteristics of the devices used:

Table 1. Summary of the characteristics of the devices used during the experiment.

Measured parameters	Devices	Characteristics	Measurement mode
Fuel mass Sand mass	Balance CAMRY	Max = 150 kg; Min = 1 kg; ME = ±50 g	Power up the device; place the weights to be measured on the device.
Mass of remaining fuel Mass of ashes	Balance SBS-LW-10000A	Max = 10 kg; Min = 0.5 g; ME = ±0.1 g	
Internal temperatures External temperatures	Data logger &	Précision ± 0.08˚C	Place the thermocouples in contact with the surfaces to be measured and record the data using the data logger.
	Thermocouples	Type K; Min = −40˚C; Max = 1200˚C	
Heat flow	Thermal Camera	Type Ti480 PRO; précision ±1.5˚C	Infrared capture of the surface to be observed.

2.3. Experimental Protocol

The protocol for this study aims to characterize the thermal and energy performance of the rotary kiln. To this end, we used two types of fuel: charcoal and organic charcoal available on the market. The tests will be carried without a thermal storage system, with combustion according to fuel type.

In this phase, we first undertook a number of steps before moving on to combustion. These actions included:

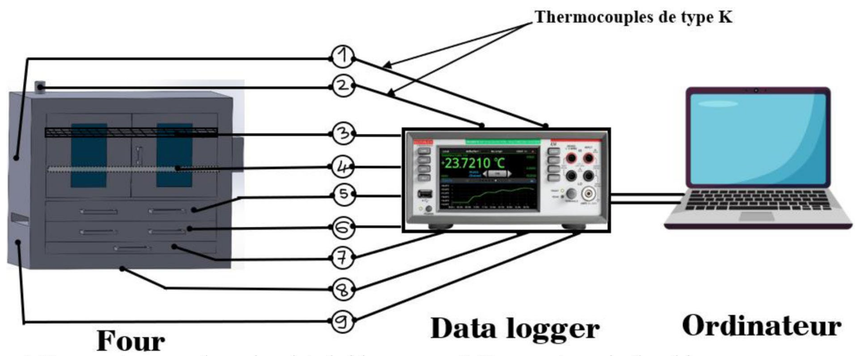
- Installing K-type thermocouples in nine (09) different locations, including five (05) placed inside the kiln, notably at the ash box, the vacuum storage system, the fuel box, the rotation bar, and the grate; Four (04) other thermocouples were placed respectively below the furnace, on the insulated left side, on the uninsulated left side (since both sides and the rear have the same configurations), and finally at the chimney. These thermocouples were placed in these different locations to measure the different temperatures over time.

- Weigh the fuels (charcoal and organic charcoal) of different masses, namely 1 kg, 2 kg, and 3 kg, before proceeding to combustion for each weighed fuel mass.

We then moved on to the combustion tests. We used the same test procedure for both charcoal and organic charcoal.

During combustion, the thermocouples connected to the data logger measure the temperatures at the nine (09) locations at five (05) minute intervals. Infrared images of the furnace taken with a thermal camera also allowed us to monitor the temperature distribution on the outer walls of the furnaces. The experiment was conducted over a long period of eight hours, which included combustion and cooling times. At the end of each experiment, the fuel was weighed to determine the amount of fuel burned.

Combustion is carried out without interruption for each type of fuel and according to mass. The different oven temperatures are measured over a long period of at least eight (08) hours to observe the behavior of the storage system at five (05) minute intervals. Our experimental setup is illustrated in Figure 6.



1-Temperatures on the uninsulated side
2-Temperatures in the chimney
3-Temperatures on the grate
4-Temperatures on the rotating bar
5-Temperatures in the fuel box
6-Temperatures in the storage system
7-Temperatures in the ash box
8-Temperatures below the furnace
9-Temperatures of the insulated side surface

Figure 6. Experimental setup diagram.

2.4. Comparative Properties of the Fuels Used

i) Characteristics of charcoal and organic charcoal

When evaluating the results of tests conducted using the furnace, it is important to first understand the properties of the fuels used. The characteristics of the fuels used are presented in Table 2.

Table 2. Characteristics of charcoal and organic charcoal.

Characteristics	Traditional Charcoal	organic charcoal (made from stalks and binders)
Origin	Origin Solid wood (often from forests)	Agricultural waste (stems, husks, etc.)
Process	Slow pyrolysis (carbonization)	Carbonization + Grinding + Mixing + Briquetting
Heat Capacity	**Very high** (≈8000 kcal/kg)	**Good to Average (≈ 5000 - 7000 kcal/kg)**
Burning Time	Long	Shorter
Allumage	Relatively easy	May be more difficult (depending on the binder)
Smoke & Odor	Low smoke after ignition, characteristic odor	Variable smoke, may have a distinctive odor
Environmental Impact	**Negative (Deforestation, CO_2)**	**Positive (Waste recycling, carbon neutral)**
Price	Variable, often high due to the scarcity of wood	Generally more competitive
Ashes	Small quantity	Larger quantity (depending on residues and binders)

ii) Detailed Characteristics of Traditional Charcoal

1) Origin and Manufacture:

- Produced by pyrolysis (heating at high temperatures in the absence of oxygen) of solid wood (bark, trunks, branches).
- The type of wood (oak, beech, acacia, etc.) directly influences its quality and burning time.

2) Physical and Combustion Properties:

- High Energy Density: It has a very high calorific value, which means it releases a lot of heat per kilogram.
- Long and Stable Combustion: Ideal for long cooking times (grilling, slow barbecues). It forms stubborn embers that last a long time.
- Low Ash Content: High-quality pure charcoal produces little residue.
- Ignition: May take longer to light but provides intense, consistent heat once lit.

