Assessing stoves in Northern Tanzania

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Liana, 2011 (modified by adding Lorena user experiences)

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Introduction

Indoor air pollution from open household cooking fires is listed by the WHO (World Health Organisation) as the leading environmental cause of death in the world. It contributes to nearly two million deaths annually —more deaths than are caused each year by malaria. About three billion people rely on firewood or charcoal for cooking. The cooking fires typically fill kitchens with dense smoke sickening those within. [1]

Firewood satisfies most of the developing world's domestic energy needs and is collected mostly from unregulated common land. Africa is suffering deforestation at twice the world rate, according to the United Nations Environment Programme (UNEP)[2]. Tanzania had the third-largest net loss of forest area in Africa (and the sixth largest in the world) between 2000 and 2005 (FAO 2005b[3]). In addition to cutting trees for firewood, other primary drivers of deforestation include logging for domestic use and export, and agricultural conversion (Tanzania National Bureau of Statistics 2005[4]).

Promotion of stoves has formed an important part of three Liana development projects in Northern Tanzania from 2009 to 2011. Prior to the project activities Susanna Mäkelä of Liana conducted an Internet based study of the best-documented and commonly promoted firewood-saving stove models and their performance[5].

There is an assumption that these stoves save a lot of firewood and cook quickly. Web pages of projects promoting them typically claim 30 to 80% savings in firewood consumption - without producing the data supporting the claim. There are some studies that have compared the traditional 3-Stone fire with a particular improved stove. Some stoves are thoroughly tested[6] or designed on thorough scientific understanding[7], but others have inadequacies in describing the study methods and data collection[8]. There are practically no useful studies that would have attempted to compare different models of improved stoves[9].

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[1] Science 14 October 2011: Vol. 334 no. 6053 pp. 180-181.

[2] Africa: Atlas of our changing environment. UNEP. http://na.unep.net/AfricaAtlas

[3] FAO (2005). Global Forest Resources Assessment. Rome: FAO. http://www.fao.org/forestry/site/fra/en/

[4] Tanzania National Bureau of Statistics (2005). Environmental Statistics. Dar es Salaam, Tanzania.

[5] This report is available from http://www.liana-ry.org/.

[6] e.g. Berkeley Tara stove tests: Amrose, Susan 2008. Development and Testing of the Berkeley Darfur Stove. Lawrence Berkeley National Laboratory.

[7] e.g. Vita tests: Dean Still and Nordica MacCarty 2007: Gasifying Rocket Stove. Aprovecho Research Center. Creswell. http://listserv.repp.org/pipermail/stoves_listserv.repp.org/2007-July/006902.html and scientific understanding behind Vita design: Samuel F. Baldwin 1987: Biomass stoves: Engineering design, development, and dissemination. Princeton University.

[8] It is not clear where the basic data of firewood saving comes from in reports like Habermehl Helga, 2007. Economic evaluation of the improved household cooking stove dissemination programme in Uganda Dissemination of the Rocket Lorena stove in the districts of Bushenyi and Rakai and dissemination of the improved charcoal stove in Kampala in the years 2005 and 2006. On behalf of the German Agency for Technical Cooperation (GTZ), Household Energy Programme – HERA.

[9] This is due to inadequate recording of data collection and/or uncontrolled testing methods or inadequate description of what the tested stoves were like. An as example, see Academy for Educational Development 2007. Fuel efficient stove programs in IDP settings – summary evaluation report, Uganda. Produced for review by the United States Agency for

As we wanted to offer some choice of stoves to families with very differing means and needs, nine of the better documented models or locally known models were introduced to the farmers in Mwanga and Moshi in the initial theory training sessions. These were Jiko Sanifu, Lorena, Kilakala, Nyungu, [10] Upesi[11] with and without a table, Vita[12], Turbo[13], Brick and cement (locally known[14]) and Kisangani [15](known in Southern Tanzania). Following an exercise in which each farmer selected a stove type s/he would like to have and could afford to have in her/his home, the number of potentially suitable stoves was reduced. As women became more aware of the dangerous effects of indoor smoke, having a chimney became more and more important and many models without chimney dropped out. Thus we remained with four main stove models. These are Vita metal stove, Upesi burned clay stove, Lorena mud stove (or built with bricks inside) and a rocket Brick and cement stove. During the process two of the stove models, Vita and Upesi were considerably modified. Vita obtained a short chimney (90cm measured from the middle of the hole to the top, 8x8cm) and Upesi was developed into two slightly different new models, both with a fire grate allowing air intake to the fire chamber through holes in the grate.

All models have been locally constructed within Liana projects. Anyone who was interested in building a Lorena mud stove could apply to attend building courses that were run in seven villages in Eastern Mwanga. The best builders in those courses were offered a course on Lorena with bricks inside (more suitable if the soil does not have enough clay in it). Improved Upesi stoves were developed with and built by a potter in Jipe where good clay is available. Six metal fundis were taught how to build Vita stoves. And the best builders of the Lorena courses who had some additional experience in masonry were trained in building the Brick and cement rocket stove. In addition, school stoves have been built, but this report is about household stoves only.

