TLUD-OVEN
LOW MASS OVENS POWERED BY "TLUD" STOVES

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ABSTRACT

Tested the operation of a low thermal mass oven powered by TLUD stoves. Wood pellets were used as fuel biomass. Stable temperatures inside the oven between 180ºC and 300ºC has been measured, and between 200ºC and 900ºC directly over the stove. Mean measured baking time has been 111 minutes. Although emissions hasn't been measured, no smoke has been seen in the overall process, assuming a pretty clean combustion. Many breads and foods have been baked in this oven. Strenghts and weaknesses of the TLUD-Oven have been identified. Has been concluded that, despite more research is needed, the TLUD-Oven has a great potential to achieve very energy efficient baking processes.

Key words: TLUD-Oven, oven, gasifyer, TLUD, pellets, bread, efficiency, appropiate technology, almond, husks

INTRODUCTION

Traditionally, ovens are “high mass ovens”, usually built with stone, bricks, and other high density materials. The fire is normally lit inside the oven, and when it gets enough hot, the fire is removed or put aside and the food is baked using the stored heat emitted from the walls and the floor (radiation heat). This procedure has the following handicaps:

- Lots of smoke
- Lots of fuel consumption (usually wood)
- Lots of time to get heated enough
- Requieres training for a proper use
- When the heat is over, fire has to be lit again

Looking at the advances of efficient stoves and low thermal mass ovens, the idea was designing better ovens that can take profit of these improvements.

Initially, the oven was made like a Rocket-Oven, following the rocket oven developed by Jon and Florence Anderson in 2011 (see below for link and details). This rocket oven showed a good performance, but frecuently (specially when lit, and with some types of wood) it left some blackening on the surface of the baked food.

Then the idea came naturally: what would be the result of combining the two technologies? Could we make the very efficient and clean burning TLUD stoves to run an oven like this?

These kind of ovens can be called “Black ovens”, as the hot gases enters inside the food chamber, and also “Convection ovens”, as the main heat source are the hot gases from the combustion, instead of the stored heat in the walls.

KNOWN ANTECEDENTS

After publishing the first edition of this paper, Jon Anderson pointed out the work of “Haiti Reconstruction International” (http://haitireconstruction.ning.com/) as the first known case of linking together TLUD stoves and low mass ovens.

METHODOLOGY

First a gasifier stove was built, TLUD type, with enough power to run the oven. (See Figure 1 and 2)

This stove uses a downward secondary air flow, provided by the inner chimney (See Figure 3). Another important characteristic is that the primary air flow has been increased in general, and in particular during the char-gasification phase. This has been achieved by placing a cone-like shape in the bottom cente of the fuel colum (see Figure 4 and 5)

Figure 1. TLUD parts and assembled

Figure 2. TLUD Reactor**.** Diameter: 15cm. Total length: 29cm. Fuel Height: 18cm. Primary air entrance is at the bottom. Secondary air entrance are 8mm holes rings, one at 9cm from the bottom of the fuel, the other at 14cm.

Figure 3. TLUD Combustor. Exterior diameter: 20cm. Interior diameter: 10 cm. Total length: 14 cm. Total lengh internal chimney: 8cm. The interior chimney

Figure 4. Cone-like shape to improve air flow during the char burning phase

Figure 5. The cone-like shape can be seen in its position in the bottom center of the fuel column.

Low thermal mass oven

Initially, the oven was made as a Rocket Oven, following the rocket oven developed by Jon and Florence Anderson in 2011 (http://www.rechoroket.com/Links_to_albums.html). Below can be seen the picture of the oven. The process of construction can be seen at http://cuinessolars.jimdo.com/forns-1/forns-tlud/

Holding the stove with a fixed support

In the first tests, the stove was put on a brick support.The riser was inserted through this hole until its top reached the same level as the floor inside the oven. In this way, the assembling of the stove was found to be very annoying and difficult, it was necessary to find some kind of simple mechanism that can allow moving up and down the stove.

Figure 6. TLUD Oven assembled

Holding the stove with a moving mechanism

In order to control the distance between the stove and the oven (for example, to control the temperature inside the oven) a jack was put under the stove, which allows to easily move the stove up and down.

Figure 7. Holding the stove with the jack. Objects below the jack (like the black box) can be added depending on the total height of the stove

TLUD-Oven linkage

It is a crucial point in the design of the TLUD-Oven. The riser (or upper part) of the TLUD stove should fit as tight as possible to the hole of the oven. This is for 2 reasons: not losing draft and preventing cold air from below the oven to enter the baking chamber.

