PRACTICAL ACTION
Technology challenging poverty

FUEL FROM THE FIELDS: CHARCOAL FROM AGRICULTURAL WASTE

Introduction

Worldwide, 2.4 billion people use wood, charcoal, other plant material (biomass), and coal as their primary source of cooking fuel. In developing countries, the burning of biomass accounts for up to 80% of all household fuel use. Widespread burning of unprocessed biomass has well-characterized impacts on health and the environment. Indoor air pollution, which is largely due to exposure to smoke and particulate matter emitted by the combustion of unprocessed biomass, is estimated to kill over 1.6 million people each year (figure. 1); women and young children are worst affected. Deforestation also causes soil erosion, increasing vulnerability to flooding and causing lower crop yields from farms.

Figure 1: Indoor air pollution from cooking with biomass is associated with pneumonia. Photo credit: Fuel from the Fields.

The Fuel from the Fields (FftF) team developed a method of producing charcoal from previously unused agricultural waste products. Charcoal provides significant advantages over raw biomass fuels because the process of carbonisation reduces the particulate emissions, and reduces the risk of developing respiratory infections. Unlike Liquefied Petroleum Gas (LPG) or kerosene, charcoal does not require people to purchase new stoves or change the way they cook.

The background

Charcoal making is a traditional industry across the world – charcoal is an energy dense fuel that can easily be transported from rural to urban environments. In Haiti, the charcoal industry employs an estimated 150 000 people.
Making charcoal requires three conditions:

- A carbon-rich material (traditionally wood).
- Heat.
- Anaerobic conditions (i.e. it must burn without air present).

Traditionally, charcoal is made by cutting down a tree, setting fire to the trunk, and covering it with soil. The tree carbonises (turns into charcoal) over 1-3 weeks. The environmental impact is worsened because hardwood trees (those that grow most slowly) make the highest quality charcoal. The Fuel from the Fields technology involves filling a metal kiln with agricultural waste (the source of carbon.) This waste is ignited, and later sealed, to create anaerobic conditions. After two hours, charcoal is formed.

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Raw material

Charcoal can be produced from any appropriate agricultural waste. The FftF team encourage the use of biomass that has no other value – that is unsuitable for animal or human consumption, or for composting. In Haiti, bagasse (dried sugar cane) is a readily available by-product of sugar production. In other countries, we have tested corn cobs, palm fronds and coconut shells, but other crop wastes may also be used.

One full oil drum needs about 16kg of crop waste, and will produce about 4kg of charcoal.

The equipment

The FftF technology has been deliberately designed in collaboration with Haitian farmers and technicians to be an appropriate technology. All materials are readily available in the developing world; the technology can be manufactured using simple tools and welding equipment; the total equipment cost is $20-40 (All prices are quoted in US dollars).

A 55-gallon steel oil drum (figure 2). This forms the kiln, in which the waste is burned, to produce charcoal. Oil drums are used to transport crude oil and other materials throughout the developing world; they are readily available and cheap, costing around $10-20. **A lid for the oil drum is also needed**, which can be made out of scrap metal.

Figure 2: A steel oil drum with lid forms the kiln. Photo credit: Fuel from the Fields.

A briquette press (figure 3). This is a small, cheap impact press, which costs around $2-3 in the developing world, and is used to make briquettes from carbonised powder.

Figure 3: A briquette press, made from angle iron and sheet metal. Photo credit: Fuel from the Fields.

Other required materials:

- **A long, straight object like a stick** – to create a central chimney in the oil drum; it should be taller than the oil drum, and as wide as a fist in diameter.
- **Three bricks or flat stones about the same size.**
- **Rice bags or other large bags** - to crush the charcoal powder in.
- **Grated cassava, or some other starch** - to make strong briquettes, a small quantity of starch binder must be added to the charcoal powder. Grated cassava porridge is ideal, although any other starch (e.g. cornflour or cassava flour) can be used.
- **A basin –** to mix the charcoal powder with the starch porridge.
- **Matches** – to set fire to the agricultural waste.
- **Sand, mud or dirt –** to help create an airtight seal around the drum.

Preparing the equipment

The oil drum

The first time you make charcoal, the 55-gallon oil drum must be turned into a kiln. To do so, cut one large hole in the top (this is a loading hole), and a number of small holes in the bottom (these are air holes).

The holes in the oil drum may be cut with either a hammer and chisel, or an angle grinder.

- Do not use an angle grinder or any other tool that will create sparks unless it is certain that there are no flammable or explosive residues inside the oil drum.
- The drum should not contain any toxic or explosive residues.
- If it has safe residue (oil or food) a small fire should be made inside the drum to clean it out. Allow the drum to cool before starting to cut holes.
- Both flat ends of the drum must be intact. The drum cannot be used if one entire flat side has been cut off.
- There must be no holes in the curved sides of the drum.

The loading hole (figure 4) in the top of the drum may be round or square. The edges of the loading hole should be at least 8cm from the edge of the drum, providing enough space for the lid to rest on. The empty drum will be easier to move if the edges of the loading hole are not rough and jagged so people can lift the drum more easily.