This document reports the results of the boiling point tests, controlled cooking tests and an interview study on user experiences of 11 women in Mwanga and Moshi.

International Development. The report records its methods very inadequately, controls its tests poorly (e.g. due to many operators) and does not clearly describe the stove models tested. For example, the Lorena stove took an hour to boil 3 litres or water, suggesting it was either poorly constructed or incorrectly used.

[10] As described in Stephen Gitonga: Appropriate Mud Stoves in Africa. Intermediate Technology Kenya's, Household Energy Regional (HER) Project.

[11] e.g. Vivienne Abbott, Clare Heyting and Rose Akinyi 1995: How to make an Upesi stove. Guidelines for small businesses. Intermediate Technology Kenya.
Guidelines for small businesses Guidelines for small businesses Guidelines for small businesses Guidelines for small businesses

[12] Samuel F. Baldwin 1987. Instructions for Building a VITA Stove. Biomass Stoves: Engineering Design, Development, and Dissemination. Princeton University.

[13] http://www.turbostove.fi/englanti/turbostove.php3

[14] Promoted locally by TaTEDO (Tanzania Traditional Energy Development and Environment Organisation) and known also by the name of 'Okoa'.

[15] Case study summary Kisangani Smith Group, Tanzania. The Ashden Awards for Sustainable energy.

Stoves tested

Table 1. Critical measurements of stoves tested.

Stove type	Upesi with removable bottom	Upesi made of one piece	Vita	Vita with a chimney	Lorena	Brick and cement rocket stove	3-Stone
Pot diameter in cm	26.5	26.5	26.5	26.5	25 boiling tests 23.5 cooking tests	25.5	26.5
Distance between grate and pot in cm	13.5 boiling tests 12.5 cooking tests	17 at the edge 18 in the middle	12	10	18 boiling tests 24.5 cooking tests	38	12 boiling tests 11 cooking tests

Figure 1. Stoves included in the tests (from top left), Upesi with removable grate, Upesi with fixed grate, Vita, Vita with chimney, Lorena mud stove, Brick and cement rocket stove and 3-Stone fire.

Methods

Boiling point tests

The aim of these tests was to measure time to boiling and the firewood used to reach boiling. Boiling point tests were done for all seven stoves. Five of the stoves (the portable ones) were tested in a kitchen shed with a low wall to keep the wind away. Stoves were placed on concrete floor so nothing blocked the air inlets. Lorena and Brick and cement stove were tested in a local home. The time to get 2 litres of water boiling and the amount of firewood it consumed were measured. Tests were repeated 5 times.

To control the starting temperature of the water, water was kept in a container in a shaded place. Old construction wood was used for firewood. It was all the same type of wood and very dry. Weighing the bundles was done by a kitchen scale and time was measured by a stopwatch.

3 different pre-tests were conducted to find out a useful amount of firewood for the actual tests, the size of firewood pieces, whether to use a lid or not, and the way to light the stoves (pre-tests were not conducted for Lorena and Brick and cement stoves).

Based on the outcome of the pre-tests, it was decided that a bundle of 500g of firewood, about 8-10 pieces of firewood at approximately 50 -100 g per piece was a good standard bundle to do the tests. Some of the wood was cut into thin shavings to help light the fire. One torn page of a newspaper was also used in lighting.

In the tests for the two Vitas and the two types of Upesi all the wood except one piece was added to the fire chamber before the pot was put on. Firewood was cut short enough that the pieces fitted into the stove. The one piece of firewood left out was used only if the fire was not burning well or long enough. For the 3-Stone fire longer pieces of wood were used. They were inserted from all three sides and fed little by little into the middle.

The owner of the Brick and cement stove commented immediately that 500 g would not be enough to get the fire going due to the long ‘cave’ from where to feed the fire. However, the fire was started with the 500g, all of it, and more wood (1-2 pieces) was added little by little from the second 500g bundle that had bigger pieces (3-4 in total). The owner showed how she usually placed the wood to get the best outcome. Firewood was stacked leaning against the walls of the fire chamber. The owner of the Lorena had the same reaction. She thought 500g was too little for the task. The whole 500g bundle was used to light the fire and 1-2 pieces from a second bundle were added if needed.

Timing started when the pot with water measured inside it was placed on the stove. Pot was placed on the stove only when the firewood had caught fire (not just shavings and the paper). When the water started boiling, timing stopped.

The choice of a pot was determined by the size of the pot used for Vita, 26.5cm diameter standard sufuria. So the same size was used for the two Upesis and the 3-Stone fire. However, this size could not fit the Brick and cement stove and the Lorena since both are built to fit a certain size. So a size very close to the original Vita pot was selected, namely 25.5 cm for the Brick and cement and 25cm for Lorena. A lid was kept on the pot throughout the test.

To be able to calculate how much firewood was used, wood that was left in the fire chamber was weighed together with the wood left in the standard bundle. To extinguish the wood before weighing, water was sprinkled on the burning wood. As the water steamed off immediately it was not believed to add weight. Most of the part-burned charcoal was also collected for weighing. Smaller pieces and the ashes were not weighed.