3) Environmental Impact:

- Negative: Its production is often associated with deforestation and forest degradation if the wood does not come from sustainably managed sources (e.g., FSC label).
- CO_2 emissions: It emits fossil carbon dioxide (from wood) which contributes to climate change.

iii) Detailed Characteristics of organic charcoal (made from stalks and binders)

This product is often referred to as green charcoal, densified biomass, or charcoal briquettes.

a) Origin and Manufacture:

- Raw Material: Uses agricultural waste: corn stalks, cotton stalks, rice husks, cashew or peanut shells, sawdust, etc.
- Process:

Carbonization: The residues are first carbonized at low temperature.

Grinding: The resulting charcoal is ground into a fine powder.

Mixing: The charcoal powder is mixed with a natural binder (cassava starch, corn flour, clay, molasses) and sometimes water.

Briquetting: The mixture is compressed under high pressure in a briquetting machine to give it its shape (usually balls or paving stones).

b) Physical and Combustion Properties:

- Correct Calorific Value: Although generally lower than that of pure charcoal, it offers a very good alternative. Its calorific value depends on the raw material and the binder used.
- Faster Combustion: Often burns faster than traditional charcoal.
- Ignition: May require a more powerful firelighter, especially if the briquettes are very dense.
- Smoke and Odor: The smoke may be different and give off an odor related to the binder or residue used (e.g., a slight sweet smell with a starch binder). It is generally less harmful than charcoal, which may contain chemicals if the wood has been treated.
- Ash Content: Produces more ash than traditional charcoal because binders and agricultural residues contain non-combustible minerals.

c) Environmental and Socioeconomic Impact (Major Advantages):

- Waste Recovery: An environmentally friendly solution for managing agricultural waste, which is often burned in the open air, causing pollution.
- Carbon Neutral: The CO_2 released during combustion was previously absorbed by plants during their growth. The carbon footprint is therefore much better.
- Reduced Deforestation: Reduces pressure on forests by offering an alternative to charcoal made from solid wood.
- Local Job Creation: The collection of residues and the production of green charcoal can create local economic circuits.

The choice between the two types of charcoal depends on the use and priorities:

- For pure performance and long cooking times (e.g., restaurants, large barbecues), traditional high-quality charcoal remains unbeatable.
- For regular, more environmentally friendly, and economical use, organic charcoal is an excellent alternative. It transforms a problem (agricultural waste) into a useful energy resource, with a positive environmental and social impact. Its quality continues to improve with innovations in manufacturing processes.

It is crucial to note that the quality of "organic charcoal" can vary greatly depending on the raw materials and the rigor of the manufacturing process. It is advisable to purchase it from reputable producers.

3. Results and Discussions

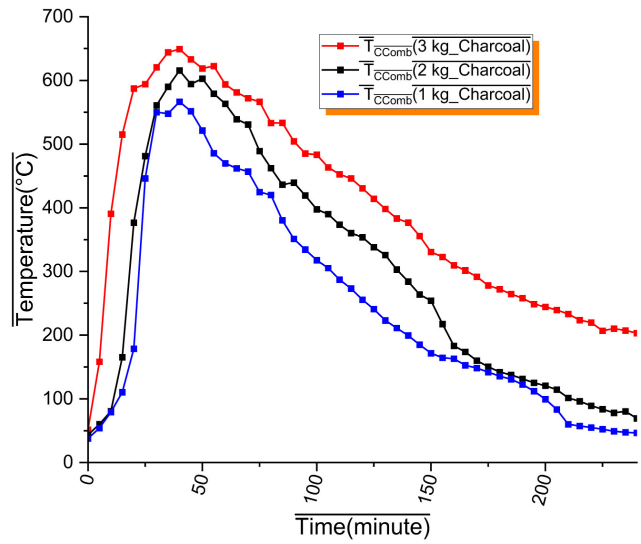
This section presents the results on the temporal evolution of temperatures in different parts of the rotary kiln, subdivided into two main sections: the internal parts and the external parts of the kiln. Each result obtained will be discussed.

This section analyzes the results of the two fuels used without storage.

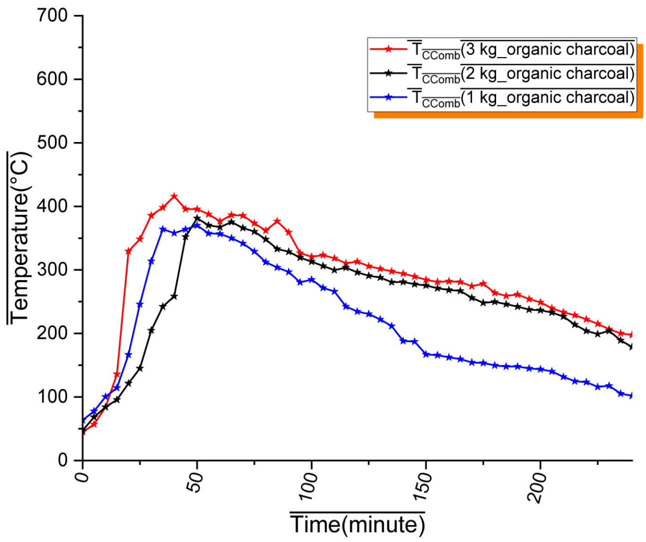
3.1. Evolution of Temperatures in Different Internal Parts of the Kiln

3.1.1. Evolution of Temperatures in the Fuel Box

Figure 7 shows the changes in experimental fuel box temperatures (TCComb) during combustion as a function of time, fuel type, and fuel mass.



(a) Charcoal



(b) organic charcoal

Figure 7. Temperature evolution in the fuel box as a function of the mass of fuel used. (a) Charcoal; (b) organic charcoal.

