Introduction of Rocket Stove Cooking Devices (Household Stoves, Bread Ovens and Institutional stoves) into SADC Region

Chomoio, Mozambique

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Draft Report

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Attached Appendixes

1.0 Terms of References (Nov 10th-Dec 8th 2003)

The original Terms of Reference specified three goals for Mozambique:

1. To work with the World Food Program, local metal workers, and local schools to design, produce, and disseminate a prototype fuel-efficient institutional cook stove to support WFP's school feeding programs.

2. To collaborate with Werner Klaus of DED to introduce a Rocket Bread Oven suitable for baking Portuguese Style bread rolls.

3. To work with local tin smiths to design an inexpensive single pot Rocket stove for the household market

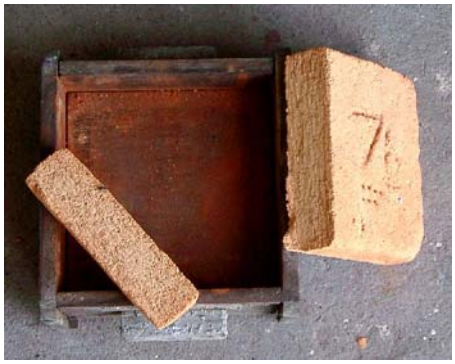
2.0 Material Outputs

Five MangiMangi 60L stoves were constructed. The students at the technical school also designed a 150L stove - which was partially constructed but not completed - before the consultant departed.
Retail price: approx US$48-US$70

2 prototype Portuguese Rocket Bread Ovens were constructed. These ovens are still in the early development phase and are not ready for commercial dissemination.
Retail price: approx US$ 212- 250

Approximately **16 single pot MangiMangi Household stoves** were constructed. These stoves are light (approx 7kg), simple to make (1 artisan can make 3-5/day) and inexpensive. Retail price: approx US$12-15)

Approximately **33 clay/sawdust test bricks** were produced and fired with cooperation of DED and Ceramica Vila Pery (Chomoio). These bricks are highly insulative and inexpensive to produce. Retail price per brick: approx US$0.15



3.0 Design Training and Stove Manufacturing

An informal 2.5-week training was held at Escola Technicos Y Artificios (the local technical college in Chomoio). A number of metal workers from around the city were invited to attend the training. One independent tinsmith (who specialized in the production of tin water buckets), 3 alumni and a professor from the Escola, and two employees from Savepla attended the course. The students **learned to produce the bread oven baking compartment, the MangiMangi 60L, the MangiMangi household and the new vermiculite cement bricks**. The goal of the training was twofold: to produce prototypes for testing and to teach the students how to independently design a stove using first principles of clean combustion and heat transfer. (**See Appendix A for Rocket stove design principles).** Near the end of the training, the students were able to design and construct a larger stove (suitable for the school's 150L institutional pot) with minimal guidance and supervision.

After the training, the tinsmith, the school alumni and Savepla were keen to set up three independent businesses to continue stove construction. This approach of employing metal workers and students to build prototypes (at a minimal cost) while training them on design principles appears to be a useful strategy for initiating stove projects.

4.0 The Portuguese Rocket Bread Oven

4.1 Constructing the bread oven

See appendix B for construction detail

4.2 Design Challenges

The Portuguese style oven presents a number of unique challenges that we didn't encounter with the Uganda or Lesotho Style oven. In the latter, bread is made in loafs that are baked in pans. The bread is baked with circulating hot air at approximately 180 degrees Celsius. These temperatures are not difficult to reach with a rocket bread oven and there is sufficient heat to bake multiple trays of bread. This allows for a large volume of bread to be produced with a single combustion chamber.

The Traditional Portuguese style oven is different. The bread is baked using conductive heat that is transferred from the combustion chamber into clay bricks and then directly into the bread itself. Higher temperatures are needed in this style of oven (approx 300 Celsius**). The traditional oven is extremely inefficient, relatively expensive to build and is not very durable.**

During my first week we interviewed two bakeries to learn about their baking practices. The first baker that we went to (where we didn't actually build an oven due to complications with oven ownership) told us that to bake rolls equivalent to six 50kg bags of flour he

required 5-6 trunks/day, 6 days/week and that each trunk cost approx 45, 000 Meticais. He was quite surprised when we told him that this amount of wood would cost him roughly **$2906- 3487 per year.** Given that wood prices are so high in Chomoio, and that an improved oven could quickly pay for itself, I would recommend that **we put more resources into oven R&D.**

4.2.1 The Rocket Style Bread Oven

Producing a Rocket style bread oven that can bake Portuguese rolls presents a number of challenges:

1.The higher temperatures that are needed put a greater strain on the metal baking compartment

2. Uniform temperatures on the clay-baking slab are required because the bread is baked directly on the clay tiles,.

3. Unlike the Lesotho style oven, which has multiple baking racks, only the bottom of the oven can be utilized for baking. This means that less bread can be baked with a single combustion chamber.

