Research Paper

International Journal of Research and Review
[Indexed, Peer-Reviewed Journal]
Volume 12; Issue: 4; April 2025
Website: www.ijrrjournal.com
E-ISSN: 2349-9788; P-ISSN: 2454-2237

Construction and Operational Testing of an Improved and Intelligent Traditional Oven

ADIHOU Coffi Wilfrid[1,2], KPLÉ Melhyas[3], AZA-GNANDJI Maurel[3], AMOUZOUN Yémalin Emmanuel[1], KOUTCHIKA Bignon Arnold[1], HOUNGAN Comlan Aristide[1]

[1]Laboratory of Engineering Sciences and Applied Mathematics (LSIMA) of the National University of Science, Technology, Engineering and Mathematics, BP 486 Abomey, Sogbo-Aliho, Bénin
[2]Laboratory of Applied Energetics and Mechanics (LEMA), 01 BP 2009 Abomey-Calavi, Bénin
[3]Rural Engineering Laboratory, National University of Agriculture, BP 43 Kétou, Bénin

Corresponding Author: ADIHOU Coffi Wilfrid

DOI: https://doi.org/10.52403/ijrr.20250417

ABSTRACT

This work focuses on traditional ovens used in several regions, notably in Benin, for the production of wheat flour pancakes, soya croquettes and mini-croquettes, sweet breads and cakes. To provide some solutions to the many difficulties encountered by users of these ovens, this document proposes a simple and improved traditional oven integrating an automated system for controlling and regulating the internal temperature, cooking management and ventilation for fuel combustion. The objective of the work is to preserve the environment and the health of users of these traditional ovens. Specifically, it is firstly a question of replacing the wood used as fuel with palm nut shells and secondly of eliminating accidents, smoke inhalation and losses experienced by users of the oven. The oven is easily reproducible because it is built with locally available materials and non-complex techniques. Tests on the improved traditional oven carried out show that in four minutes of heating, the internal temperature rises to 300 °C. After stopping the ventilation system, thus stopping combustion, the temperature slowly decreases and drops to 100°C after a period of 1 hour 05 minutes.

Keywords: Words: Oven, energy efficiency, deforestation, combustion, temperature regulation.

INTRODUCTION

Today, energy issues have taken a central place in our concerns. Faced with the challenge of preserving our environment while meeting our daily needs, traditional technologies have also been questioned. The need to develop other energy sources and improve cooking methods has therefore arisen. Indeed, cooking energy needs in developing countries are mostly covered by the combustion of wood, coal, agricultural residues, gas and electricity. In Benin and almost everywhere in the world, traditional ovens are widely used for different productions requiring heat. These traditional ovens are used for high and low temperature applications. Low temperature ovens are used for cooking foods such as bread, cakes, appetizers, croquettes and mini-croquettes of flour. In Benin and especially in the Southern region, breads, rolls, croquettes and mini-croquettes of wheat or soy flour are produced in large quantities. The ovens used for this are mainly traditional ovens because of the financial, technical or environmental constraints related to the use of modern ovens. But these traditional ovens are built locally by people who do not have great knowledge of the behavior of the thermophysical parameters that influence the efficiency of the oven. Wherever these ovens are used, problems are noted, namely significant energy losses, direct exposure of the user to the heat flow, prolonged and uncertain cooking times, lack of control of the internal temperature, repeated burns and heating of the immediate environment of the oven, to name a few. As in traditional ovens used in developing countries, these ovens mainly use firewood and also charcoal in large quantities [1]; which contributes to deforestation.