The results obtained indicate that the evolution of temperatures over time is broadly similar for both types of fuel. A rapid rise in temperature is observed from the start of combustion, demonstrating good calorific value and reactivity for both charcoal and organic charcoal. Furthermore, Figures 7(a)-(b) show that the maximum temperatures reached vary according to the mass of fuel used. A gradual increase in temperature is recorded with increasing masses: for 1 kg, 2 kg, and 3 kg of charcoal, the maximum temperatures reach 566˚C, 615˚C, and 649˚C, respectively; for organic charcoal, they are 370˚C, 381˚C, and 415˚C. These results confirm the direct effect of fuel mass on thermal intensity, in agreement with the work of Zhang *et al.* (2017) [10], who showed that the higher the fuel feed rate, the higher the temperature reached during combustion.

Figure 8 shows the thermal profiles obtained with 3 kg of each fuel, allowing for a clearer comparison of the thermal performance of charcoal and organic charcoal.

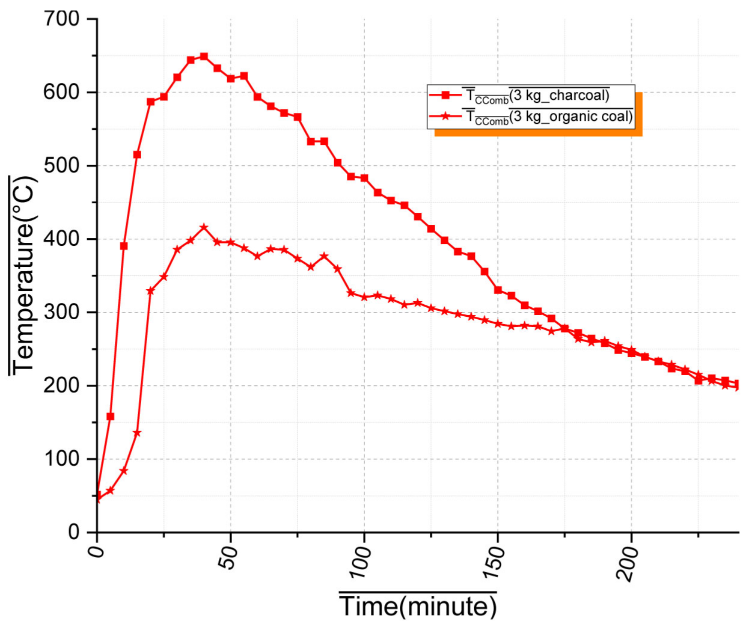


Figure 8. Temperature evolution in the fuel box for 3 kg of charcoal and organic charcoal used.

The results presented in Figure 8 show that, for a mass of 3 kg, charcoal reaches a maximum temperature of 649˚C, compared to 415˚C for organic charcoal, after approximately 40 minutes of combustion. This difference reflects the higher calorific value of charcoal, in line with data from Otieno *et al.* (2022) [11], who report a PCS of 25.7 MJ/kg for charcoal and 19.8 MJ/kg for biochar.

This difference in performance can be attributed to the composition of biochar, which is characterized by a higher content of volatile matter and ash, limiting the fraction that is actually combustible. Mierzwa-Hersztek *et al.* (2019) [12] demonstrated that net calorific value is strongly influenced by the chemical composition of fuels, particularly their ash content. Finally, unburned residues are observed at the end of the cycle for charcoal (**Figures 9-11**), with remaining masses of 179.9 g, 180.4 g, and 176.8 g for 1 kg, 2 kg, and 3 kg of initial fuel, respectively, while organic charcoal is completely consumed, as shown in **Figure 12**. This difference is illustrated in **Figures 12-13**, where the combustion of 3 kg of organic charcoal generates 1567.6 g of ash, compared to only 237.1 g for charcoal. In addition, the temperature curve for organic charcoal shows a slower decrease, reflecting a more gradual and evenly distributed combustion over time.

Figure 9. Remains of charcoal after combustion.

Figure 10. Remains of organic charcoal after combustion.

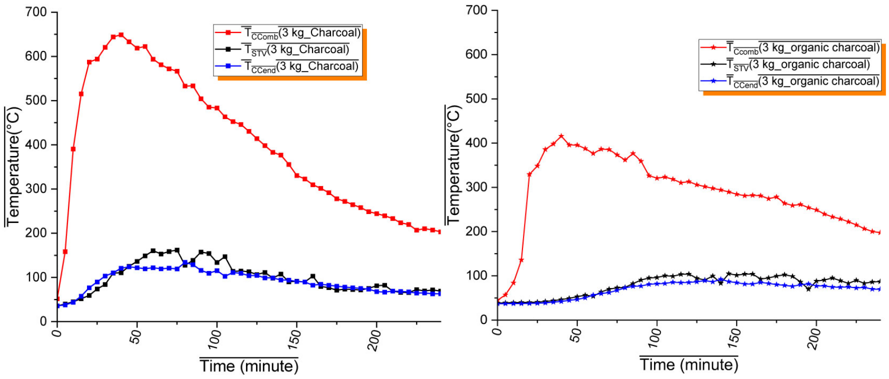
Figure 11. Remains of charcoal after combustion.

Figure 12. Quantity of ash after the consumption of 3 kg of charcoal.

Figure 13. Quantity of ash after the consumption of 3 kg of biochar.

3.1.2. Evolution of Temperatures in the Combustion Chamber

In the combustion chamber where the fuel box, the ash box and the storage system are housed, temperature differences are also observed with the same quantity of fuel. Figure 14 shows the evolution of the experimental temperatures in this chamber.



(a) Charcoal (b) organic charcoal

Figure 14. Evolution of combustion chamber temperature for 3 kg of fuel used; (a) Charcoal; (b) organic charcoal.

Figure 14 highlights significant temperature differences between the fuel box and the lower compartments, particularly the empty thermal storage system (TSTV) and the ash box (TCCend). The temperatures recorded in these two areas show little variation and remain much lower than those measured in the fuel box. This difference is mainly explained by the thermal configuration of the device: located below the combustion zone, these compartments receive little heat, which naturally tends to rise by convection [8] [13] [14]. Furthermore, the presence of the ventilation system between the fuel box and the storage system reinforces this effect by facilitating the rise of hot air towards the upper part of the enclosure.