4.3 Stove costing

Mozambican Bread Oven

Material	**Cost (M)**	**No. Required**	**Total cost**
Bricks 30*20*15	5200	80	416000.00
Bricks 30*20*10	4700	40	188000.00
20 x 20 x 1.6 Square tube	295000	3	885000.00
zinc sheets	225000	2	450000.00
1225*2450*2.0	1315000	0.5	20000.00
1225*2450*1.6	1190000	1.5	1785000.00
50Kg Cement	140000	3	420000.00
clay tiles for oven base	4000	16	64000.00
bag vermiculite	150000	2	300000.00
Overheads	15%		679200.00
		TOTAL	**5207200.00**
		Manufacture time in days =	**6.00**
		Labour charge per day	**200000.00**
		Subtotal	**5407200.00**
		Business Profit (10%) =	**540720.00**
		Total	**5947920.00**

The price of the oven (approx US$238) would be reduced if a cheaper type of brick were used. After completing the construction of the bread oven we found a brick that only cost 1000 Meticais each. By substituting this cheaper brick we could **lower the price by approximately 22 dollars**

4.4 The way forward

Unfortunately, due to the usual challenges – locating a cooperative bakery partner, collecting materials, finding appropriate builders, etc- the construction of the oven was slower than desired. The 2 ovens were not completed until after I left Mozambique. This meant that the bakers could not be trained to use the new oven. Not surprisingly, this lack of training has led to a number of problems such as over-firing the oven with too much wood, burning the bread and improper use of the shelf. However, from my on going conversations with Werner, it seems that the bakers are now using the ovens successfully. Of course, they might still be using too much wood, or using the stove inefficiently, so obviously more training is necessary.

One of the first complaints was that the oven burned the bottom of the bread before the top was baked. This problem seems to have been rectified by regulating the volume of wood that is placed in the combustion chamber. The second complaint was that the oven took too long to reach baking temperature (approx 1 hour). To rectify this problem, ore insulation is needed around the baking compartment to reduce the preheating time. I would recommend building a 10cm slab of cement vermiculite on top of the bread oven. This can be made with 50% less cement than the normal bricks (85 grams of cement per litre of vermiculite instead of 170 grams. Generally speaking, more data needs to be collected before future recommendations can be made.

We should build future oven combustion chambers with both cement vermiculite and clay/sawdust bricks to test durability

4.4.1 Oven Design: **two options**

It should be pointed out that there are two broad categories of wood fired bread ovens: white ovens and black ovens. The traditional Mozambique oven and the new Portuguese Rocket Bread Oven are both types of **white ovens**. In this type of oven the fire is built **outside** of the baking compartment. The hot flue gases wrap around the baking compartment and transfer their heat in to the baking compartment via convective flow.

A **black oven**, on the other hand, is similar to an Italian style wood fired pizza oven, where a fire is built **inside** of the baking compartment before baking, and the radiant and conductive energy of the fire is transferred directly into the massive walls of the clay or brick baking compartment. The fire is then

extinguished and the bread is placed inside the baking compartment. The bread is baked using the retained heat of the massive oven walls. . If properly constructed, with sufficient insulation around the baking compartment, this can be an efficient type of oven.

If the bakers are not satisfied with the Rocket style oven, or if there isn't sufficient wood savings to make the investment viable, then we can build a black oven prototype and compare the results between the two.

5.0 School Assessment

Mozambique, in contrast with Lesotho, presents us with an even greater opportunity for the successful dissemination of institutional stoves because:

- The MangiMangi stove is considerably cheaper and easier to use than in Lesotho.
- Fuel wood prices are skyrocketing in urban areas.
- Schools often pay for wood themselves

So if we can't create a self-sustaining stove business here then we will be hard pressed to do it anywhere in SADC.

5.0.1 First School visit

ADPP (Formigas del Futuro/Ants of the Future) was the first school that we visited. It is presently a semi boarding school (with a total of 215 students) but is in the process of expanding its boarding facilities. They cook 2 meals per day: for breakfast they use one 100L aluminium pot; for lunch they use three 100 L aluminium pots (1 for curry, 2 for sudza/pap). As you can see from the opposite photo, one pot is cooked outside on a three stone fire while the other is cooked in the same manner inside the covered cooking area. As the weather was fine it was unclear why they chose to cook outside and 'inside' at the same time. They do not dry their wood; they purchase whatever wood is available - sometimes wet, sometimes dry. They only purchase wood and never collect it. If they are able to purchase the wood rurally, it costs US$8 /week, if they buy it in the city then it costs US$40/week. This means that their **annual wood cost ranges between US$416 and US$2080 per year**. In each of the last three years the price of wood has

doubled - **a 6 fold increase in the last three years**! The school pays entirely for the fuel wood through school fees and additional donations. **This school, and other urban/per urban schools that purchase fuelwood, clearly have an incentive to purchase an improved stove like the MangiMangi.**

The Mozambican government pays the teachers and the cooks salaries and they are *supposed* to pay for 23% of the school's food expenditures but have not done so in a long time. At the moment, WFP provides 77% of food and the school pays for the other 23%. This amounts to cooking expenditure of US$433/year above and beyond the price of fuel wood.