Regarding the energy consumption of ovens, F. A. Manhiça et al [1] conducted a study on the Consumption of wood and analysis of the bread baking process in wood-fired bakery ovens. In these ovens, up to 0.90 kg of wood must be used for 1 kg of cooked wheat flour. In this same study, it was noted that the temperature in the oven and its distribution influence the quality of the bread prepared. Studies, recently carried out on different types of ovens, allow the analysis of the changes in some operating parameters. The study of the thermal performance of a traditional metal oven by S. W. Igo et al [2] allowed the analysis of the changes in the temperatures of the outer wall, the combustion chamber and the water introduced into the oven. For this type of metal oven, the temperature of the outer wall is high and generates a large energy loss, requiring the use of a large quantity of wood. In 2021, C.F. K. Hatou et al proposed in their work a mathematical model of the thermal behavior of solid fuel bread ovens commonly used in developing countries. These studies revealed among other things that the optimal surface area and filling factor of the baking chamber are 3m2 and 0.67 respectively [3]. In Italy, a semi-empirical model of a traditional wood-fired pizza oven was developed in order to control and predict the evolution of the various operating parameters. This study showed that approximately 46% and 26% of the energy from wood combustion is lost in the smoke and through the walls respectively [4]. To reduce wood consumption in wood-fired ovens, gas can be used as a second fuel, thus making the oven hybrid. The physical properties of wood-fired bread correspond to those of the gas oven [5,6,7]. One of the problems for this system is the cost of gas and the other is related to the preservation of endogenous values. Solar energy can also be used as cooking energy in a bread oven but this requires a long cooking time ranging from 2h30 to 3h30 depending on the materials used for a radiation of 850 W/m2 [7].

In relation to the control of technical operating parameters, A. A. Begum et al proposed in Bangladesh an improved traditional oven that can produce the same quality of bread with a cooking time reduced by up to 25% compared to traditional ovens built by workers [8]. The outer wall of the proposed oven was made of stainless-steel sheet and the inner wall of aluminium sheet. The insulation is made of silicone rubber and asbestos sheet. In the same vein, MS Sanusi et al, seeing the high cooking time at the level of ovens locally built by small and medium-sized bakeries in Nigeria, proposed a mobile rotary oven made of sheet metal in which the grids are turned over. This facilitates uniform temperature distribution and not only reduces the cooking time but also produces quality bread [9]. This study also focuses on improving the performance of traditional ovens used in the South Benin region by proposing an improved traditional oven model adapted to local constraints for the production of breads and rolls, croquettes and mini soy croquettes. This oven model uses locally available materials for the exterior walls. Palm nut shells being waste from the palm oil production process in the region, they are used as fuel for the oven. A unit for controlling the temperature of the cooking chamber and the cooking time is produced and installed on the oven.

MATERIALS & METHODS

The work methodology is summarized in four stages, namely: interview with the stakeholders, 3D design, construction of the oven and experimental tests followed by analyses and interpretations.

Interview with the stakeholders: To carry out this work, we conducted discussion sessions with users of traditional ovens in the Mono department. This stage made it possible to identify the shortcomings and difficulties related to the use of these ovens;

3D design: a model was designed with Solid Works software. This model, presented in Figure 1, offers solutions to some of the limitations and difficulties listed during the interview with the stakeholders. The external dimensions of the oven produced are 1200 mm high, 700 mm wide and 800 mm long;

Construction of the oven: this important stage consists first of choosing the different materials and equipment (Tables 1 and 2). The bricks were then manufactured as well as the various components of the oven. The bricks used for the exterior walls are 70 mm thick. After this, the outer walls of the oven are built and the different elements are integrated into the oven. This step led to the manufacture of the oven shown in Figure 2. The fuel used is carbonized palm nut shell.

Table 1: Study material

Elements	Functions
Ventilator	Ventilate the inside of the oven in order to burn the carbonized palm nut shells
Stoves	Contains the fuel that will be burned inside the oven
Chimney	Evacuates the exhaust gases
Wooden door	Enters and removes the food
Drawer	Emptys the ashes
LED	Emits light signals
Battery	Powers the fan and the control
PV solar module	Recharges the battery
Accessories (grill, drip pan, spit) in stainless steel	Places the food to be cooked
Arduino UNO	Runs the programs, reads the thermocouple data and sends the command to the fan
Type K thermocouple with Max 6675 module	Used to retrieve the temperature values and sends analog values, which will be conditioned and converted into digital value by the Max6675 module
4×3 numeric keypad	Give instructions to the oven
20×4 LCD screen	Display instructions and data
Relay module	Control the fan to regulate the desired temperature
Buzzer	Emit sound signals

Table 2: Oven construction materials

Materials	Illustration	Use
Clay (from Agbangnizoun)		Make the briquettes and slips that will be used to assemble the oven
Iron bar (flat iron and round iron)		Reinforce the oven structure
Cement		Use when founding the oven

Sand		Mix with cement for the foundation
Water		Allow to to hydrate mixtures
Paint		Beautify the oven
Binding agents		Reinforce the use of clay to avoid cracks

Experimental tests: their objective is to assess the performance of the oven produced. To do this, the internal temperature of the oven is measured every 5 minutes. The measurements were carried out empty and with cake cooking. This temperature is measured using the K-type thermocouple and displayed on the control system screen.