Tests were started with cold stoves. However, the Brick and cement stove could have had a little bit of heat even when the stove had not been used since the night before.

The tests were done with the help of a local woman used to cooking with firewood and overseen by the primary tester (Jorunn Myra).

Controlled cooking tests

This test was done with the Lorena, Upesi with removable grate, Vita with chimney and the traditional 3-Stone fire. It was repeated 3 times for each stove. The three portable stoves were outdoors next to a low wall with a hedge on two sides. 3 dl of green grams was cooked in 2 litres of water.

500g firewood bundles were used. The wood was very dry *Senna spectabilis,* cut into pieces of about 80-150g. Some of these were further chopped into sticks of the size of a pencil or two pencils to help start the fire and keep it going very slowly towards the end. One page of newspaper was used to start the fire. The lid was kept on the pot throughout the test. The starting temperature of water was controlled by keeping it in a jerry can in shade. Stoves were left to cool down between tests.

Time measuring started from when the fire caught the firewood and the pot was put on. Time was next marked down when the water started boiling. Water was kept just boiling with a fire that was tended very carefully to keep it as small as possible. 30 minutes from when it started boiling, green grams were checked for the first time. After that they were checked every 5minutes till they were cooked and timing stopped. Optimally, if the tests are conducted exactly the same way each time, it takes the same amount of time from when the water starts to boil to when the beans are cooked. It is the amount of firewood consumed and the time it takes to bring the water to boiling that vary. The controlled cooking tests could have alternatively been conducted by keeping a certain amount of water boiling for a certain amount of time, and measuring the amount of firewood consumed to do so.

26.5cm diameter standard sufuria was used for Vita, Upesi and 3-Stone fire. The Lorena used was not the same Lorena as for the boiling point tests and was built for a smaller pot (clay pot) but was suitable for a 23.5 cm standard sufuria.

Firewood left in the fire chamber was extinguished before weighing by spraying it lightly by water. Firewood consumption was calculated as with the boiling point tests. All tests were overseen and/or done by the primary tester (Richard Coe) with the help of a local woman used in cooking by firewood.

Interviews

Eleven stove users were interviewed for their user experiences of the stoves[16]. Table 2 lists the number of users that used a particular stove or stoves. Two persons answered questions about Brick and cement stove, 6 persons about Lorena, 6 persons about Upesi and 4 persons about Vita. All could compare these with a 3-Stone fire.

Two different questionnaires were used, one (1) for the first 4 women and the other (2) for the remaining 7. Questionnaire 1 started by an open question about what the user thinks about the new stove(s) she has used for some time. If necessary more specific questions were prompted about the performance of the stove for different tasks such as quickly boiling tea or cooking food that takes long time to boil, her impression about the difference in firewood usage between the two new stoves (if she had two different) or between her new stove and the 3-Stone fire, cooking performance, and convenience of cooking (how handy it is). More specific questions followed about the stoves (such as sootiness, danger of burning oneself or children, steadiness when stirring, easiness or difficulty in lighting, if it leaves charcoal or not, its cost, how it looks, durability, smokiness). Questionnaire 2 was a semi-structured questionnaire that focused on finding the major good and bad aspects of each stove that is used in the household, comparison of firewood usage between the different improved stoves and the 3-Stone fire, preference of stoves (how often each type of a stove is used and to cook what), whether smoke is still a problem in the kitchen, change in time usage to fetch firewood or money used after getting an improved stove). A lot of extra questions were asked to make sure the interviewer had a very clear picture about what the interviewee thought about the stove and its performance. Interviews were conducted in Swahili, with quotations reported in results translated by Eija.

Combinations of stoves used by the interviewees	Number of users interviewed
Brick and cement	2
Lorena and Upesi	3
Vita and Upesi	2
Vita and Lorena	1
Vita	1
Lorena	1
Lorena, old unimproved Upesi and improved Upesi (the potter)	1

Results

Boiling point tests

This test was done to all 7 models. Table 2 shows the average time needed to bring two litres of water to boiling. As the first test of each stove type took considerably longer than the following tests, it was excluded from the analysis. After this, Vita test number 3, showed an anomalously large boiling time (about double the average) and it was dropped (A note to this test records that the fire went out before boiling).

[16] However, later a separate survey was conducted to interview 42 women, mainly on user experiences using Lorena. These interview results are added in a text box in the results section.

Statistical analysis (F –test in one-way ANOVA) shows that there are clear differences in mean boiling time between stoves. The table of means shows that the 3-Stone fire has clearly the longest boiling time, 3 to 6 minutes longer than improved stoves. The Vita stove (with or without chimney) is fastest if the Vita with the chimney is used without pot holders. Using without pot holders allows the right size of a pot close the top gap between the stove and the pot. With the same pot but with pot holders raising the pot up and thus leaving the gap open around the pot, the average boiling time is much longer, 10.1 minutes. There are no clear differences in boiling time among the other stoves.

