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. Two types of fuel were used: wood pellets and almond husks. Stable temperatures inside the oven between 200ºC and 300ºC has been measured for the two fuels. Measured baking time has showed big differences, 161 min for wood pellets and 68 for almond husks, due to its lower density inside the fuel column. Although emissions hasn't been measured, no smoke has been seen in the overall process, assuming a pretty clean combustion. Many breads and food has been baked in this oven. Strenghts and weaknesses of the TLUD-Oven has 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 is enough heated, the fire is removed or put at the sides and the food is baked using the stored heat contained in the walls and the floor (radiation heat). This procedure has the following problems:

- 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 shows a good performance, but sometimes (specially when lit, and with some types of wood) it left some blackening on the surface of the food being baked. Also, it didn't allow to use a chunky fuel like almond husks, which is an agricultural residue and is cheaper than other fuels like wood-pellets.

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. This stove is very similar to the TLUD "Champion" type, developed by Paul S. Anderson ("Dr. TLUD"). Although, two changes were introduced:

a) **Increased primary air draft**, which can apport enough oxigen to burn the coal generated during the gasification process and continue giving heat to the oven. Now the primary air enters all around the lower perimeter of the reactor, instead of having a single inlet tube like in the original model.
b) **Increased the length of the riser**, which also sustains the diffuser. This extra extension allows the complete combustion of gases gasification to completely remove the visible smoke in the oven.

Based on previous experiences with the same oven and similar TLUD stoves, it was decided that the stove should have the following characteristics:

Figure 1. TLUD parts and assembled

Figure 2. TLUD Reactor**.** Diameter: 20cm. Total length: 30cm. Fuel Height: 20cm. Primary air entrance is at the bottom and also at 12cm from the bottom through a set of 11 rectangular holes (2,5*0,5cm). Secondary air entrance are 7 rectangular gaps (5*1,5cm)

Figure 3. TLUD Outskirt. Diameter: 22cm. Diameter central hole: 12,5cm. Total length: 25cm

Figure 4. TLUD Riser and diffuser. Diameter: 12 cm. Total length: 30cm. Diffuser: granite piece 2cm thick and 15cm diameter

Figure 5. Fuel load. Fuel type: pellets (left) and almond husks (right)

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.

Starting the fire
Fire was started at the top of the column of pellets with lighter fluid.

Recording data
Temperatures were monitored using a temperature datalogger with a type K probe. This probe was inserted through the wall of the oven, half way between the baking surface and the top hole.

2 tests were done with each fuel:

