Some Experiments With Sawdust-Burning Stoves

Report To ETHOS 2008 by Jim Wilmes

Background

For the past two years I have been working as a volunteer in Lima, Peru, teaching people to build "rocket" stoves and ovens, mostly for use in "popular kitchens" where a group of women prepares an inexpensive meal every day for dozens of families in their community. In one of these kitchens I was shown a sawdust-burning stove made from a 10 liter aluminum container with the top removed and a small hole cut in one side. The women would place a couple of pipes in the container, one vertically in the center and the other horizontally through the hole, and pack sawdust around them, wetting the sawdust so that it would hold its shape better. Then they would carefully remove the pipes and create a small fire at the bottom of the vertical shaft. It burned without a flame and produced considerable smoke. But they liked the fact that it would continue to burn unattended for 4 or 5 hours. I offered to help them create an improved version.

Beyond my interest in helping the women of this popular kitchen, I saw an opportunity to solve one of my own problems. I frequently use my own rocket oven (made from recycled barrels) to bake large cakes that take an hour to cook. I typically spend 15 to 20 minutes stoking the combusting chamber until the inside temperature reaches the desired level of 200 degrees C, then another hour monitoring the thermometer and tending the fire. I wanted to find a way to avoid having to tend the fire while the oven was baking, and it seemed to me that a steady-burning sawdust combustion chamber might be adaptable to the oven as well.

Prior Designs

Joseph Massaquoi of the University of Sierra Leone and Michael Bassey of the International Development Research Centre in Senegal published several papers from 1977 to 1983 about "hole through sawdust" burners for use in baking ovens, drop dryers, stoves, smokers and water heaters. They report a calorific value of about 16000 kJ/kg at a moisture content of about 20%.

They developed several prototypes of an oven. Their approach was to create multiple small holes (2cm diameter) in a mass of sawdust up to 14 cm high, situated below the baking space. While they were able to generate adequate baking temperatures of 150 to 250 deg C, they reported that it took between 95 and 146 minutes to reach the desired baking temperature, and that the time during which this temperature could be maintained was only 30 to 55 minutes. And the device produced a significant amount of smoke.

Jason Dahlman and Charlie Forst of ECHO published a design for a sawdust cookstove in 2001 based on ones he had seen used by sawmill cooks in West Virginia. His consists of a brick enclosure with an entry for air at the bottom of one side. A vertical and a horizontal pipe are placed in the enclosure and sawdust is packed around them, creating an elbow-shaped air passage. Before lighting the stove, he placed a flat metal plate with a round hole on top of the sawdust mass, and sealed the edges with a little dirt or sand. The plate drops as the sawdust is consumed and keeps the fuel burning in the center. The dirt or sand prevents smoke from exiting at the edges of the plate.

A variation of this stove was designed by Dale Fritz of ECHO using a round metal can, with a round hole cut in the bottom of the same diameter as the pipe that was used to create the empty space during filling of the stove. The can was placed on top of two bricks to allow air to enter from the bottom, and the space between the bricks was used to control the air flow. A stove 6 inches in diameter and 8 inches high was reported to burn for 3 hours, and a stove 16 inches in diameter and 20 inches high for 8 hours, with little smoke.

Other approaches to using sawdust as a fuel are continuous feed, briquetting and gasification. More information about these approaches can be found at www.bioenergylists.org.

Construction of the Stove

A single-charge sawdust-burning stove was made from two recycled metal barrels that are commonly available in Lima. The smaller of them, 24 cm in diameter and 52 cm high, serves as the combustion chamber. The larger, 44 cm in diameter and 68 cm high, serves as a pot skirt. One end of the larger barrel was cut off, leaving an open barrel 40 cm high. Two nested circles were drawn in the middle of the other end of the barrel, with diameters of 14 cm and 24 cm. The inside circle was cut out, and then cuts were made every 2 cm from the inner to the outer circle, perpendicular to both, creating "teeth" 5 cm long. A small hole was drilled in the middle of each tooth large enough to accommodate a rivet. These teeth were then folded inward at a 90 degree angle.