Differences in firewood consumption are statistically significant (Table 3). The rocket brick and cement stove uses clearly more firewood than the other stove types, though it is likely that after the stove has been heated up, its firewood consumption would be more efficient. The rest of the stoves are very similar, though Lorena tests are very variable (Figure 3).

Table 2. Time in decimal minutes to bring 2 litres of water to boiling.

Type	3-Stone	Brick and cement	Lorena	Upesi with removable bottom	Upesi made of one piece	Vita with chimney used 'wrongly' with pot holders	Vita with chimney used without pot holders	Vita
Minutes	13.1	9.9	9.1	9.4	9.8	10.1	7.4	7.4
p=0.027								

Table 3. Firewood consumed (in grams) for bringing 2 litres of water to boiling.

Type	3-Stone	Brick and cement	Lorena	Upesi with removable grate	Upesi made of one piece	Vita with a chimney used without pot holders	Vita
Firewood consumption	303	528	313	259	266	288	258
p <.001							

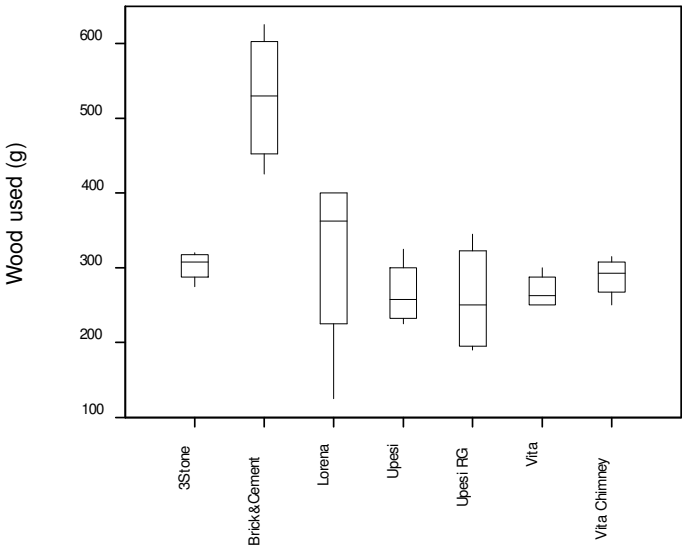

Figure 2. The mean and variation of firewood consumption (g) used to bring 2 liters of water to boiling.

It is clear after the tests that cooking food that needs cooking longer time (the controlled cooking test results) is a better way of assessing fuel wood use.

Controlled cooking tests

Figure 3 shows firewood consumption of the stoves tested by boiling 3dl of green grams in 2 litres of water till ready to eat. It took on average 39 minutes to cook the beans after the water had started boiling. The extreme values for 3-Stones and Vita occurred when it was particularly windy and were removed from the analysis.

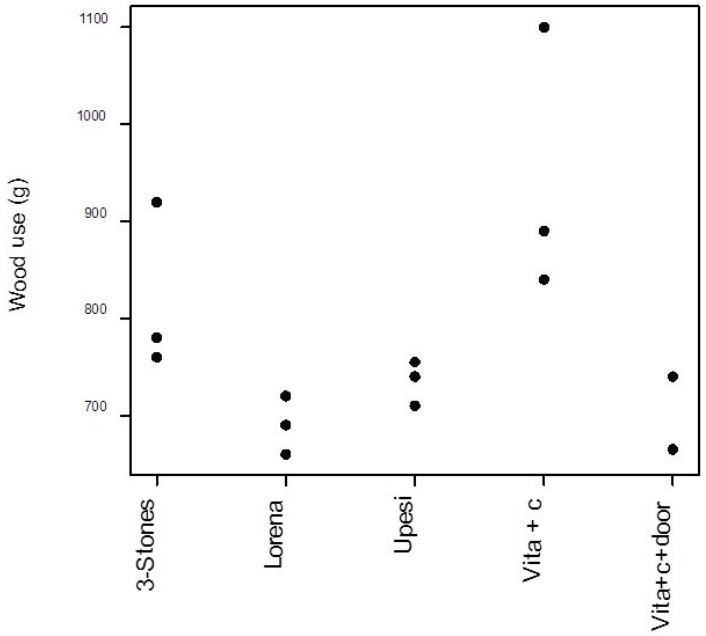

Figure 3. Firewood consumption of the test repetitions.

When testing Vita with chimney, it became apparent that due to its chimney it gets a very powerful draft. This means not only that firewood catches fire very easily, but that it gets consumed very quickly, burning fiercely leaving no charcoal. Thus two extra tests were conducted for Vita with chimney with its door blocked. This improved its firewood efficiency considerably.

Table 4 shows the average firewood consumption of the tests. The difference in firewood consumption between the stoves is statistically significant. Lorena, Upesi and Vita with chimney and door use distinctly less than 3-Stones. However, Vita without door uses more than 3-Stones.

Table 4. Firewood consumed (in grams) in cooking 3 dl of green grams in 2 litres of water.