(A) and (B) with Almond Husks
(C) and (D) with Wood Pellets

RESULTS

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

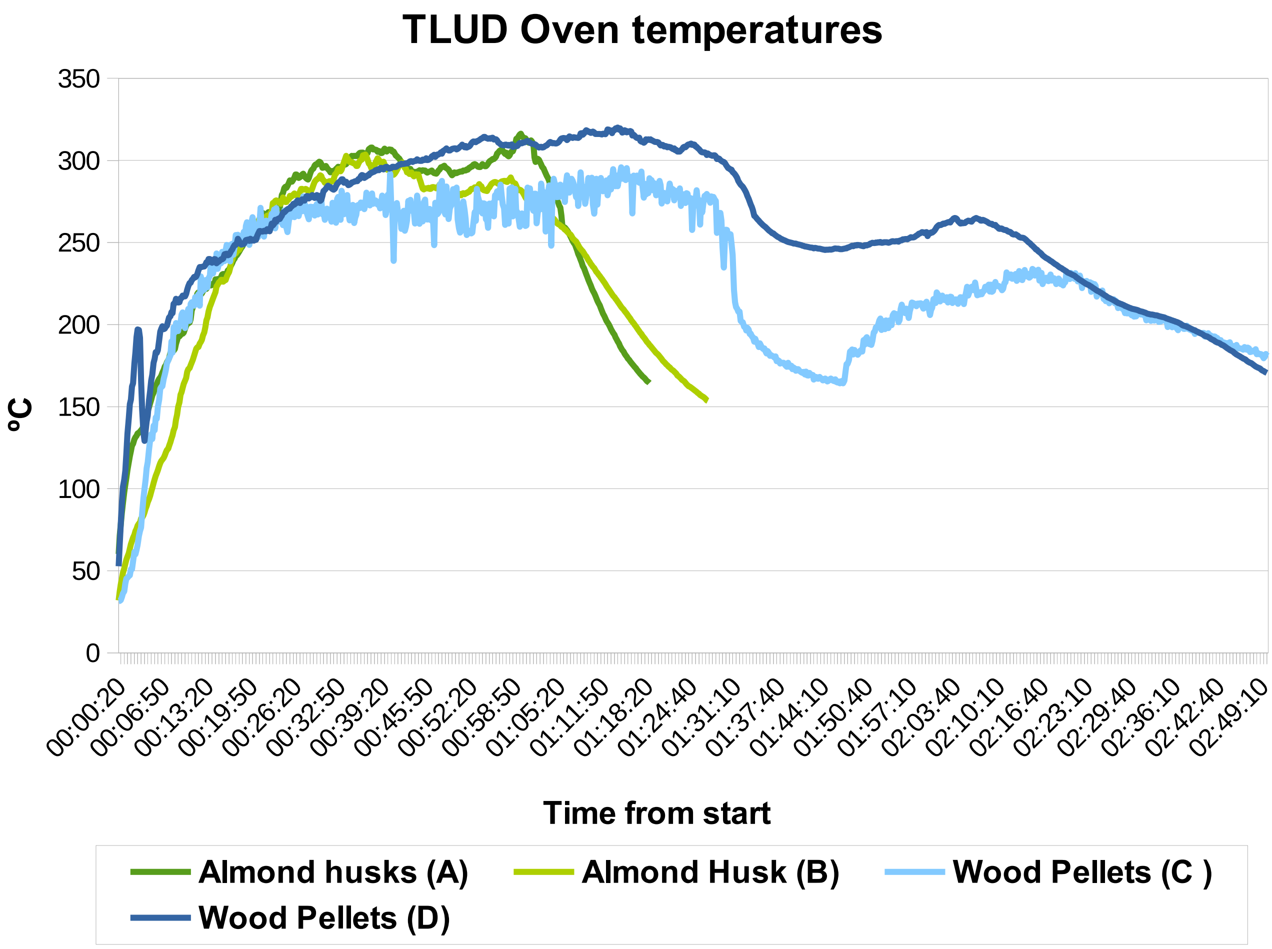

Figure 9. Oven temperatures profiles

		Wood Pellets (mean A,B)	Almond husks (mean C,D)
LCV (Lower calorific value)	MJ/kg	18,00	16,70
Quantity of fuel	Kg	3,38	2,00
Diameter of reactor	cm	20,00	20,00
Fuel column height	cm	20,00	20,00
Fuel density	Kg/litre	0,54	0,32
Radius of reactor	cm	10,00	10,00
Radius² of reactor	cm²	100,00	100,00
Area of reactor	cm²	314,16	314,16
Baking time (Temp >180ºC)	min	160,83	68,08
Average baking temperature	ºC	235,44	270,26
Average stable temperature	ºC	292,50	290,00
Maximum temperature	ºC	309,05	309,85
Yield (consumption rate during baking time)	Kg/min	0,021	0,029

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

Temperatures were very similar using the two fuels, ranging from 235ºC to 270ºC, which are considered in the upper range according to most bread and other food recipes. (We can say in general that bread needs a temperature of 250ºC the first 5-10 minutes but then lows to 180-200ºC for the rest of the baking process)

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 9** as a temperature fall, followed by a temperature recovery.

We can see big differences in the behavior of the 2 tested fuels:

- Pellets: showed a big temperature drop (from 275ºC to 175ºC) which lasts about 15 minutes, and a following recovery up to 230ºC
- Almond husks: showed a more little drop (from around 300ºC to 280ºC) which lasts only about 5 minutes, and a following recovery to more than 300ºC.