In this case, as this oven was originally a Rocket-oven, it had a 10cm diameter hole, so we had to enlarge it until aprox. 15cm diameter. The junction between the riser and the hole was sealed with mud mixed with some plaster, to give some strenght. Although, as we need to constantly putting in and out the riser, it keeps being a weak part of the whole set.

With time, we realised the benefits of having the riser fixed at the oven structure, moving only the rest of the stove. This assures the air gaps can be fully sealed.

Figure 8. 15cm diameter pipe and 20cm long connecting the stove with the oven. Gaps sealed with mud with some plaster.

<u>Fuels used</u>
Although in the first and second edition of this paper I published results from 2 types of fuel (wood pellets and almond husks), I decided not to cotinue using almond husks anymore, as the gases from combustion showed some kind of irritating odour that I supposed not healthy enough for black ovens, where the combustion gases are in touch with baking food.

So, all the test presented in this paper were made using exclusively wood pellets.

<u>Starting the fire</u>
Fire was started at the top of the column of pellets with lighter fluid or directly with blowtorch.

<u>Recording data</u>
Temperatures were monitored using a temperature datalogger with 2 type K probes. Probe 1 was put through the pipe connecting the stove with the oven, while probe 2 was inserted through the wall of the oven, half way between the baking surface and the top hole. Temperatures were recorded each 10 seconds.

6 tests were done:

RESULTS

Figure 9 shows the oven performance with wood pellets and almond husks:

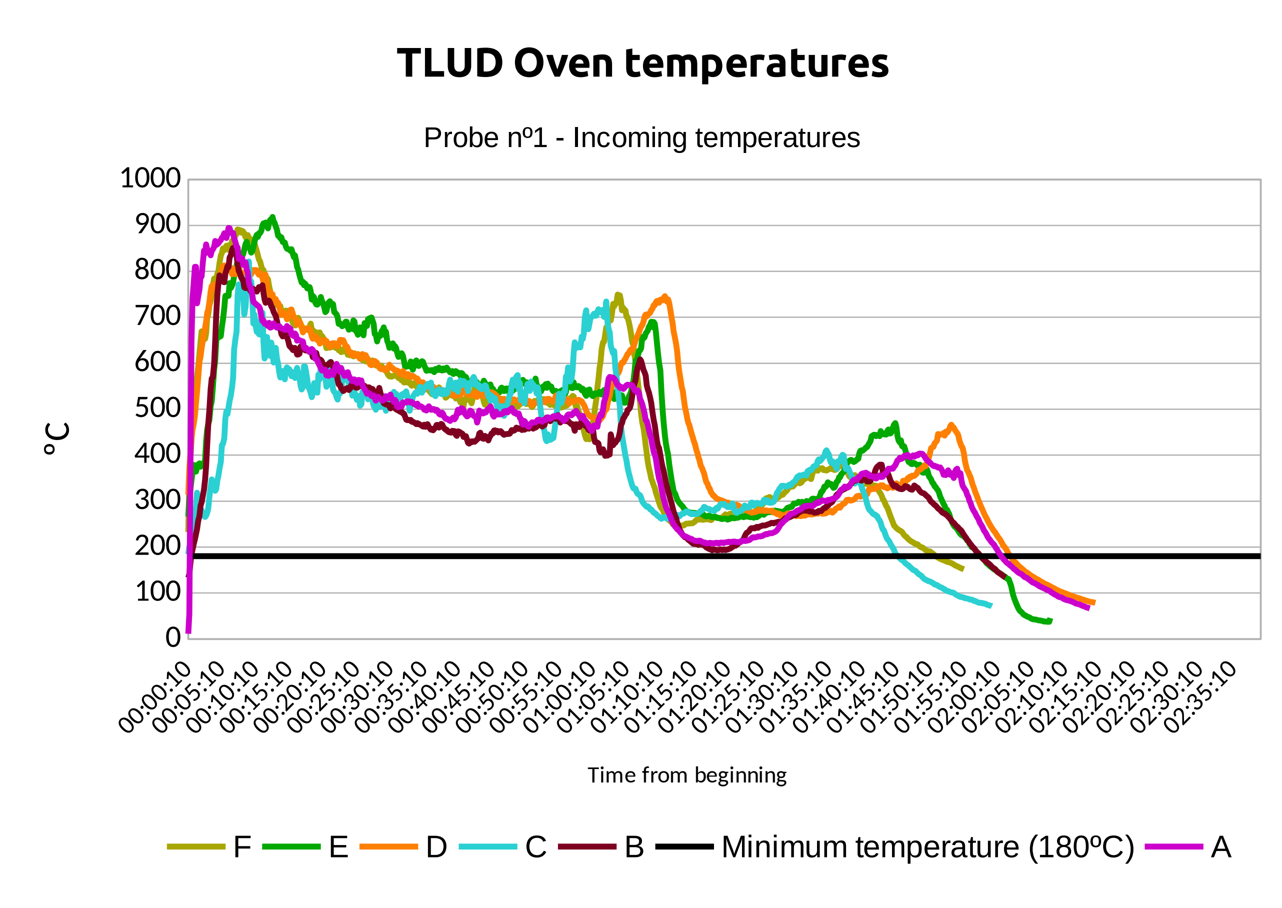

Figure 9. Incoming temperatures profiles

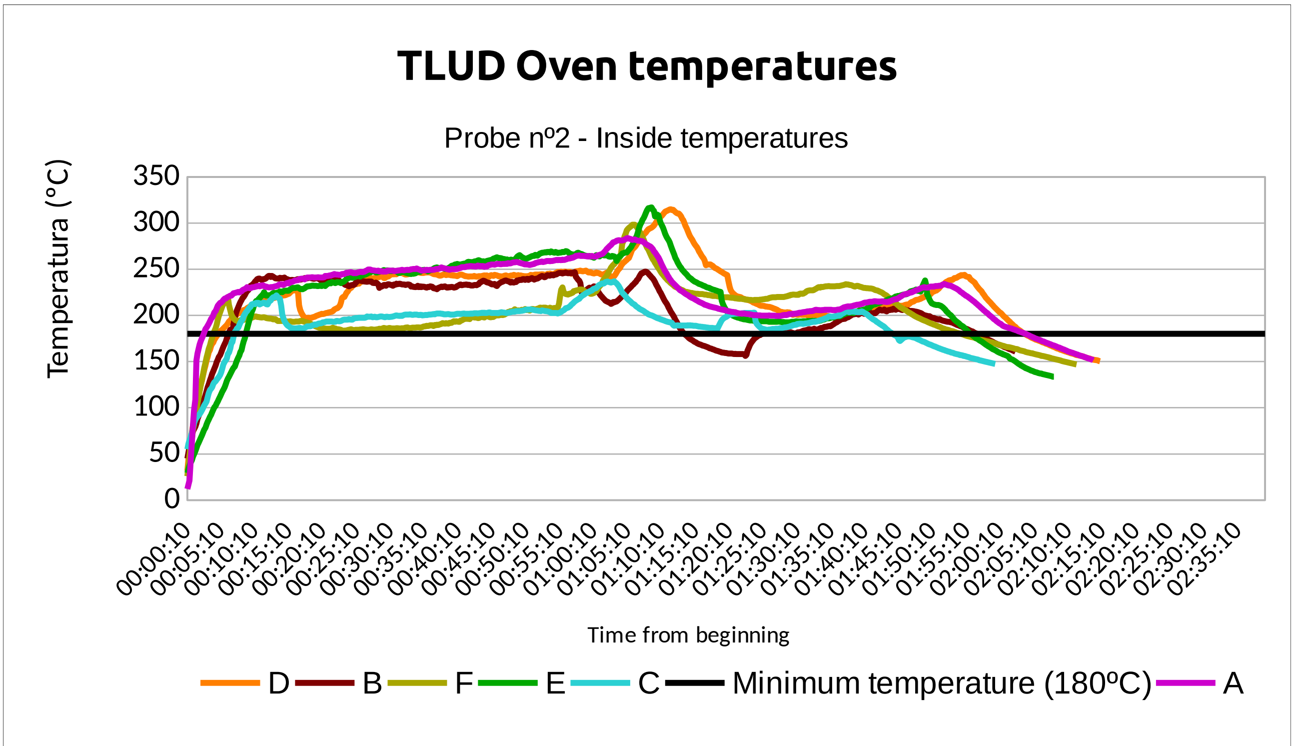

Figure 9. Oven temperatures profiles

Measure	Units	Results
PCI	MJ/kg	18
Quantity	Kg	2,00
Diameter	cm	15
Fuel column height	cm	18
Volume	litres	3,2
Fuel density	Kg/litre	0,63
Radius	cm	7,5
Radius²	cm²	56,3
Area	cm²	176,7
Baking time (Temp >180ºC)	min	111,0
Yield (consumption rate during baking time)	Kg/min	0,018
Cost per quilo	€/kg	0,20
Cost per batch	€/batch	0,40

Figure 10. Results table

Since May 2014, a lot of bread, pizzas, fish and meat have been baked in the TLUD-Oven:

Figure 11. Pictures of TLUD-Oven baked breads.