3.1.3. Temperature Evolution in the Cooking Chamber

In the cooking chamber, particularly at the rotating bar and the grate, temperature differences are observed despite the same amount of fuel used. Figure 15 illustrates the temperature evolution measured at these points.

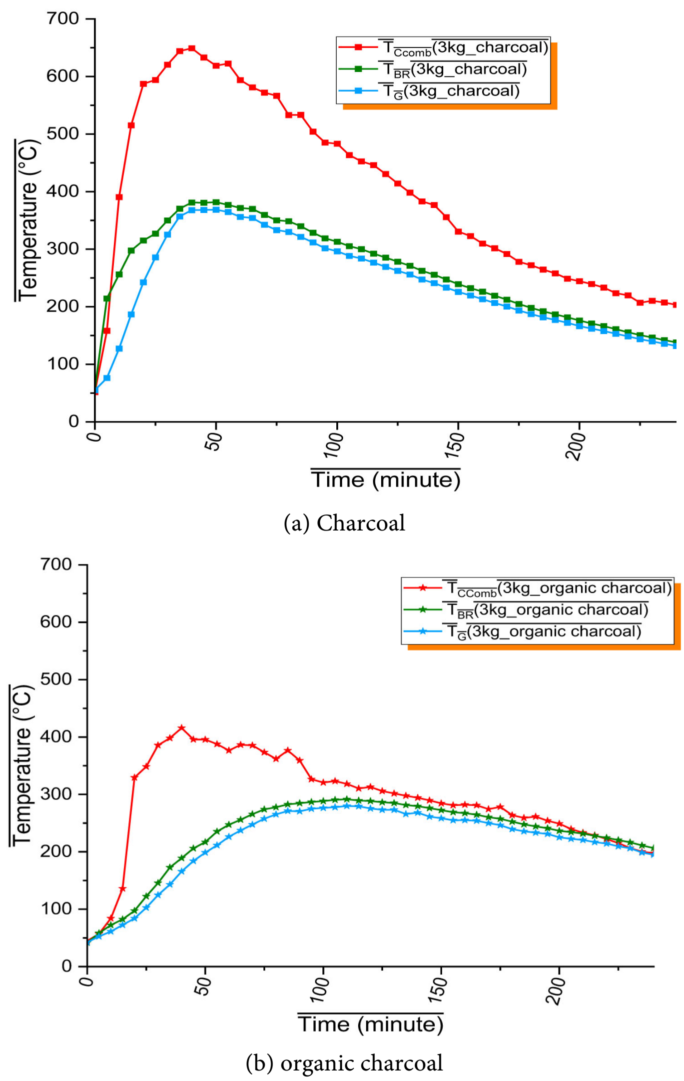


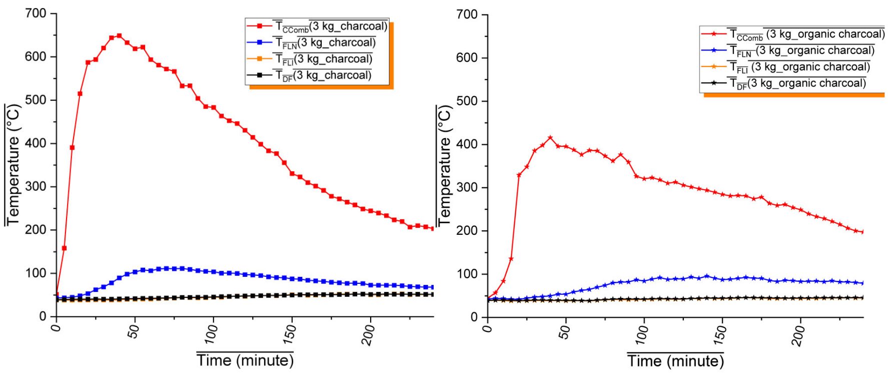
Figure 15. Evolution of the cooking chamber temperature for 3 kg of fuel used; (a) Charcoal; (b) organic charcoal.

Figure 15 shows the evolution of temperatures at the rotating bar (TBR) and the grate (TG) for the two fuels tested. With charcoal, the temperature increases rapidly during the first 40 minutes, reaching peaks of 381.06˚C (TBR) and 368.64˚C (TG). These valuescoincide with the maximum temperatures recorded in the fuel box, demonstrating efficient heat transmission in the cooking chamber, mainly ensured by radiation and convection [15]-[17]. Heat is therefore quickly available, but also decreases more markedly after the peak. In contrast, organic charcoal shows a slower and more gradual rise over nearly 100 minutes, with maximum temperatures of 291˚C (TBR) and 279.81˚C (TG). This gentler evolution reflects a less intense but more stable thermal propagation over time.

Thus, charcoal is more suitable for cooking requiring high initial heat, while organic charcoal is better suited to long and moderate cooking, offering better thermal stability. These trends corroborate the observations of Guo *et al.* (2020) [18], according to which organic charcoal briquettes, although less powerful at start-up, ensure prolonged and controlled heat emission, ideal for gentle cooking applications.

3.2. Evolution of the Temperatures of the External Walls of the Furnace

Figure 16 shows the experimental temperatures measured on the external parts of the solar rotary kiln.



(a) Charcoal (b) Organic charcoal

Figure 16. Temperature evolution of the external walls of the kiln for 3 kg of fuel used; (a) Charcoal; (b) organic charcoal.

Figure 16 illustrates a contrasting thermal distribution across the kiln zones: the temperature measured on the uninsulated left side face (TFLN) is significantly higher than those recorded on the insulated side face (TFLI) and below the kiln (TDF). This thermal distribution is observed regardless of the type of fuel used.

