

Thermal efficiency and fuel use of cookstoves
Plancha versus open fire in San Lorenzo¹
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1. Introduction

The main purpose of this pilot study, done during July 2003, was to adapt standard methods of measuring stove performance to the local situation in rural highland Guatemala where the UCB ARI Intervention trial is being conducted. The intervention project needs to develop reliable methods to determine how the improved stove being introduced, the *plancha*, changes fuel consumption in households compared to the traditional method, basically an open fire between bricks or rocks. Nearly all households in this area use only wood for cooking, heating, and bathing.

This report discusses briefly the method employed to do the tests and then, in sections 2 and 3, the results. The appendix presents the detailed methods as adapted for San Lorenzo with recommendations for those conducting testing in the future.

1.1 Methods from VITA (Volunteers in Technical Assistance)

The most commonly used standard methods for measuring the efficiency and fuel use for biomass stoves are those developed by VITA, an NGO focused on third-world development issues (<http://www.vita.org/>). In the VITA stove-testing handbook (Turyareeba, P.J. and Kimani, M.J., 1992), there are three standard tests:

- The water boiling test (WBT), to measure how much fuel is used to boil water under fixed conditions. This is a laboratory-like test, which is the most controllable out of the three. The test facilitates the comparison of stoves under controlled conditions with relatively few cultural variables. This is the only one of the tests from which an actual physical efficiency, i.e., energy absorbed by cooking vessel divided by energy in fuel consumed, can be determined.
- The kitchen performance test (KPT), to measure how much fuel is used in actual households when cooking normally over a few days. The amount of wood the family used per day is calculated in this test.
- The controlled cooking test (CCT), which serves as a bridge between the KPT and WBT. Trained local cooks prepare pre-determined meals in a specified way and the fuel consumed per standard meal is used for comparing different stoves.

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1.2. Tests used

Due to time limitations and underestimating the time to complete the other two tests, the controlled cooking test was not conducted during this pilot testing. WBT and KPT do not require trained local cooks, and KPT takes a long time for each sample.

1.3. Obtaining the fuelwood.

The fuelwood used in the study is the Cypress and Pine species. These are representative of the species of wood typically used in the area in the season. The Cypress used initially was too moist, and the wood was switched to Pine in subsequent testing. The pine was drier in water content but slightly more expensive. One cord of Cypress cost 100Q. or 12.61\$ (at 7.93 Q.=1\$), while the Pine cost 120 Q. or 15.13\$. One cord of Cypress weighed 395 kg, while one cord of Pine weighed 325 kg, this variation may be due to the moisture content, or the variation in measuring out the cord, as they were purchased from two different vendors.

2.0 Boiling Water Tests

The BWT were conducted in the house of a fieldworker and his neighbors. These houses were chosen mainly for their convenience in proximity and obtaining approval. Since the stove should be at room temperature at the start of the experiment, these tests were conducted when the families were not planning to use the stoves.

2.1 BWT results

Table 1. *Plancha Results*

<i>Date</i>	<i>Time to Boil</i>	<i>Time to Boil (pot 2)</i>	<i>Weight of wood used</i>	<i>Weight of unburnt coal</i>	<i>Thermal Efficiency</i>
	<i>Min.</i>	<i>Min.</i>	kg	kg	%
10JUL03*	42	47	6.5	---	---
14JUL03	33.5	43.5	5.58	1.86	7.5
16JUL03	30	---	5.34	1.62	5.9
17JUL03	29.5	33	4.66	1.09	6
17JUL03	22	---	4.34	1.33	7.1
21JUL03	32	35.5	4.85	1.53	6.6
Average	31.5 ± 6.5	39.7 ± 6.6	5.2 ± 0.78	1.5 ± 0.29	6.6 ± 0.69

*Results for 10JUL03 lack some collected data, and thermal efficiency could not be calculated.

Table 2. *Open Fire Results*

<i>Date</i>	<i>Time to Boil</i>	<i>Time to Boil (pot 2)</i>	<i>Weight of wood used</i>	<i>Weight of unburnt coal</i>	<i>Thermal Efficiency</i>
	<i>Min.</i>	<i>Min.</i>	kg	kg	%

18JUL03	18.5	30	4.18	1.62	15.4
18JUL03	16	16.5	3.56	1.3	15.3
21JUL03	17	18.5	3.36	1.33	15
21JUL03	18.5	19.5	3.38	1.24	14.2
Average	17.5 ± 1.2	21.1 ± 6.0	3.6 ± 0.38	1.4 ± 0.17	15.0 ± 0.54

From the results, a significant difference can be seen between the plancha and the open fire. The mean of 15% compared to 6.6% shows a significant advantage for the open fire. However, because of the design of this test, these numbers do not show the effect of heat being retained by the body of the plancha, which is where some of the efficiency could be lost.

3.0 Kitchen Performance Tests

The KPT is a longer test, so this test was conducted in series. The most difficult part of the KPT is getting started. Recruiting houses, purchasing, preparing, and transporting the wood. Also the testing form was continuously evolving and compared to the form used on the first day of Group A, the form used for Group C was significantly more complex and detailed, to include any confounding factors.