Type	3-Stone	Lorena	Upesi with removable grate	Vita with chimney	Vita with chimney and door
Firewood consumption	770.0	690.0	735.0	865.0	702.5
F pr <.004					

User experiences (Interviews)

All the stoves were very much liked by their new owners and it was difficult for the users to come up with any suggestions for improving them. Lorena and Upesi seem the most popular of the stoves. This is a summary of opinions collected in the interviews.

Lorena

Lorena is particularly liked due to its chimney that takes all the smoke out of the kitchen through the wall and due to allowing two pots of food to cook in one go with the same fire. This seems a huge step in development in a local kitchen. As one woman put it: "Mama Liana, I want to say thank you on behalf of all the women in the groups in Mgagao, because you have revolutionized our cooking. Now we cook in style like Europeans with a smokeless kitchen and two pots of food being prepared at the same time."

The other positive aspect of Lorena is its efficiency and quickness. They praise its ability to cook tea in just ten minutes and beans (maharagwe) in 1-1,5 hours shorter time than with three stones. They think that getting the second pot heated as well comes without any additional energy use. If they do not need to use both pots for cooking they use the second pot to heat water for washing.

Women also claim that they have reduced their firewood consumption (and thus for some the cost of firewood) by about half after getting a Lorena or both Lorena and Upesi (one woman even claimed that it had reduced it to 1/3: instead of buying three bicycle loads per week she now buys only one). The firewood consumption question was cross-checked carefully by asking about the time used for firewood fetching or money used weekly to buy firewood and head loads or bicycle loads of firewood used in a week. Both answers always indicated about halving the firewood consumption.

Another aspect that makes this stove popular is its ability to use long firewood that can be fed little by little into the fire. Yet the stove is safe to children and the cook. It leaves soot only on the bottom of the pot. It is steady to stir food because the stove is made to fit a certain pot that sinks some way into its place. It produces good embers that keep the stove hot a long time. And it looks very good in the kitchen.

The stoves have also lasted very well. Yet, they use these stoves 2-3 times every day. The soil in Mwanga is good for clay stoves (this same stove model did not work well for a village in Moshi district where the termite hill soil had so much sand in it that the stoves cracked very badly). Some women repair their Lorena every 3-4 months, some smear it by new clay every week, one covered the initial cracks one month after it was built and has done nothing since then, and some have not done anything since it was built about a year ago. One interviewee had plastered the stove with a thin layer of cement.

Two women thought that a high chimney going through the roof would be better and would solve the problem of wind blowing straight to the hole in the wall pushing back smoke. No other improvements were suggested. It is good just as it is.

We interviewed 42 persons out of 109 who had taken part in the Lorena building courses. 41 of them had a Lorena stove in their house, two of them had a Brick and cement stove, four of them reported of having a Solar cooker (Cookit), three had Upesi clay stoves, one had a Mud and brick stove built by a local NGO from Same, one had a charcoal cooker, and 11 reported of still having the 3-stone fire (mainly for a special purpose like cooking doughnuts or roasting maize).

Lorena was by far the most popular stove. Thirty-seven interviewees ranked it as 'best to use'. Those two who had had the expensive Brick and cement one built, both ranked their brick and cement stove as the best. Three persons still preferred the 3-stone fire. This was because the chimney of their Lorena was blocked and they were not able to use their Lorena.

The reasons why Lorena was perceived as the best stove were several. It was mentioned 33 times that it saves a lot of firewood. The benefit of smoke-free kitchen was mentioned 24 times, its quickness to cook 20 times, and in addition easiness of lighting, the benefit of enabling two pots to cook at the same time, and heat preservation were mentioned by few.

Thirty-eight Lorena users use their stove more than once a day. The level of maintenance varies a lot. Some have smeared it with clay 12 times since they built it (about a year ago) and some haven't done anything at all.

There was basically no suggestions to improve the Lorena. But because many of the Lorenas were built with a short chimney that pushes the smoke up to the room above the cook's head (not the one that goes out from the wall) users thought their stove should be modified so that all the smoke went out from the wall. Twenty-eight interviewees reported that they don't yet have a smoke-free kitchen. Four users reported that their chimney is often blocked. The likely reason for this is that the hole of the chimney was built too small. Banana stem is one of the best objects around which to build the chimney, however, as no one cultivates bananas in this area, any piece of wood was used for the purpose. Sometime builders might have chosen too thin a branch and the diameter of the chimney was built too small.

The average household size was 5.9. It varied between 2 and 11. All of them report very big savings in firewood usage. Most typically they used about 2-3 head loads per week before their improved stove. Now they are using only 1 (some big households were using 5-6 loads before and now they use only 2). The same applies in the number of times per week households go to fetch firewood. In most cases they went 2-3 times before and now they go only once.

Upesi

Upesi is another very popular stove. It is liked because it cooks very quickly with very little firewood, it is very easy to light and leaves good embers. Those who have both Lorena and Upesi claim that it uses even less firewood than Lorena (but it is not easy to compare, as one cooks two pots of food and the other only one pot). They typically use it for making morning tea when they do not need to heat a stove with two pots, though women also claim that Upesi is good for cooking things that take a long time. It absorbs the heat and thus keeps the food cooking with no need to monitor the fire all the time. One interviewee had noticed that it is good to block the door while simmering food and thus preserve the heat inside the stove. With the door blocked it makes a lot of good embers to cook a long time and to heat water after cooking.