These differences are supposed to be related to the differences in density of the fuel column (0,54 Kg/litre for pellets and 0,32 Kg/litre for almond) which allows for more draft and primary air that leads to a quicker transition phase.

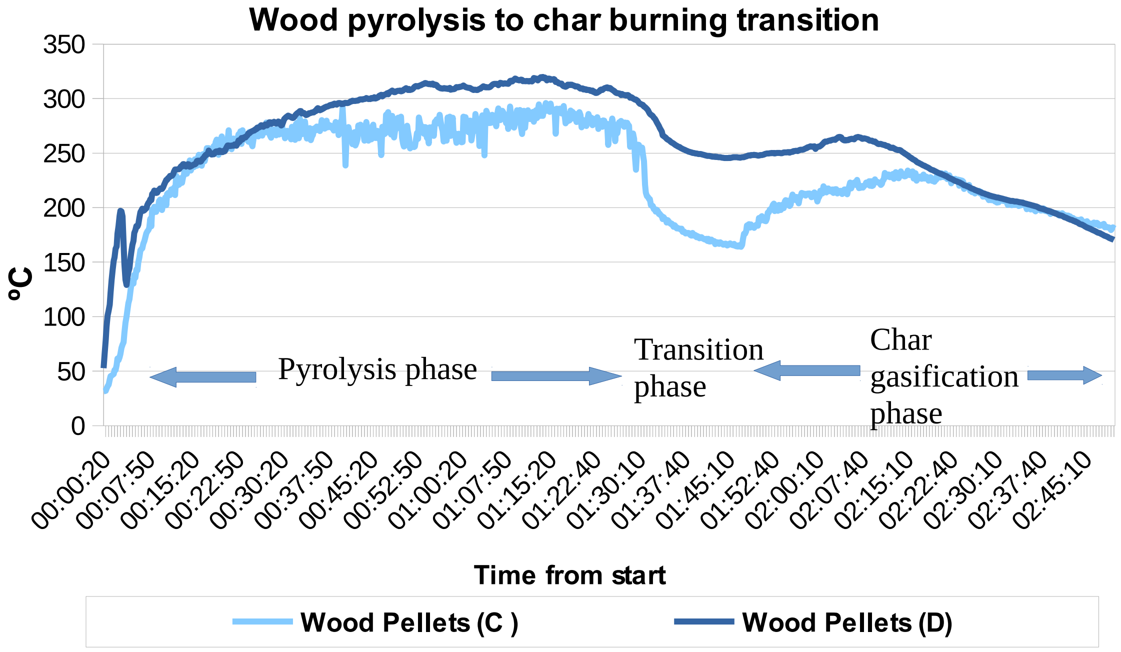

Figure 12. Example of wood to char burning transition

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
The tests showed big differences between the 2 fuels, while pellets giving a total baking time of about 160 minutes, the almond husks only giving 68 minutes.

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.

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: type of fuel (chemical composition), density of the fuel, fuel column height, primary air entrances and total draft. In the case of almond husks, we have a low density fuel (0,32 Kg/litre), that can allow primary air to pass through easier than in the pellets case, and this allows much more draft that translates into quicker chemical reactions, more power, and less total reaction time.

In the case of fuels with low density inside the fuel column, like almond husks, two solutions are possible:
1. Designing longer reactor chambers that can allow for more baking time
2. Increasing the density of the fuel.

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
These are the prices we bought the fuels for the tests:

	Amount spend (Kg)	Price per kilo (Kg)	Batch price (€)
Pellets	3,38	0,3	1,01
Almond husks	2	0,11	0,22

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) Find the exact diameter of the TLUD stove that can mantain an average constant temperature between 180ºC-220ºC, suitable for baking most bread types and recipes.
b) 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)
c) Test the combination of a high thermal mass oven with a TLUD stove.
d) Measure the emissions of a baking process in the TLUD-Oven.
e) Increase safety
f) Test the performance of different size light mass ovens, in order to find the most efficient combination, linked to the users needs.

REFERENCES

- Jon and Flip Anderson amazing and inspiring work on rocket stoves and rocket ovens: http://www.rechoroket.com/Links_to_albums.html
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