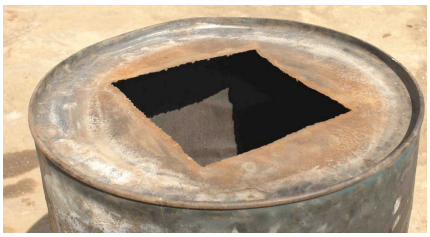

Figure 4: The square loading hole in the top of the drum. Photo credit: Fuel from the Fields.

Cut about 9 small air holes (figure 5) in the bottom of the drum to allow for air to flow through it, making a hotter initial fire. The air holes should be evenly distributed and roughly 8cm apart. One air hole should be near the centre. They can be any shape, but no more than about 8cm in diameter, to stop material falling through the holes.

Figure 5: 9 small air holes in the bottom of the drum. Photo credit: Fuel from the Fields.

The cover

You need a lid, to cover the large loading hole in the top of the oil drum. The lid should be large enough to cover the loading hole in the oil drum, (figure 2) but small enough not to extend over the edges of the oil drum. An ideal lid is made from a piece of sheet metal. It is easier to place the lid on top of the hot kiln if a handle is welded onto the lid. If you can't make a curved handle, a handle shaped like a short, flat 'T' has worked well. You can also use metal without a handle.

The briquette press

This is a small impact press used to make briquettes from the charcoal powder. The press can be round or square and can be easily manufactured by any car mechanic or local blacksmith, if they can weld metal. A round press can be manufactured using metal pipes; a square press, using angle iron and sheet metal.

The outside diameter of the cup does not have to be exact; the larger the cup, the larger the briquettes produced. The preferred size of briquettes varies in different countries. Presses made by Fuel from the Fields range from around 5 to 10 cm in cup diameter.

The press is made up of four parts: the cup, the ejector, the plunger, and the hammering station (a block is shown here) (figure 6).

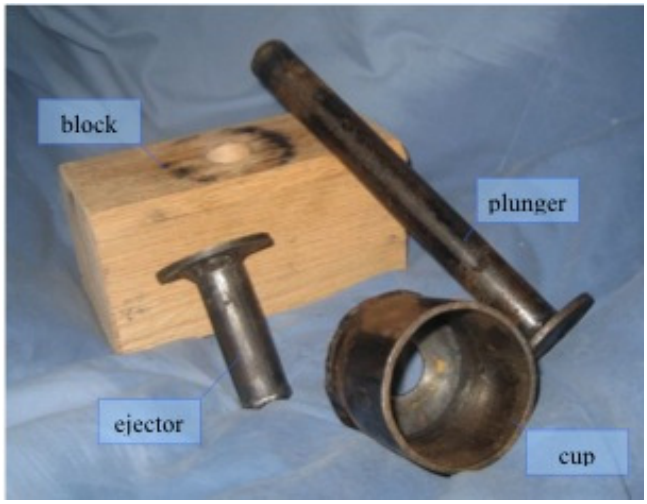

Figure 6: Parts of the briquette press. Photo credit: Fuel from the Fields.

- The cup is made from a large, hollow pipe, with sheet metal welded to the bottom. The bottom should have a hole drilled in the centre, wider in diameter than the ejector pin.
- Cut two sheet metal discs, slightly smaller in diameter than the inside of the cup. These form the ejector and plunger plates.
- To make the ejector, weld the ejector plate to a short length of pipe. The ejector should be as tall as the cup. When using the briquette press, the bottom of the pin is pushed on the surface of the hammering station, to eject the briquette. If the ejector is as tall as the cup, the briquette is ejected completely, and the ejector pin stays in the hole at the bottom of the cup.
- To make the plunger, weld the plunger plate to a length of pipe.
- The hammering station is made by drilling a hole into a table or block of wood. The hole must be larger in diameter and length than the ejector pin, but smaller than the diameter of the cup. This allows the base of the cup to rest flat on the surface of the table, with the ejector pin dropping through the hole, while the press is in use.

Making charcoal

The process of charcoal production is as much an art as a science. It requires experience to produce high quality charcoal, and to get high yields of charcoal from an oil drum. The method must also be adapted slightly for different materials. Whilst this guide provides approximate details, the time required at each stage is variable; there is no substitute for experience.

When conducting a charcoal burn, it is important that the weather is dry. It is possible to make charcoal when it is raining, but it is much harder to light a fire. The oil drum also cools down more quickly, so the yield is lower.

Filling the drum

When filling the drum, it is necessary to allow air to flow through the drum so that the fire can burn hotly and evenly and produce high quality charcoal.

Figure 7: Fill the drum with a central chimney. Photo credit: Fuel from the Fields.

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- Place a large stick (figure 7) in the centre of the drum and pack the bagasse, stalks or other material around it until the drum is full.
- If you are using corn cobs, or other material that is more difficult to light, create 4-5 layers of corn cobs, separated by husks or dried grasses. This allows the whole drum to get hot, and produce high quality charcoal.
- Carefully remove the stick, leaving a hole that goes to the bottom of the drum.
- Take a small amount of material and poke it into each of the holes in the bottom of the drum, leaving about 20 cm sticking out. (figure 8) This creates a wick, allowing you to easily ignite the material at the bottom of the drum.