Upon my arrival at the school I was brought to the 'improved' kitchen that had recently been built. They showed me the 'stove' that is pictured in the adjacent photo. The basic idea of the stove is that wood is fed from the **outside** of the building and the cooking is done on the **inside**. The wood is inserted under and through the grate and into the arched cavity. Inside the kitchen (not visible) the pots are placed on top of the bricks – roughly behind where the arches are visible in the picture. Obviously trying to heat the pots through the bricks was wasteful and time consuming and was therefore quickly abandoned, as was the idea of cooking inside a permanent kitchen. I offer this cooking technique only to highlight the contemporary level of ignorance of proper stove construction.

6.0 The MangiMangi Institutional Stove

6.1 Constructing the MangiMangi

See Appendix C for construction detail

The MangiMangi stove is similar to the Nkokonono but has a couple of unique differences. First, the stove is cheaper and easier to build and second, it features an insulated top plate. This top plate has two features: it improves heat transfer into the pot and it increases the longevity of the stove, as there is less metal exposed to open flame. Although no lab tests were performed

on the MangiMangi, an informal test showed that it could boil 40 Litres of water in 35 minutes with 2 kg of wood. Cooking tests as well as a WBT should be performed on the stove to ascertain its overall efficacy. Initial response from cooks at Formigas del futuro has been overwhelmingly positive.

6.2 Stove costing

MangiMangi Institutional stove

Material	Cost (M)	No. Required	Total cost
1225x2450*1.6 sheet metal HR	1000000	0.5	500000.00
10mm Dia. Bar (6m)	109000	0.6	65400.00
25 x 25 x 3 angle (6m)	250000	0.2	50000.00
25*25*1.5 square tube	295000	0.3	88500.00
50kg Cement	140000	0.2	28000.00
90L vermiculite bag	150000	0.5	75000.00
Overheads	15%		121035.00
		TOTAL	**927935.00**
		Manufacture time in days =	**0.50**
		Labour charge/day =	**200000.00**
		Subtotal	**1127935.00**
		Business Profit (10%) =	**112793.50**
		Total	**1240728.50**

This brings the retail price for the **MangiMangi to a minimum of US$48**.

The owner of Ceramica Villa Peri estimated that he could produce and sell sufficient bricks to make one institutional stove for approx US$2. This would lower the retail price to about US$46.

6.3 The way forward

A report has come back that the insulation of the top plate of the 2 stoves that were transported to Beira were cracked. It was not clear if they cracked in transit of during firing. More data needs to be collected on this situation

We should proceed with the two types of combustion chambers. 50% of the Mozambique stoves should be made with clay/sawdust bricks and the other 50% should be made with cement vermiculite. Both bricks need to be tested for durability.

More clay/sawdust test bricks need to be made and fired as we still do not have the ideal brick for the combustion chamber. Although we have a number of test bricks that would be suitable for prototypes we still need to refine the recipe to increase the 3 point bending strength and abrasion resistance of the bricks. I

have heard that there is white clay that is found on the road to Beira. This clay - if it is at all similar to other types of white clay - could be used as an adjunct to our existing mixtures.

6.3.1 Long term

If we can find a suitable sawdust/clay mixture all of the institutional stove combustion chambers should be built exclusively with this mixture. However the top plate will still need to be made with the cement vermiculite mixture.

A user manual needs to be produced to accompany the stove

We need to understand how usage/ consumption patterns vary between the wet and dry season

Note: the MangiMangi 60L (or a larger version of it) should also be marketed to beer brewers, funeral service providers and hotels

7.0 The MangiMangi Household

Most of the focus of the 4 weeks in Mozambique was placed on the bread oven and institutional stoves. Our household stove is still in its infancy. Before we proceed more data needs to be collected on fuel usage patterns in Chomoio and more time should be spent perfecting and testing the household stove. One of the challenges was that the stoves needed 10+ days to dry. The individual bricks used in the institutional stove tend to dry in 10 days, whereas the monolithic stoves need more time. As the vermiculite didn't arrive until 2 weeks into the Contract we didn't have sufficient time to test and develop the stove.

7.1 Stove costing

MangiMangi Household

Material	Cost (M)	No. Required	Total cost
Zinc bucket	75000	1	75000.00
1225*2450*1.2	700000	0.05	35000.00
Ceramic shelf	25000	0.3	7500.00
10-16mm round bar	109000	0.1	10900.00
90L of vermiculite	150000	0.25	37500.00
50Kg Cement	140000	0.1	14000.00
		TOTAL	**179900.00**
		Manufacture time in days =	**0.20**
		Labour charge /day	**100000.00**
		Subtotal	**279900.00**
		Business Profit (10%) =	**27990.00**
		Total	**307890.00**

This brings the retail price of the stove to US$12. Some market analysis is necessary to ascertain the price elasticity of stoves in the Chomoio market. Perhaps a more expensive stove would be preferable?

7.2 The Way Forward

The 16 stoves that were produced have been distributed: each of the students from the training was given one to take home and Werner disbursed the remaining. A survey needs to be drawn up and disseminated to the users.