DISCUSSION

Overall performance

The TLUD-Oven tested here was able to reach enough temperature, in a short amount of time, to be able to bake and cook succesfully, without emitting any visible smoke in the process.

Range and control of baking temperatures

Baking and cooking temperatures were achieved in all tests.

Certain level of temperature control was achieved in two ways:

- Opening the front door of the oven
- Increasing the distance between the TLUD stove and the oven actioning the jack under the stove.

Obviously, the TLUD-Oven would greatly benefit of the turn-down capabilities that are now being developed on some models. (for example, see Methods of Substantial Turn-down in the TLUD Wood Gas Cook Stove, from Kirk Harris)

Wood to charcoal pyrolysis transition

In these tests, the primary air entrance of the stove has been left wide opened, so as the charcoal generated during the pyrolysis phase could be completely burned. This transition wood-charcoal burning, can be seen in **Figure 12** as a temperature fall, followed by a temperature recovery.

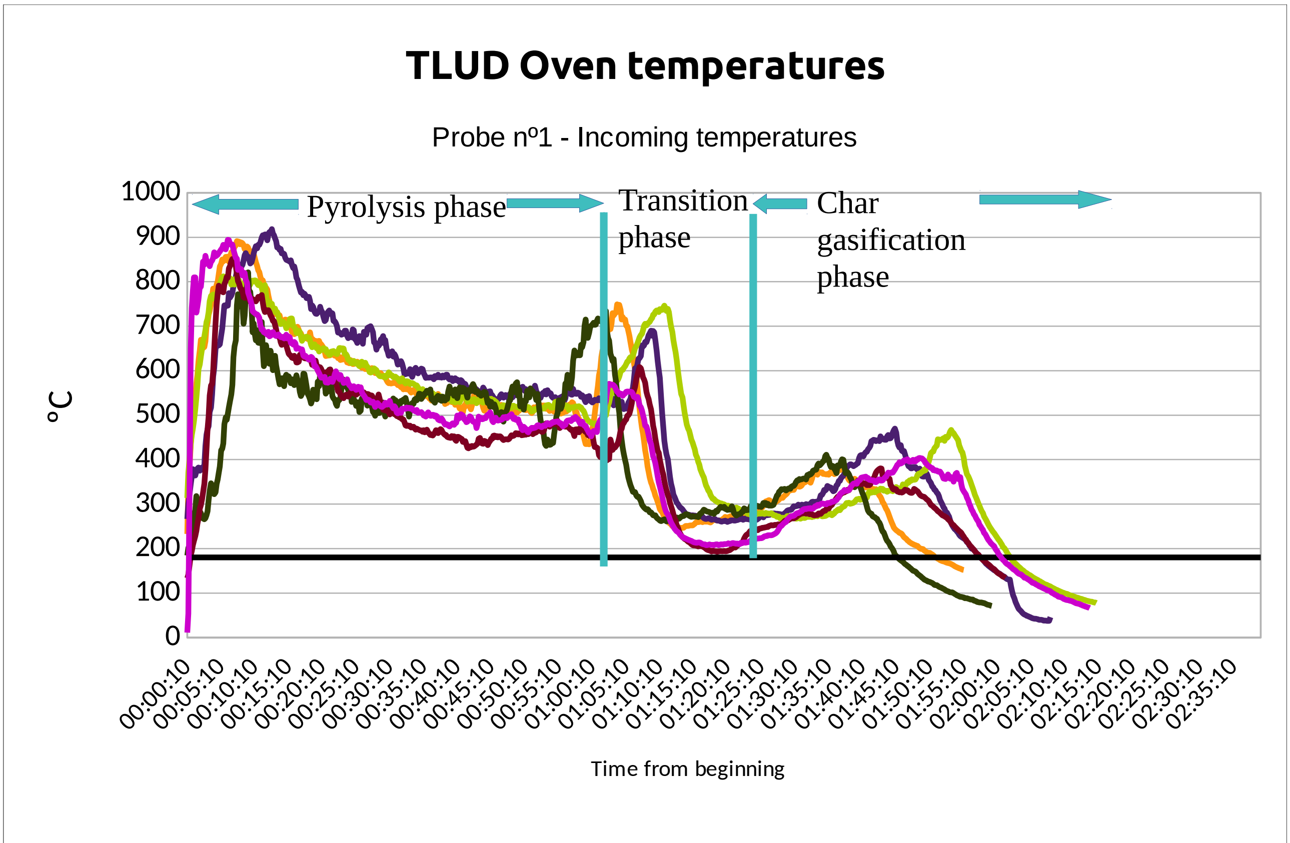

Figure 12. Example of wood to char burning transition

Why burning the charcoal?