RESULT AND DISCUSSION

Presentation of the oven produced

The oven produced is shown in Figure 1. It is composed of three parts, namely the oven itself, the ventilation system and the control system. The oven itself consists of the exterior walls, the door, the ash pan, the blower support, the combustion chamber, the grates and the chimney. The ventilation system consists of the blower, the battery and the photovoltaic solar panel. The control system is limited to the control box and the internal temperature sensors of the oven. The control system is also powered by the photovoltaic solar panel and the battery.

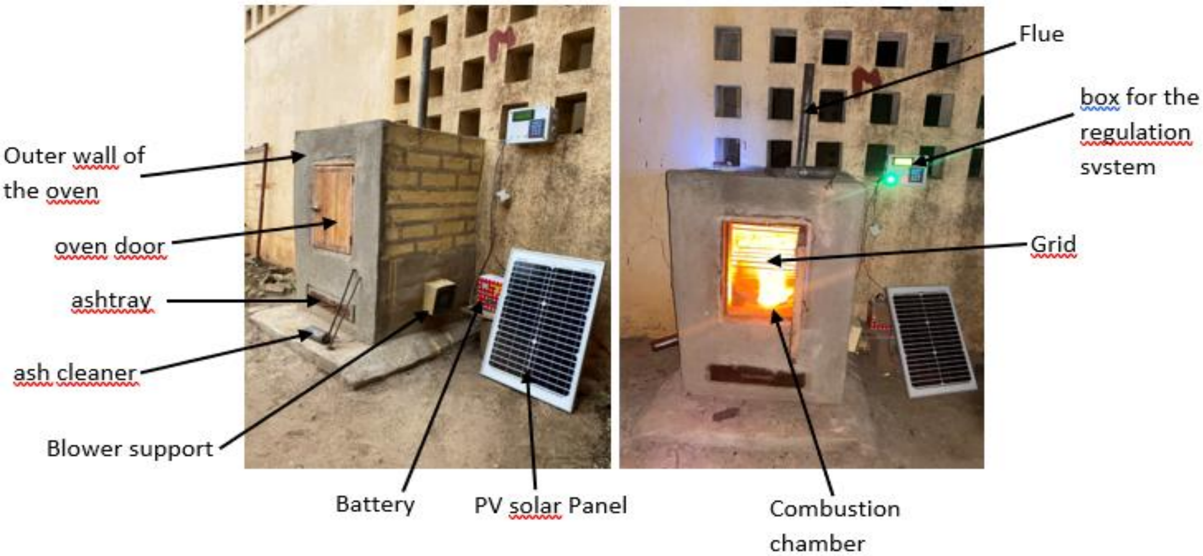

Figure 1: improved traditional oven made (left) – improved traditional oven made in heating mode and open (right).

Oven operation

After opening the oven door, the user enters his password to access the automatic system. We observe a first loading of carbonized palm nut shells into the hearth. The user is invited to make the fire in the fuel then he enters the desired cooking temperature after pressing the 0 key. But when the temperature entered by the user is lower than that existing in the oven an error message is displayed on the screen then he is asked to enter another temperature higher than the existing one or to wait for the oven to cool. When the temperature is correct, the drip pan, the grid or the spit containing the product to be cooked is inserted into the oven and he closes the oven door. The interior of the oven heats up to the entered temperature then light and sound signals are emitted. The user enters the appropriate cooking time and the food is brought to the regulated temperature during this time. Once the set temperature is reached, the ventilation system is cut off. In order to maintain the fire, the ventilation system is restarted every minute and operates for 5 seconds. If the temperature drops by 5°C, the ventilation system starts as well as the combustion of the fuel and remains so until the set temperature. Once the cooking time is over, the light and sound signals are still emitted; this indicates that we are already at the end of cooking. After turning off the oven, the user removes the food. If he wants to start another cooking at a higher temperature than the previous one, he presses the 0 key, but when he wants to do another cooking at the same temperature, he presses the 1 key, in the case where his cooking is completely finished, he carries out the maintenance operations after cooling the oven.