A hole 5 inches in diameter was cut in the bottom of the smaller barrel. The top of the smaller barrel was removed and this barrel was then inserted into the hole in the larger barrel until it was aligned with the ends of the teeth. Holes were drilled in the small barrel using the holes in the teeth as guides, and rivets were used to join the two barrels. A ring-shaped blanket of fiberglass wool was inserted into the 5 cm high space between the two barrels, and a ring made of sheet metal was placed on top of it to enclose the area.

A set of circular sheet metal plates were cut with the same diameter as the smaller barrel, and a hole cut in the center of each plate. These holes had diameters varying from 5 to 10 cm. By placing one of these plates in the bottom of the small barrel before packing it with sawdust, various configurations of the stove could be tested.

Four 144 cm lengths of 3/8 inch steel construction bar were each bent with two 100 degree angles to form a base of 24 cm and two legs of 60 cm each. Pairs of legs from different bars were joined at top and bottom with heavy wire to create a stand with four legs to support the stove above the ground. Another pair of bars 32 cm in length each were bent at right angles and joined in the middle with heavy wire to form an "X" that served as a pot support. The total cost of the stove was $6 to $10, depending upon the source of the recycled barrels.

Experimental Procedure

Sawdust was obtained from a local lumber yard with about 40% moisture content. The first several trials were performed with the sawdust as obtained, but for later trials the sawdust was dried in the sun on a sheet of plastic on my roof until its moisture content was approximately 15%.

The stove was configured for each experiment by placing a metal plate with a round hole of a selected diameter at the bottom of the combustion chamber. Diameters of 5 to 10 cm were tested.

The stove was weighed before filling. A plastic tube was inserted in the combustion chamber, passing through the hole in the plate at the bottom. (The tube's diameter was greater than or equal to the diameter of the metal plate. An adapter was used to keep it centered in the hole when the diameters were different.) A few inches of sawdust at a time were packed around the tube until the combustion chamber was filled within 7 cm of the top (a height of about 45 cm of sawdust). The stove was weighed again to determine the weight of the sawdust.

Another metal plate with a circular hole was slid over the pole and placed on top of the packed sawdust. The pole was then carefully removed from the barrel. A small amount of dirt or sand was sprinkled around the edges of the metal plate. Thermocouple probes were installed just above the top of the hole in the metal plate (to measure the maximum temperature in the combustion temperature), and inside the upper barrel just below the rim (to measure the exit temperature of the gas).

A rolled sheet of newspaper was inserted through the hole in the middle of the sawdust and lit from the bottom. Sometimes it was necessary to repeat this lighting two or three more times until the sawdust was well lit. When the entire surface of the sawdust was glowing, a pot support and a 42 cm diameter pot were placed in the stove. A thermocouple was installed in the bottom of the pot and 20 liters of water were added. The temperatures were recorded until the combustion chamber temperature dropped below 100 degrees C, and occasional observations of smoke (sight and smell tests) were made. Testing was always performed after sunset to eliminate any solar heating effect.

Results

With 5cm diameter entry and exit holes, the stove holds about 6 kg of sawdust. High power is produced by the stove for the first two-and-a-half hours (bringing 20 liters of water to a boil during the first 45 minutes). The output then decreases gradually over the next two hours, after which time there insufficient heat to boil water and the smoke produces significant smoke. (See graphs from data logger below.)

In many trials, sudden spikes in the temperature were observed one or more times, which lasted 15 to 20 minutes. These were accompanied by ash and embers falling through the air entry hole, and were attributed to partial collapses of the burning surface which exposed a large patch of unburned sawdust.

If the sawdust was not dried before using it, the stove took more than three times as long to boil the water and produced a significant amount of smoke.

A tight-fitting pot skirt integrated with the stove body (maximum gaps of 1 cm between pot and combustion chamber, and between sides of pot and skirt) provided sufficient draft to maintain a flame. When there was no pot skirt, or when there was no pot placed on the stove, the fuel glowed and produced very little visible smoke, but irritating fumes indicated incomplete combustion.

For columns of sawdust up to a height of 45 cm and diameter of 24 cm, an air entry hole 5 cm in diameter and exit hole of the same size provided better performance than a larger hole.