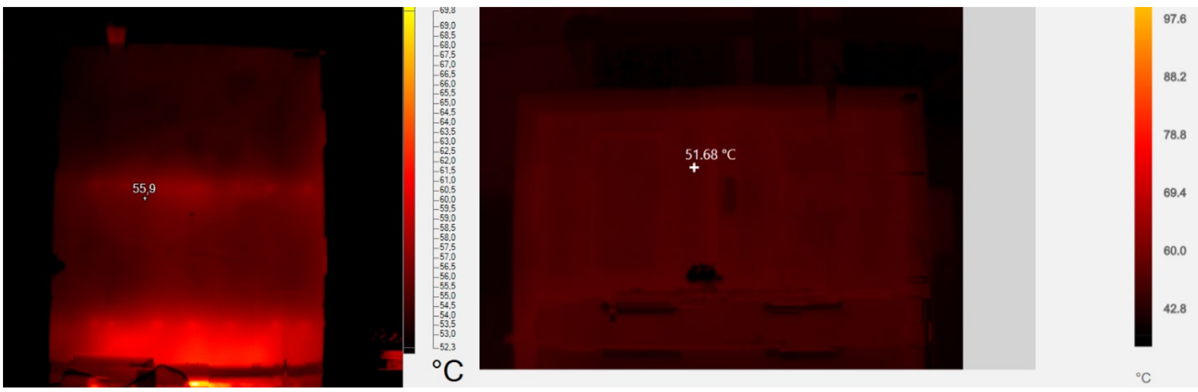
The relatively low (<50˚C) and almost constant temperatures observed in the insulated zones demonstrate the effectiveness of the Compressed Earth Bricks (CEB) integrated into the combustion chamber shell. This material limits heat losses, thus promoting a high temperature in the combustion zone. These results are consistent with those of Sawadogo G. (2020) [4], who showed that the use of CEB improves thermal efficiency by reducing energy losses.

On the other hand, although the uninsulated side reaches high temperatures (up to 111.34˚C with charcoal and 95.59˚C with organic charcoal), they remain lower than those measured in the cooking chamber (374.85˚C and 285.41˚C respectively). The wall, although uninsulated, includes a layer of air that slows down thermal conduction. These observations are consistent with those of Tarpilga *et al.* (2023) [19], who showed that air acts as an effective insulator, helping to limit heat losses between the combustion chamber (up to 600˚C) and the outer walls (100˚C to 120˚C).

Furthermore, these trends were observed by Abdoulaye Ouédraogo *et al.* in 2007 [14], who found temperatures below 250˚C for the oven walls.

3.3. Infrared Infographics

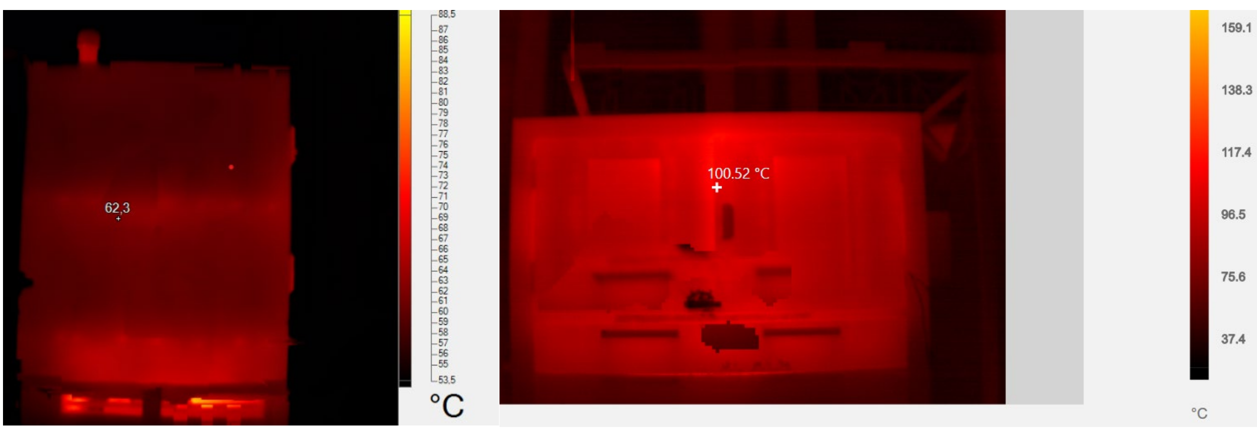
Infrared images of the left side and front surfaces were used to monitor the temperature distribution on the furnace's external walls. The following figures (Figures 17-21) show the infrared images at different times during furnace operation.



(a) Left side lateral face

(b) Front face

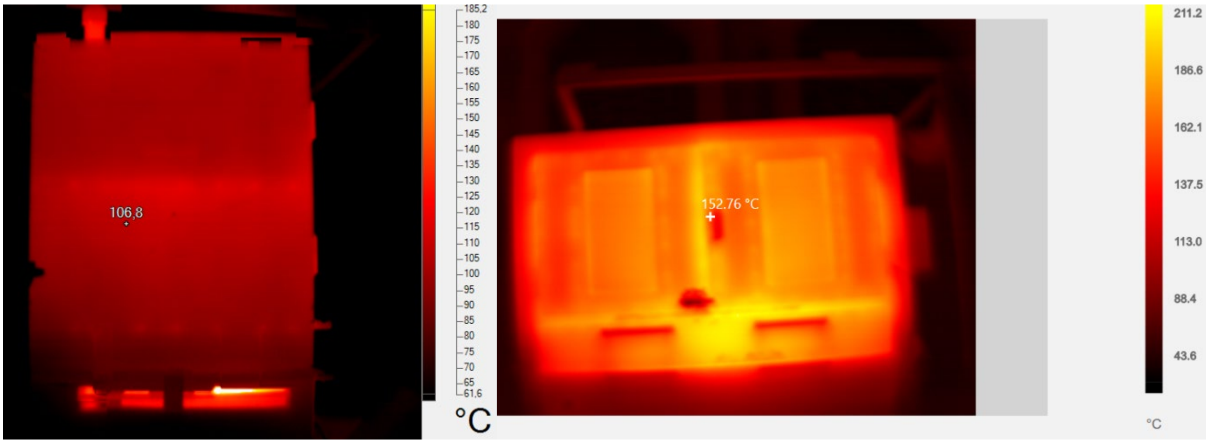
Figure 17. Start of experiment.