Operational tests

In order to follow the evolution of the internal temperature of the empty oven, we left one kilogram of carbonized palm nut shells burning in the hearth. The values of the internal temperatures measured as a function of time are presented in Figure 2.

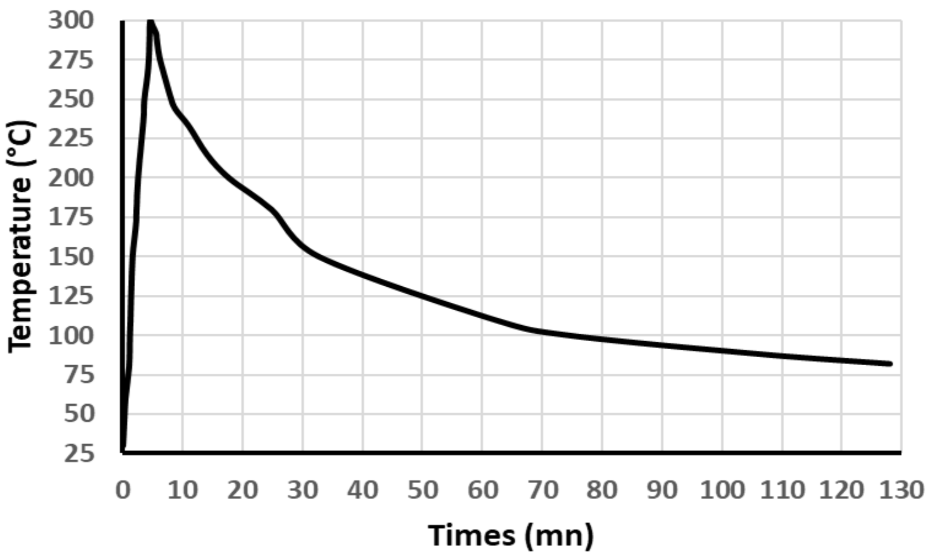

Figure 2: Evolution of the internal temperature of the empty oven as a function of time

From the analysis of these graphs, we see that the oven temperature increases considerably to reach a level of 300°C after approximately 4 minutes of heating. Then after stopping the ventilation system, this temperature begins to decrease gradually to 100°C after about 60 minutes. We therefore conclude that the oven system used accelerates its internal heating but slows down its internal cooling; which confirms the good thermal insulation of the oven.

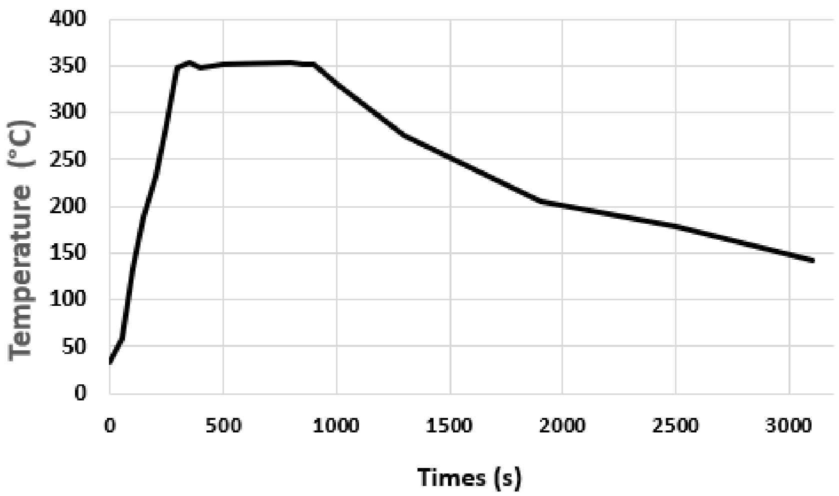

Figure 3: Evolution of the internal temperature of the oven during the baking of the cake as a function of time

From the analysis of this graph, we see that the oven temperature increases, considerably and abruptly, after about 5 minutes of heating to reach a peak of 350 ° C. Then after inserting the cake dough for cooking, the temperature remains almost constant after 10 minutes, the time to bake the cake. Once the cake is cooked, the ventilation system stops, this temperature begins to decrease gradually to about 150 ° C after 45 minutes. We therefore conclude that the oven system used accelerates its internal heating but slows down its internal cooling and then remains at the peak of the useful temperature to cook the food during the cooking time; which confirms the good internal regulation of the oven.