3.1 Houses tested

Group A. Two houses were chosen for the KPT on 10JUL03 for the first round. These were the two closest houses to that of the Fieldwork Supervisor (Vicente) chosen out of convenience since the wood had to be carried to the houses. This was in Community 29008 (La Cienaga) house 028 (open fire) and house 024 (plancha). The wood used for Groups A and B was Cypress, which was very wet. The average moisture reading from the Delmhorst moisture analyzer was 31.6%. Also when the moisture read above 40%, the Delmhorst moisture analyzer could not read it, so the actual moisture may be somewhat higher.

Group B: The following week, four more houses were chosen according to family size, accessibility, and proximity to where the wood was being kept. After five days of the wood drying out, the Cypress was drier for use in the plancha. Also on the last day 19JUL03, there was a large festival in San Lorenzo, which every household was planning to go. Thus, the Mam-speaking fieldworker (Bernabe) and I had to go to Cienaga earlier than usual (at 7 am), sometimes catching them cooking breakfast.

Group C. On 16JUL03, I started two more houses.² These two houses were given Pine, which was drier with average moisture content of 23%. This switch was made after numerous complaints of the cypress not being dry enough.

3.2. KPT results

² I planned to do four houses, but I engaged in a battle against a group of evil microorganisms, which attacked my body.

Table 3: *Plancha Fuel Use*

House no.	Day 1 (kg)	Day 2	Day 3	Day 4	Ave.
024	29.2	41.4	---	---	35.3
029	33.4	42.0	23.6	22.8	28.2
113	14.8	12.4	10.2	11.4	12.2
95	15.8	34.4	27.6	---	25.9
Ave Daily Use	24.5 ± 11.2				

Table 4: *Open Fire Fuel Use*

House no.	Day 1 (kg)	Day 2	Day 3	Day 4	Ave.
028	30.7	39.7	---	---	35.2
030	30.1	47.3	38.3	27.2	29.4
101	11.3	24.1	27.1	32.7	23.8
87	27.5	26.5	21.5		25.2
Ave Daily Use	29.5 ± 8.94				

Table 5: *Plancha Specific Daily Consumption*

House no.	SAE	Day 1	Day 2	Day 3	Day 4	Ave.
024	5.56	4.6	6.5	---	---	5.6
029	4.95	7.0	8.0	4.9	4.8	6.2
113	3.8	3.9	3.3	2.7	3.0	3.2
95	8.51	1.8	4.1	3.3	---	3.1
Ave. Daily Use	4.4 ± 1.8					

Table 6: *Open Fire Specific Daily Consumption*

House no.	SAE	Day 1	Day 2	Day 3	Day 4	Ave.
028	5.2	5.9	7.6	---	---	6.8
030	6.72	4.9	6.9	5.6	4.3	5.4
101	4.97	2.8	5.9	6.3	6.1	5.3
87	5.1	5.4	4.2	5.2	---	4.9
Ave. Daily Use	5.5 ± 1.2					

House 024: Of the eight households tested in this study, this was the only family with out a breast-feeding baby. Also, they cooked for their four pigs throughout the duration of the study. Also, the household consumed all of the 29.2 kg of wood on the first day. They told us they ran out half way though breakfast, so the additional amount of wood they used for breakfast is not known. Thus, in reality, the amount of wood used in day 1 should be slightly higher.

House 028: Cooked for their two pigs starting on the second day.

House 029: Heated water for bathing baby on day 1. Also cooked to feed a rather large (and dirty) pig and its 8 piglets for the entire length of the study. The pig feed was on the

plancha on every visit. The kids also tend to play with the wood, as implied by a few pieces of wood scattered over the yard.

House 113: The grandmother in the family was sick, who does not live with them. The mother spent some time with her grandmother and was often not home, implying she may not have had much time to cook as in a normal week.

House 030: On the third day, we added 25.2 kg of pine, not cypress because we did not have any more cypress. Cooked for her three large and two small pigs for three out of the four days. Also heated some water using the wood from the study to bathe her 3 children on day 2, which may explain the large amount of wood used.

House 101: This house had a birthday party on the last day. Many visitors, lots of food, and above all that, they also used their own wood for some reason.

House 095: Cooked for two large pigs during day 2 and day 3 of the study.

House 087: The last day, they were still cooking breakfast, so we estimated the number of logs they would need.

4. Discussion

As apparent from the BWT, the average and standard deviations of the thermal efficiencies of 6.6 ± 0.69 % for the plancha and 15.0 ± 0.54 % for the open fire clearly shows that the open fire is much more thermally efficient. In the open fire, the temperature of the stove increased much faster compared to the plancha, this may be due to the heat being absorbed by the plancha itself. Also on the plancha the sides of the pots are not exposed, and the temperature on the sides of the pots were significantly colder as compared to the open fire.

From the KPT the Plancha families did get a slightly lower daily specific consumption of wood. But the high variability in the results makes the result not significant. More data needs to be collected for a significant result. Also variation within homes indicates data needs to be collected for a longer period of time at each house.