This is an important decision we have to take during the TLUD stove design.
In this case, as baking time was a crucial factor when baking bread, we decided to maximize it allowing the charcoal to burn until ashes. However, there can be other reasons for not doing it, for example keeping the biochar for other uses, or avoiding too high temperatures in the stove that may shorten its life.

In any case, we want a stove that can power the oven the most efficient and cleanest way.

Baking time

As normally TLUD stoves are batch operated (and allows little to no refilling while in operation) total burning time parameter is a crucial factor when thinking in TLUD-Ovens. For baking bread, for example, minimum time is 60 minutes and optimal could be between 90-120 minutes for most bread recipes.

In these test, we achieved a mean baking time of 111 minutes (ranging from 97 to 121 minutes), which is pretty optimal.

As it is a Low-Thermal-Mass-Oven, the baking time strongly depends of the duration of the pyrolysis and combustion in the stove, as very little heat is stored in the oven walls, when the fire is out, the oven quickly looses heat until below baking temperatures.

So the parameters that affect the baking time are: fuel column height, primary air entrances and total draft. Compared to other TLUD stoves, this one has increased primary air aperture, and in theory this should allow much more draft that translates into quicker chemical reactions, more power, and less total reaction time.

More research is needed to check if reducing primary air aperture can led to longer baking times.

Convenience

Once the fire is lit and the stove set in place, it doesn't require more maintenance until the end of the process, so one can concentrate in cooking and baking. Compared with other types of stoves and ovens, this has found to be a great advantage.

On the other hand, refilling the stove or manipulating it someway is very difficult and dangerous, due to its high temperatures and its position under the oven.

Price

Figure 13 compares the price of wood pellets with electricity for the same baking time:

	Amount	Price per unit	Batch price
Pellets	2,00 Kg	0,20 €/Kg	0,40 €
Electricity (assuming a 2000W oven and a 4kW power installation)	2000 W x 111 minutes = 3688 Wh = 3,7 kWh	Consumption:0,10 €/kWh Power service: 0,04 €/h Equipment rental: 0,005 €/h	Total Cost: 0,37+0,08+0,01=0,46 €

Figure 13. Fuel prices comparison

STRENGHTS AND WEAKNESSES

Performance of the TLUD-Oven strongly depends upon the features of its two components. It is necessary to build well insulated low mass ovens powered by clean and efficient burning stoves.

Based on my own experience, **figure 14** shows the strenghts and weaknesses of the TLUD-Ovens. This analysis assumes that the oven used for these tests is an experimental one and may be far from being perfectly built. Also the TLUD stoves could be much more improved and has not some capabilities that can be found in more advanced ones.

STRENGHTS	WEAKNESSES
• CLEAN. Cleaner emissions than other ovens • CONVENIENT. Batch process, don't need to attend the fire.Can use both TLUD stove or Rocket stove in the same oven. • FAST. Gets hot very quickly • CHEAP. Minimum fuel consumption. The oven can be easily made with cheap and local materials (mud, straw, stone, wood) • DURABLE. Maintenance can be done easily with same cheap and local materials • APPEALING. Mud and straw allows to easily decorate the oven, making it more good looking.	• UNCONVENIENT. Difficult to control the power/temperature. Batch process, the duration is fixed • UNSAFE. Difficult and dangerous to manipulate the TLUD stove under the oven once it is lit. • UNRELIABLE. Different fuels can give very different performance. • NO WEATHER PROOF. Oven and mud parts cannot hold the rain, they need some kind of protection roof.

Figure 14. TLUD-Oven strenghts and weaknesses analysis. The items rated here have been taken from Christa Roth's First Experiences and Questions Arising from GIZ-Stove Implementation

CONCLUSIONS

1. The combination of low thermal mass ovens and TLUD stoves, has a great potential to achieve very energy efficient and clean baking processes.
2. This is the beginning of the path. Much more research is needed (see list below)

ITEMS NEEDED RESEARCH

a) Develop a TLUD stove that can quickly heat until desired temperature and then turned down to maintain it. (primary and secondary air control or other methods)
b) Test the combination of a high thermal mass oven with a TLUD stove.
c) Measure the emissions of a baking process in the TLUD-Oven.
d) Increase safety
e) Test the performance of different size light mass ovens, in order to find the most efficient combination, linked to the users needs.

REFERENCES

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