Upesi was commonly praised for its portability enabling cooking wherever one needs and wants, also outdoors. One interviewee was using it to heat his chicken hut, to keep the young chicks warm

during the cold hours of early morning. Someone also mentioned that it is very good for tiny pieces of firewood, like carpentry leftovers that would not be useful for other stoves. It also looks good, "even better than Vita and neighbours who see it admire it".

It did matter to most interviewees that Upesi produced smoke in the kitchen, however others did not seem to mind that it does not have a chimney. They claimed that it burns so well that the amount of smoke is nothing compared to that from 3-Stones. Some had noticed that it smokes when you light it, but not when it is burning properly. It also leaves soot only on the bottom of the pot.

There were not many suggestions from the interviews to improve the design. One interviewee suggested that Upesi should have handles. It was also mentioned that something like a shelf would need to be in front of it to enable feeding long firewood (a brick would do the job). Two users (one interviewed the other not) reported that their stove had broken – one lost a leg and the other cracked from above the door. One of the boiling point test stoves lost one of its pot holders. The holder is a little knobble inside the stove on top of which the removable grate rests. If the holder reached all the way to the ground, it would probably last better. It is interesting that the potter who makes Upesi stoves still thinks that the original Upesi (the 'liner' which is just the clay wall without a bottom and meant to be built into a table structure) is better than the improved models. The main reason for this is that she thinks the simple 'liner' is more robust especially when children cook. There is nothing in it – such as the grate or the pot holders - that can break.

Vita

Vita with chimney is liked specifically because it has a good draft to make it easy to light and keep the fire going, and the short chimney takes the smoke high up where it does not bother people. In general, users think that the stove does not produce much smoke because it burns so well. It leaves the pot sooty only on the bottom.

Vita is also seen as the most durable stove and very good looking. However, it can become dangerously hot to touch, though it is not hot for the cook to stay close as heat is contained in the stove quite well. Compared to Lorena (basically free of cost) and Upesi (Tsh 4500, € 2.25), Vita is seen as an expensive stove with its Tsh 30,000 (€ 15) price.

Users claim reduced firewood consumption. A hotel keeper who uses it mainly for quickly cooking foods quantified this as follows: he has cut down his firewood consumption per week by 40% because he has reduced the money used for buying firewood from Tsh 10,000 per month to Tsh 6000 per month (one bundle is Tsh 2000).

To make it more useful to more users it should come in two or three different sizes. For two of the families interviewed it is too big. One of these families later bought an Upesi and use the Vita only when they have guests. The other uses mainly Lorena because their Lorena was built to fit small pots suitable for three people only. However, the hotel keeper said that he needs to use 3-Stones when he needs to use a bigger sufuria than the one that fits the Vita.

The same interview who suggested blocking the door of Upesi when keeping food simmering suggested the same for Vita. Another user, a metal builder, suggested that as a lot of heat gets into the chimney he should partially block the top of the chimney to reduce the draft.

Brick and cement rocket stove

The Brick and cement stove is a rarity due to its high cost (about Tsh 100,000, € 50). However, those who invested in it are very proud of their stoves and think they are very good to use, fine looking and thus a good investment.

They use the stove for all cooking and think that it saves firewood. It keeps the heat inside very well if the door is closed. Most of the time there is enough charcoal to start a new fire. If you leave a pot on the stove for the night over the coal, you have warm water in the morning. To keep fire going on hot embers, one needs only one or two pieces of firewood to cook.

It is a fine stove with tiles on top to keep it shiny clean. One can do all the preparations on the tile top. It never becomes hot from the surface and thus is convenient to the cook and safe with children.

As it is made to fit a certain pot, it is steady to stir and smoke does not escape from between the pot and the stove. Thus pot only gets sooty on the bottom. It takes all the smoke out to the chimney through the roof.

And the Brick and cement stove is of course considered very durable.

Discussion

Trade-off between bringing the water to boil fast and saving firewood for cooking

As the controlled cooking tests also recorded boiling time (from when the pot was laid on the stove to when the water started boiling), as an additional exercise, results of the cooking tests were combined for an analysis with the boiling point tests. Figure 4 depicts the average, the spread and the extremes of both results.

The results for 3-Stones are very similar for both test sets (boiling point tests and controlled cooking tests). However, the cooking tests had generally longer boiling time than the boiling point tests. This is because the cooking tests aimed not to have too large a fire burning once boiling started, so that fuel would not be wasted during simmering. The largest differences between the two tests are for Lorena. The very long Lorena boiling times for cooking tests are certainly due to trying to keep the fire small in order to save firewood during the whole test. Lorena retains glowing embers as it does not have a grate and thus, after some wood has been burned, can keep a very small fire going.