When a temperature lower than about 400 deg C was measured above the combustion chamber, the emissions were observed to be very irritating to the nose and eyes even though no visible smoke was produced. Above this temperature the emissions were no more irritating than those of a good wood-burning stove.

An attempt to produce a "constant output" version of the combustion chamber with a constant burning area, made by inserting four triangular fuel spacers, produced inconclusive results. More testing is needed.

Conclusions

The hole-through-sawdust technique appears to produce reasonably clean combustion when sufficiently dry sawdust is used in a stove with sufficient draft.

A sawdust-burning stove should have a shutoff mechanism to prevent generation of smoke when little fuel remains.

A single-charge sawdust-burning stove has several advantages:

- The fuel itself serves as insulation for the combustion chamber for the first few hours of use, reducing heat losses through the stove body.
- It is easy to ignite using a rolled up sheet of newspaper.
- It can be extinguished by covering the holes at the top and bottom of the stove, and relit later.
- It is capable of generating high power unattended for a long period of time.
- Sawdust is widely available, and is inexpensive or free.

It also has several disadvantages:

- The stove has no "turn down" capability.
- Sawdust must be dried before use. In Lima, an area of about 8 square meters is necessary to dry enough sawdust to use the stove once every day.
- Sawdust is an irritant to skin and lungs.

Plans For Further Investigation

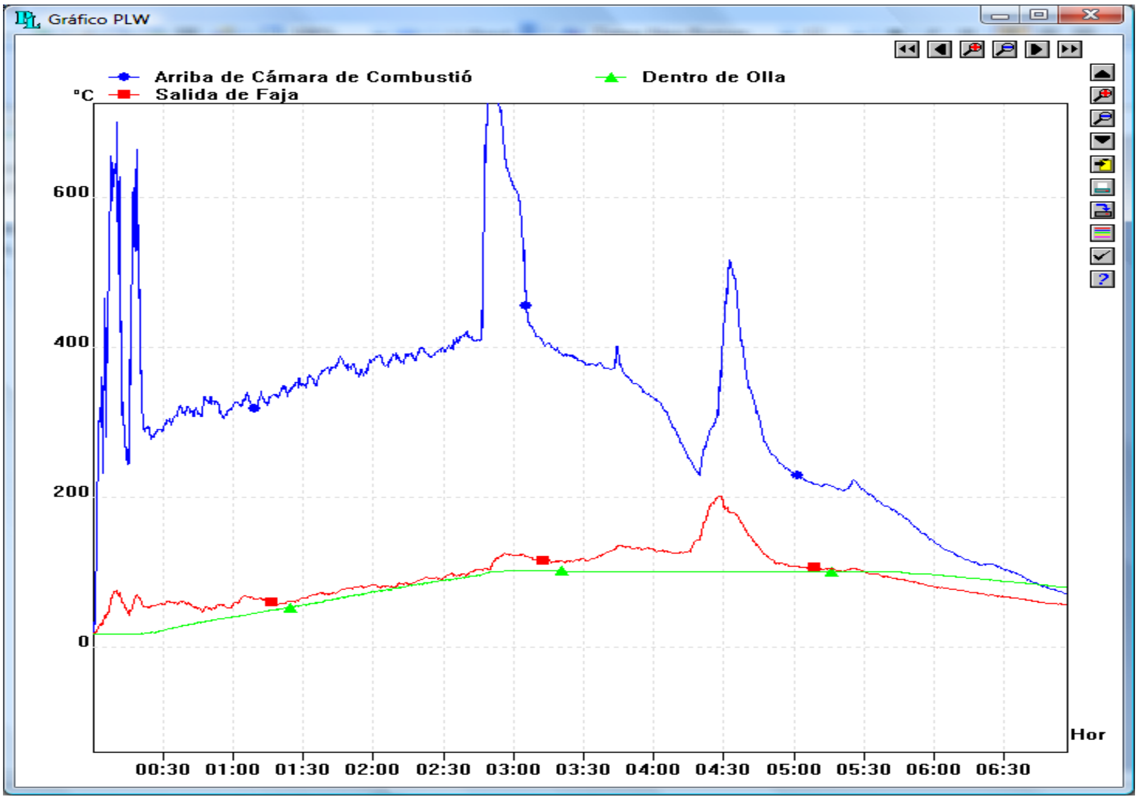
Only one or two trials of each configuration were performed, and sometimes there was significant variation between the results of two tests with identical configurations. More precise control of the moisture content needs to be implemented in order to produce repeatable results.