CONCLUSION

This document presents an improved traditional oven with an automated system. The physical model and the operational tests of the oven have also been demonstrated. This oven presents a certain simplicity in its construction with the exception of the automatic system which will be in the form of a kit to be delivered for a fixed sum. Manufacturers of traditional ovens will not experience difficulties in its construction. The use of these ovens has many advantages not only for the protection of the environment and the plant cover but also for the health of users and their income. These improved traditional ovens can also be used in the kitchen or in restaurants and hotels for the different cooking needs.

Declaration by Authors

Acknowledgement: None
Source of Funding: None
Conflict of Interest: No conflicts of interest declared.

REFERENCES

1. Fabião A. Manhiça, Carlos Lucas, Tobias Richards, “Wood consumption and analysis of the bread baking process inwood-fired bakery ovens”, Applied Thermal Engineering, 47 (2012) 63-72. DOI: https://doi.org/doi:10.1016/j.applthermaleng.2012.03.007
2. S. W. Igo1, N. Kokou, A. Compaoré and al, “Experimental Analysis of the Thermal Performance of a Metal Fired-wood Oven”, Iranian (Iranica) Journal of Energy & Environment, 11(3): 225-230, 2020. DOI: https://doi.org/10.5829/ijee.2020.11.03.08
3. C.F. Kouemou Hatou, G. Tchuen, P. Woafo, “Modeling, simulation and optimization of solid fuel bread ovens commonly used in developing countries” Heliyon 7 (2021) e06184. DOI: https://doi.org/10.1016/j.heliyon.2021.e06184
4. Aniello Falciano, Paolo Masi, Mauro Moresi, “Semiempirical modeling of a traditional wood-fired pizza oven in quasi-steady-state operating conditions”, Food Engineering, Materials Science and

Nanotechnology, 2023;88:2036–2052. DOI: https://doi.org/10.1111/1750-3841.16532
5. Babajide S. Kosemani, Adeyinka T. Ilori, Ayoade O. Atere, “Modification and Optimization of a Baking Oven for Small Scale Bread Production” Agricultural Sciences, 2021, 12, 630-644. DOI: https://doi.org/10.4236/as.2021.126041
6. Genitha I., Lakshmana Gowda B. T., John Diamond Raj, “Design, Fabrication and Performance Evaluation of Domestic Gas Oven”, IOSR Journal of Engineering, Vol. 04, Issue 05 May. 2014, V5, PP 35-38.
7. Afolabi Tunde MORAKINYO, Babatunde OMIDIJI, Hakeem OWOLABI, “Development and optimization of operational parameters of a gas-fired baking oven”, Leonardo Journal of Sciences, Issue 31, July-December 2017 p. 45-64.
8. Anjuman Ara Begum, Umme Habiba, Mohammad Gulzarul Aziz and al, “Design of an Improved Traditional Baking Oven and evaluation of Baking Performance”, Journal of Bangladesh Agricultural University, 21(2): 203–213, 2023. DOI: https://doi.org/10.5455/JBAU.147464
9. M. S. Sanusi, M. O. Sunmonu, A. L. Adepoju and al, “Development and Evaluation of the Operational Parameters of a Rotary Oven”, Nigerian Journal Of Technological Development, 2020, VOL. 17(04), 239-249. DOI: doi: http://dx.doi.org/10.4314/njtd.v17i4.1

How to cite this article: ADIHOU Coffi Wilfrid, KPLÉ Melhyas, AZA-GNANDJI Maurel, AMOUZOUN Yémalin Emmanuel, KOUTCHIKA Bignon Arnold, HOUNGAN Comlan Aristide. Construction and operational testing of an improved and intelligent traditional oven. *International Journal of Research and Review*. 2025; 12(4): 136-142. DOI: *https://doi.org/10.52403/ijrr.20250417*

******