(a) Lateral face, left side

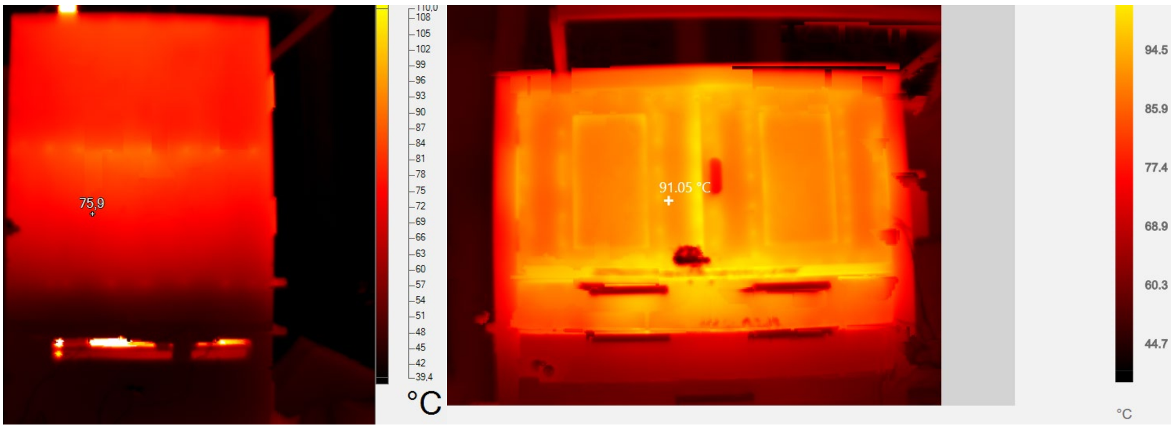
(b) Front face

Figure 18. 30 minutes after the start of the experiment.



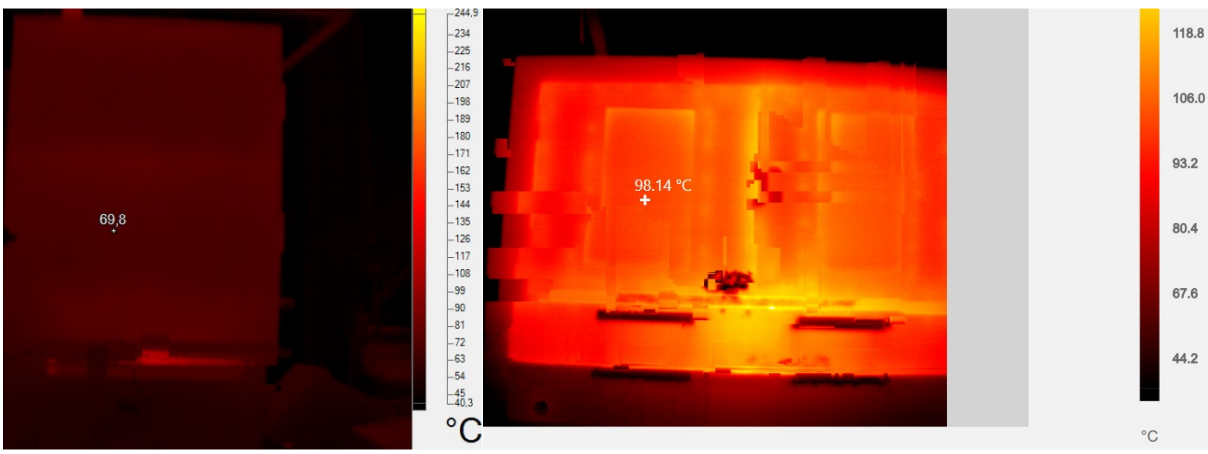
(a) Left side lateral face (b) Front face

Figure 19. 60 minutes after the start of the experiment.



(a) Left side lateral face (b) Front face

Figure 20. 90 minutes after the start of the experiment.



(a) Left side wall (b) Front wall

Figure 21. 100 minutes after the start of the experiment.

The thermal images obtained by the infrared camera made it possible to visualize the spatial distribution of the temperature field on the external walls of the furnace, through variations in thermal coloration. In all of **Figures 17-21**, the colored areas on the left side wall systematically appear less intense than those on the front wall of the furnace, indicating lower temperatures. This thermal difference can be explained by the difference in wall thickness: the side frame has a thickness of 9 cm, significantly greater than that of the front wall, which is less than 3 cm [20]. This greater thickness constitutes a more effective thermal barrier, limiting heat loss.

Furthermore, in the thermograms of the left side wall, a darker coloration is observed in the lower part, corresponding to the combustion chamber area [20]. This phenomenon is particularly visible in **Figure 20**. This low apparent thermal emission indicates better heat retention, attributable to the presence of compressed earth bricks (CEB) used as an insulating material in the combustion chamber [16]. These observations are consistent with the results of Sawadogo G. (2020) [4], who demonstrated the effectiveness of insulation in reducing heat losses in this critical area.

Regarding the front face of the kiln, the figures reveal a bright coloration in the upper part, corresponding to the fuel box (main heat source) and the cooking chamber. On the other hand, the lower part, composed of the thermal storage system and the ash box, presents a less intense coloration, reflecting lower temperatures. This vertical thermal gradient, clearly illustrated in **Figure 20** and **Figure 21**, suggests a predominant rise of heat, with a more marked heat transfer upwards than towards the base of the kiln.

4. Advantages, Disadvantages and Limits of the Study

In addition, if high temperature and cooking speed are the desired parameters, charcoal is the best choice. However, if you are interested in a more environmentally friendly and potentially more economical fuel, biochar is an excellent option, especially if you are willing to adapt to a slightly lower cooking temperature and higher consumption.