Almost half of the cost of the stove was attributable to the stand. A less expensive way of stabilizing the stove needs to be developed.

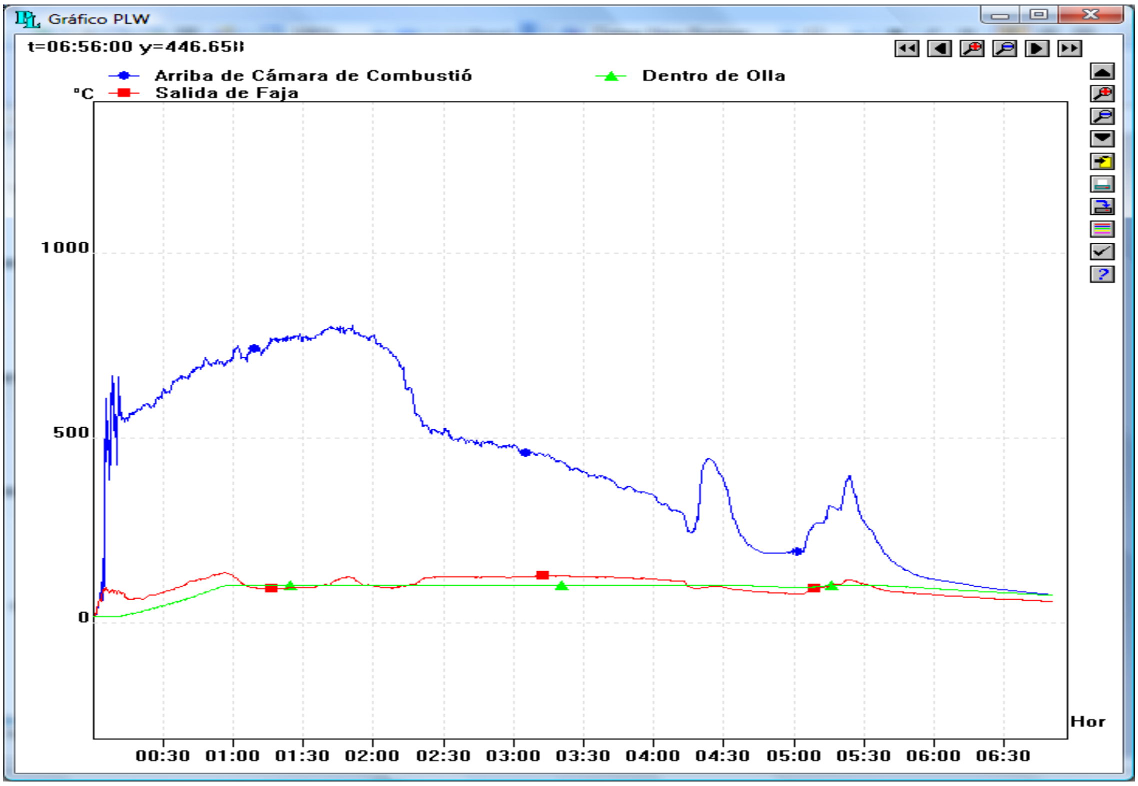
The stove can probably be fired with other inexpensive “waste products”, such as rice husks, coffee hulls or wood shavings. Testing will be performed with other biomass fuels, and with mixtures of materials.

The stove consistently burns with extremely little or no visible smoke and a high combustion temperature chamber. These are good indicators of “clean” combustion, but it would be useful to perform emissions testing on the device to find out whether it really is comparable to a good wood-burning stove on emission characteristics.

<u>Samples Of Raw Data</u>



Trial with moist sawdust, 2 inch inlet and 2 inch outlet



Trial with dried sawdust, 2 inch inlet and 2 inch outlet