These differences and the fact that different firewood was used for the boiling point tests and the controlled cooking tests mean it does not necessarily make sense to combine the two sets of data in a single analysis. What makes this comparison useful though is that it shows how much variation in performance is possible with different operators using the same (or very similar) stoves for different cooking purposes.

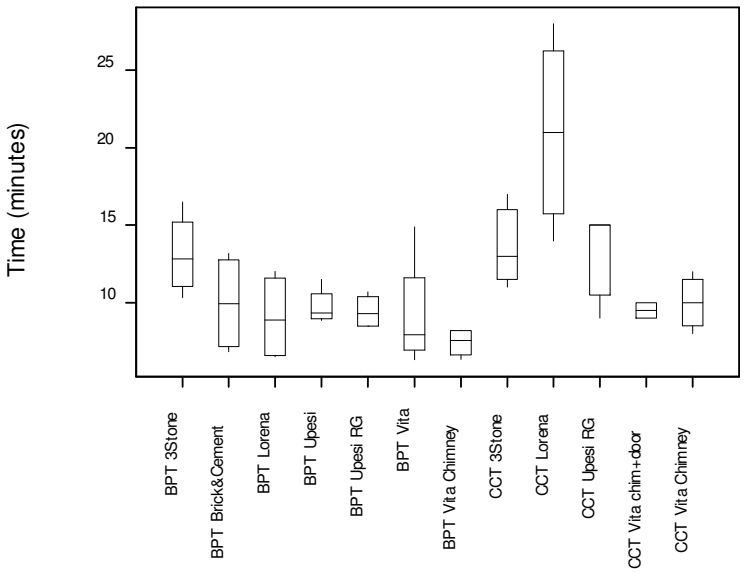

Figure 4. The average, the spread and the extremes of boiling times of 2 litres of water. The graph combines the results of the boiling point tests (BPT) and the boiling times taken from the controlled cooking tests (CCT).

The aim of the controlled cooking test was to try to cook the beans with as little firewood as possible. For this it is essential to keep the fire just big enough to keep the beans simmering. The time to bring to boiling could be minimised by making a large fire. However, the fire would then be too large for simmering and hence waste wood. Thus there is a trade-off between quickly getting the pot to boiling and minimising wood used for the whole cooking time.

Vita with chimney was the most difficult stove to keep a small fire burning. A large fire produces more heat than needed (nearly all water had evaporated from the Vita test that used most wood), but a small fire can die out. But Upesi has also such a good draft from the grate that it easily burns too fast. The door on Vita helps a lot – a very small fire will burn continually and not be in danger of going out. A bit of practice would allow wood use to be further reduced in the Vita with chimney and door and Upesi.

Controlling variation

In conducting experiments there is always a trade-off between controlling variation and keeping the context real. In addition to the actual design of the stove, testers have earlier recognised five principal factors that can influence firewood efficiency of a stove: 1. cook's fuel tending habits, 2. fuel (type and quality), 3. pot, 4. food, and 5. possible presence of wind[6].

We standardised by keeping the same operator, firewood and stove used for each test, thereby increasing the precision of comparison between stoves. But in doing so we miss out on the possibility of using operators that have become skilled at use of a particular stove, or optimising firewood size or type, and understanding variation between different stoves of the same type.

Conducting experiments by using fire in field conditions has many uncontrollable and unpredictable aspects that result in several sources of variability. One can never light the fire in exactly the same way and the fire never catches the firewood in the same way. Decisions need to be made when to lay

the pot on the stove – when the firewood has caught the fire 'adequately' to keep going, but not let the firewood burn too much before putting it on and starting to measure time. Decisions need to be made on how large to make the fire, when to add or stop loading wood, what type and size of firewood to use, how often one can raise the lid and check if the water is boiling. Wind changes within the testing hours and days and sometimes have gusts. And one learns by doing, both lighting the fire and managing it optimally.

Sample size for interviews

It may sound very inadequate to interview only 11 users for the comparative study. However, at this stage the interviews were designed to be exploratory, yet in-depth, generating insights rather than quantitative rates. Lorena and Upesi were covered by 6 interviews each and Vita by four. So, even with the small sample size, observations were corroborated by several respondents and repeating is unlikely to generate important new information. Further interviews might pick up rare things, which we were not after.

How much firewood is saved? Test results versus user claims

Claims by local adopters and by projects of 30-80% reduction in firewood consumption by using an improved stove rather than 3-Stones are not supported by these tests (Table 5).

One reason may be that the tests are conducted in windless conditions when the difference between a well shielded stove and the open 3-Stone fire does not play a big role. This is also supported by the tests. The highest wood use occurred when it was windy.

Another explanation is the size of firewood used. In the tests firewood was cut small for all stove types, including the 3-Stones. It is likely that the biggest saving by using an improve stove in local conditions comes from needing to cut firewood into small pieces (however, extra time and energy will be consumed by doing so). Traditionally firewood for 3-Stones is used as it is fetched without cutting it further. An improved stove has purposefully so small door that cutting one's firewood is necessary.