The following table shows some comparative advantages and disadvantages of the two types of fuel are presented in **Table 3**.

Charcoal is best suited for most types of cooking, as it reaches high temperatures, burns quickly, and is ideal for fast, direct grilling. Biocharcoal, although more environmentally friendly, is intended more for soil improvement, and even though biocharcoal briquettes are available for barbecuing, they have a lower calorific value and higher consumption, requiring an adjustment in cooking practices.

The limitations of this study could be the failure to take into account several fuels in order to evaluate and compare their energy performance. In addition, this study should take into account the life cycle analysis and environmental impact of fuels. Finally, socio-economic and technical-economic studies would also be interesting for wider use within the community.

Table 3. Comparative advantages and disadvantages of the two types of fuel.

Types of fuels	Advantages	Disadvantages
charcoal	○ Reaches very high temperatures, perfect for searing meat. ○ odeal for quick grilling and direct cooking. ○ Burns quickly, allowing for easy control of cooking. ○ Less expensive than other fuels.	○ Less aroma than wood. • May generate dust. • Potential pollutants: Contains pollutants (polycyclic aromatic hydrocarbons (PAHs), produced during combustion) that may be carcinogenic and migrate into food. • Environmental impact: Its production may be less sustainable. • Ignition additives: Some poor-quality charcoal may require chemical additives for ignition, which affects the purity of cooking.
organic charcoal	○ Environmentally friendly: produced from agricultural waste, which reduces bush fires and preserves the forest. ○ Economical: cheaper than charcoal. ○ Less smoke and ash than traditional charcoal.	○ Lower combustion performance: It often burns slower and less intensely than traditional charcoal, which may not be suitable for all types of grilling that require high heat. ○ High initial cost: Biochar production can be more expensive in terms of equipment and energy, which may be reflected in the purchase price. ○ Lower calorific value than charcoal, with higher consumption. ○ May take longer to heat up. ○ Some varieties may have a different taste. ○ Requires finding the right type of biochar for cooking.

5. Conclusions

The experimental approach implemented made it possible to closely monitor temperature changes in the different zones of the kiln, testing several thermal configurations and fuel types.

The results highlighted the significant impact of thermal insulation and heat storage on the overall performance of the system. The results obtained made it possible to characterize the thermal behavior of the rotary kiln based on the fuel type, insulation, and storage system. Combustion chamber insulation using BOC demonstrated real effectiveness, limiting heat loss and promoting the achievement of high temperatures, up to 649.03˚C with only 3 kg of charcoal. This performance confirms previous work on the benefits of local insulating materials. Furthermore, the use of organic charcoal, although generating more moderate temperatures, allows for a gentler rise and prolonged maintenance, which is advantageous for certain applications. Furthermore, the two fuels have distinct thermal profiles: charcoal is distinguished by its rapid heating, while organic charcoal ensures more regular and prolonged combustion.

Authors' Contributions

DABILGOU Téré: Investigation, conceptu-alization, methodology, formal analysis, writing original draft. **TUBREOUMYA Guy Christian**: Scientific and methodo-logical guidance, Overall supervision of the work, Final vali-dation of the manuscript, Ongoing scientific supervision. **NEBIE Jacques**: Technical and scientific support, Targeted methodological advice, Contribution to analysis, Critical review of the manuscript. **DAHO Tizane, NYONGESA Francis Wanjala, SANOGO Oumar**: Team leader, technical and scientific support, Targeted methodological advice. **NOMBRE Yssouf**: help with setting up the experimental equipment and carrying out the tests. **TIENDREBEOGO Eloi Salmwendé**: Language and editorial assis-tance, Translation and proofreading support, Spelling and grammar correction. **DISSA Alfa Oumar**: laboratory director, make the laboratory's experimental equipment available.

Data Availability Statement

The data supporting the outcome of this research work has been reported in this manuscript.

AI Declaration

Concerning AI use in this manuscript, it was confined to language and grammar polishing. These technologies were not employed to shape the paper's structure, draw its conclusions, or establish its core intellectual direction.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Zoma, F. (2025) Optimisation des filières valorisant la biomasse lignocellulosique à des fins énergétiques en considérant différentes sources au Burkina Faso. Institut International d'Ingénerie de l'Eau et de l'Environnement.

[2] Magrini, A., Lazzari, S., Marenco, L. and Guazzi, G. (2017) A Procedure to Evaluate the Most Suitable Integrated Solutions for Increasing Energy Performance of the Building's Envelope, Avoiding Moisture Problems. *International Journal of Heat and Technology*, **35**, 689-699. https://doi.org/10.18280/ijht.350401

[3] Belem, A., Ouédraogo-Koné, S., Lankoandé, Y., Koulibaly, B., Sakandé, F., Bamogo, A., *et al.* (2024) Evaluation du potentiel fourrager des residus de recolte dans les exploitations cotonnieres a l'ouest du Burkina Faso. *African Journal of Food, Agriculture, Nutrition and Development*, **24**, 26531-26553. https://doi.org/10.18697/ajfand.131.24365

[4] Sawadogo, G.L. (2020) Modélisation des phénomènes de transfert de chaleur dans un four isolé avec des matériaux locaux: Application à l'optimisation énergétique des équipements de grillade de la viande. Thèse, Université Joseh KI-ZERBO.

[5] Dabat, M.-H., Blin, J. and Rivier, M. (2010) Affronter le defi energetique et alimentaire au Burkina Faso. ISDA.

[6] Dao, A., Coulibaly/Lingani, P. and Lamien, N. (2020) Préférences des femmes et pouvoir calorifique d'essences de bois d'énergie utilisées pour la cuisson de la bière locale et du beurre de karité au Burkina Faso. *Journal of Applied Biosciences*, **156**, 16139-16146. https://doi.org/10.35759/jabs.156.7

[7] B. Projet Bagré Pôle (2019) Demande en bois-énergie et rentabilité économique de la

préparation de la bière locale et du beurre de karité au Burkina Faso.