Table 5. Firewood consumption of the improved stoves in the controlled cooking tests compared to 3-Stones.

	Wood use (% of 3 stones)
Lorena	90
Upesi	95
Vita	112
Vita+door	91

Other factors influencing stove choice

It is important to note that it is not merely firewood saving (and thus saved money or collection time) that matters to people when they make a decision to acquire an improved stove. Projects like to talk about 'firewood-saving' stoves or 'energy-saving' stoves, and these have become standard collective names for these improved stoves. However, equally suitable would be to call them 'smoke-free' stoves. Lorena could be primarily a 'multiple-pot' stove. As is seen from the interview results, it is a

myriad of things that make the women happy about their new stoves. These stoves have helped the women make a considerable step forward in development. The stoves have brought increased sophistication in their cooking and the resulting pride of having a good looking and well working stove in their kitchens.

Scope for further improvements

The interviews (and tests) showed a few suggestions for further improvement of stove models, such as making the Upesi stronger, controlling the draft on Vita and Upesi , and stopping Lorena from cracking when built of low quality soil. The sources of variation in test performance also point to opportunities for improving stove efficiency, such as ensuring stoves are sheltered from strong winds and controlling the draft by blocking the doors for slow burning.

Tests also showed that there is considerable scope for learning to manage the fire and stove to reduce wood use. If the fire is carefully monitored and the fuel is cut small, then wood used for long cooking tasks can be reduced. The cost is the attention needed and the effort to cut up firewood. Other testers have emphasised the importance of using really dry fuel. The fuel used in our tests was well dried, but many families use wood which is not dried, often because of the constraints of only being able to collect a little at a time and needing to use it immediately.

The danger of non-scientific local innovation is that a model, carefully designed, changes into another product that does not any more work well[17]. One example is the suggestion of changing Lorena's short chimney though the wall into a long pipe through the roof. It would be likely to increase the firewood consumption of the stove considerably. Local innovation needs to go hand in hand with proper understanding about how stoves work and their optimal measurements.

Conclusions

The main finding of this exercise was that differences in performance between the different models of stoves are detectable by boiling point tests and controlled cooking tests. However, differences in wood use between the improved and traditional 3-Stone fire are much smaller than those reported by users.

The 3-Stone fire has clearly the longest boiling time in the boiling point tests, 3 to 6 minutes longer than improved stoves. The Vita stove - with or without chimney- is fastest (if the Vita with the chimney is used without pot holders that allows the right size of a pot close the top of the gap between the stove and the pot). There are no clear differences among the others. The rocket Brick and cement stove uses clearly more firewood than the other stove types. The rest of the stoves (Vita, Vita with chimney, Upesi with removable grate, Upesi with fixed grate, 3-Stones) are very similar in the amount of wood used to bring water to boiling, though Lorena boiling point tests are very variable. More reliable firewood consumption results are obtained from the controlled cooking tests.

[17] e.g. Probably the so called Lorena in the IDP camp in Kitgum. See footnote 9.

The controlled cooking tests reveal that Lorena, Upesi and Vita with chimney and door use distinctly less wood than 3-Stones. However, Vita without door uses more than 3-Stones. (This test was not done to the Brick and cement stove, Vita and Upesi with fixed grate).

Lorena seems to have the most potential stove for adoption by large numbers of rural Tanzanians due to its affordability and all the good qualities detected by users. It makes the kitchen smoke free, it saves firewood, it is easy to use, it gives the possibility to cook two pots in one go, it is quick, it does not become dangerously hot on the surface, it retains charcoal and it supports the local labour saving habit of using long firewood.

Another stove with good potential is Upesi, though it will never compete with Lorena because it still smokes in the kitchen. Vita will, for the foreseeable future, remain a rather marginal stove due to its high price, the Brick and cement rocket stove even more so.

All the stove models are very much appreciated. It is not only their firewood-saving quality that matters. It has been an important step for the women to improve their cooking conditions by any of the stoves introduced. It is important that people can choose from several options. By building the stoves locally projects and local markets should offer variety as well as be open to local innovation to improve them.

In order to get any measurable positive environmental and health impacts by improved stoves, massive scaling up is needed. Our experiences show that even though the new users are very happy about their stoves and their neighbours come and admire their stoves, and there are trained builders within the village, there is very little spread of the stoves beyond project participants. This suggests that scaling up needs active support by either the NGO sector or the local government. It should not have high subsidies[18], but it should raise awareness and mobilise people. Any large-scale efforts to bring these stoves to more families should use methods that: 1. Continue to offer a variety of options, as the stoves have different good points and weaknesses and not all users value the same models and 2. Allow local and scientific innovation and continued development of stove models, as there is scope for further improvements. These need implementing in ways that do not reduce the quality of stoves offered.

[18] A good report about what makes stove projects work well (showing subsidies make them less sustainable): Douglas F. Barnes, Keith Openshaw, Kirk R. Smith, and Robert van der Plas 1994. What Makes People Cook with Improved Biomass Stoves? A Comparative International Review of Stove Programs. World Bank Technical Paper Number 242. Energy Series.