[8] Ménard, Y., Patisson, F., Sessiecq, Ph. and Ablitzer, D. (2001) Etude experimentale de la combustion d'ordures menageres et modelisation d'un four d'incineration. 8*e Congrès francophone de génie des proceeds*, Vol. 15, 385-392.

[9] Balli, L. and Touzani, A. (2014) Etude experimentale et modelisation des echanges thermiques dans un four a poterie. *Termotehnica*, No. 1, 53-58.

Balli L, Touzani A. Étude expérimentale et modélisation des échanges thermiques dans un four à poterie.

[10] Zhang, Q., *et al.* (2017) Experimental Study on Combustion Characteristic of Biomass Micron Fuel. In: *ASME Power Conference*, American Society of Mechanical Engineers, V001T04A016.

[11] Otieno, A.O., Home, P.G., Raude, J.M., Murunga, S.I. and Gachanja, A. (2022) Heating and Emission Characteristics from Combustion of Charcoal and Co-Combustion of Charcoal with Faecal Char-Sawdust Char Briquettes in a Ceramic Cook Stove. *Heliyon*, **8**, e10272. https://doi.org/10.1016/j.heliyon.2022.e10272

[12] Mierzwa-Hersztek, M., Gondek, K., Jewiarz, M. and Dziedzic, K. (2019) Assessment of Energy Parameters of Biomass and Biochars, Leachability of Heavy Metals and Phytotoxicity of Their Ashes. *Journal of Material Cycles and Waste Management*, **21**, 786-800. https://doi.org/10.1007/s10163-019-00832-6

[13] Suresh, R., Singh, V.K., Malik, J.K., Datta, A. and Pal, R.C. (2016) Evaluation of the Performance of Improved Biomass Cooking Stoves with Different Solid Biomass Fuel Types. *Biomass and Bioenergy*, **95**, 27-34. https://doi.org/10.1016/j.biombioe.2016.08.002

[14] Ouédraogo, A., Kiéno, F.P., Daho, T., Bathiébo, J.D. and Ouédraogo, R. (2007) Bilan Thermique Quasi-Statique D'un Four Artisanal en Argile. *Journal de la Société Ouest-Africaine de Chimie*, No. 24, 65-72.

[15] Neema Ciza, A., Vwima Ngezirabona, S., Ngandu, M. and Casinga Mubasi, C. (2019) Etude comparative de performance d'utilisation des foyers améliorés et leurs effets sur les niveaux de vie des ménages de Bukavu. *VertigO*, **19**. https://doi.org/10.4000/vertigo.24496

[16] Piton, M. (2015) Récupération de la chaleur fatale: Application aux fours rotatifs. École des Mines de Nantes, FRANCE.

[17] Filipponi, M., Rossi, F., Presciutti, A., De Ciantis, S., Castellani, B. and Carpinelli, A. (2016) Thermal Analysis of an Industrial Furnace. *Energies*, **9**, Article No. 833.

[18] Guo, Z., Wu, J., Zhang, Y., Wang, F., Guo, Y., Chen, K., *et al.* (2020) Characteristics of Biomass Charcoal Briquettes and Pollutant Emission Reduction for Sulfur and Nitrogen during Combustion. *Fuel*, **272**, Article ID: 117632. https://doi.org/10.1016/j.fuel.2020.117632

[19] Tarpilga, M.D.C., Ouedraogo, F., Woro, G.Y., Da, F., Ouedraogo, S. and Naon, B. (2023) Temporal Temperature Evolution during the Pyrolysis of Cotton Stalks, Corn Stalk and Rice Husk Using Multifunction Family Oven for the Biochar Production. *International Journal of Plant & Soil Science*, **35**, 336-347. https://doi.org/10.9734/ijpss/2023/v35i193560

[20] Konkobo, I. (2024) Études numérique et expérimentale d'un cuiseur hybride solaire/biomasse en contexte climatique sahélien. Université Joseph KI-ZERBO.

Abbreviation

Nomenclature	Signification	Unit
Cp	specific heat	$J\cdot kg^{-1}\cdot K^{-1}$
E	Energy	$J/S^{-1/2}\cdot m^{-2}\cdot K^{-1}$
h	Convective heat transfer coefficient	$W\cdot m^{-2}\cdot {}^{\circ}C^{-1}$
L_S	latent heat	$J\cdot kg^{-1}$
m	mass	kg
ME	Marge d'erreur	-
PCI	Lower Heating Value	$MJ\cdot kg^{-1}$
PCS	Higher Heating Value	$MJ\cdot kg^{-1}$
Q	Heat	KJ
R		$m\cdot K\cdot W^{-1}$
S	Surface/area	m^2
T	Temperature	˚C
T_∞	temperature of the environment surrounding the surface	˚C
T_{BR}	Rotating bar temperatures	˚C
T_C	Chimney temperatures	˚C
T_{CCend}	Ash box temperatures	˚C
T_{CComb}	Fuel box temperatures	˚C
T_{FLI}	Temperatures of the insulated side panel	˚C
T_{FLN}	Temperatures of the uninsulated side	˚C
T_G	Grid temperatures	˚C
T_p	Surface Temperature	˚C
T_{SF}	temperatures under the oven	˚C
T_{STP}	Temperatures of the sand-filled storage system	˚C
T_{STV}	Temperatures of the empty storage system	˚C
α		$mm^2\cdot s^{-1}$
ΔT	Temperature variation	
ε_p	Surface emission factor	-
λ	Thermal conductivity of the material	$W\cdot m^{-1}\cdot {}^{\circ}C^{-1}$
ρ	Density	$Kg\cdot m^{-3}$
σ	Stefan-Boltzmann constant	$W\ m^{-2}\ K^{-4}$
φ	Heat flow	W