Figure 8: Make 'wicks' in the bottom of the oil drum. Photo credit: Fuel from the Fields.

Lighting the fire

- Before lighting the fire, place the drum on top of three stones or bricks, so that air can flow in through the holes in the bottom. (figure 9). Place the drum on the stones carefully, so that it will be easy to remove the stones while the raw material is burning, to seal the drum.

- Light the wicks at the bottom before you light the loading hole on the top. One good way to light the top is to light a long piece of the biomass on one end and then drop it in the central hole, made by the stick. Sometimes the fire catches fast enough that you do not need to light the top.

Once the biomass is fully on fire, it will make a large, billowing plume of white smoke (figure 10).

Figure 9: Raise the drum on three flat stones, and light the wicks at the bottom. Photo credit: Fuel from the

Figure 10: The first, light plume of smoke. Photo credit: Fuel from the Fields.

Take care to stand upwind from all the smoke, to avoid inhaling it.

After about 10 minutes, the smoke starts to get a bit darker, thicker and yellower. As the drum gets hotter, volatile carbon gases begin to be formed. These can be ignited to make the fire burn more cleanly, giving off carbon dioxide (figure 11).

- Light a match and throw it into the top of the drum. If it is too soon, the smoke will not ignite. If the timing is right (volatile carbon gases are evaporating) the smoke will catch on fire and the fire will burn much more cleanly.

Figure 11: When the smoke is darker, carefully set fire to it. Photo credit: Fuel from the Fields.

- Let the fire burn for another 10 minutes before sealing it.

These times are approximate, and may vary depending on the material used, and the conditions of the burn.

Sealing the drum

In order for the material to carbonize, rather than burning away, it is necessary to seal the drum, preventing oxygen from getting in. This step requires at least two and preferably three people.

- Place the lid on the drum (figure 12). It is easiest to do this if the lid has a curved handle, so you can put the lid on with a stick.

If flames shoot out from the edges of the lid or from under the drum, it is not yet ready to be covered, the lid should be removed and the material allowed to burn for a little longer.

Figure 12. Place the lid on the drum Photo credit: Fuel from the Fields.

- Once the drum is covered, use the large stick to gently support one side of the drum, on the side of a stone. (figure 13).
- Kick away the stone under that side and gently lower the drum.
- When tipping the drum to be able to move the rocks or bricks from underneath, it may be safer for two people to hold each end of the stick and tilt the drum with the centre of the stick.
- Repeat this with each of the three stones until the drum is resting on the ground.
- Seal the bottom edges of the drum and edges of the lid with sand or soil until no smoke is visible. This means that there are no holes through which air can enter the oil drum.

After sealing, the drum remains hot. Make sure that no one touches the drum for at least 2 hours after sealing.

The agricultural waste will slowly carbonise inside the hot oil drum. After 2-3 hours, when you are sure that the drum has cooled, you can remove the lid.

Before removing the material, sprinkle some water inside the oil drum. This will reduce the amount of charcoal dust that is thrown up into the air.

Figure 13: Gently lower the drum to seal off the air holes on the bottom. Photo credit: Fuel from the Fields.

Charcoal

After 2-3 hours, the material inside the drum should be fully carbonised (figure 14). This means the charcoal powder will be black throughout. If corn cobs are used; the cobs will be brittle and easy to break; the centre of the cobs will also be black.

If the drum was allowed to burn for too long before sealing, the yield may be low. In this instance, a lot of material will have burned away, and grey ash will remain. If, by contrast, the drum was not allowed to burn for long enough, or some parts of the drum did not get hot enough, the material will not be completely carbonised (figure 15). If using cobs, they will still have a white core; bagasse may still be brown coloured. Uncarbonised material does not make good briquettes.

- Sort any uncarbonised material, and put it to one side. It can be used when filling the drum for the next batch, to avoid waste.

Figure 14: Fully carbonised corn cobs. Photo credit: Fuel from the Fields.

Figure 15: Corn cobs that are not completely carbonised. Photo credit: Fuel from the Fields.

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Crushing the material

The carbonised material must be crushed into a fine powder; this allows high quality briquettes to be made.

This step can throw up a lot of fine charcoal dust. Care must be taken to use airtight bags, and to avoid breathing in the charcoal dust. Sprinkling water on the carbonised material can reduce the dust.

- Fill rice bags, or some other airtight bag, with the charcoal. Sprinkle some water inside the rice bags, to minimize any dust.
- Seal the bags to stop any dust or charcoal powder escaping.
- Crush the carbonised material inside the bags, to make charcoal powder. Note that carbonised bagasse is relatively soft, and easy to crush by hand. Carbonised corn cobs, however, are much harder to crush by hand, and may need to be stamped on, or crushed using a stone.

A number of alternative methods for crushing the carbonised material exist, including using a large pestle and mortar (similar to those used to make fufu in Ghana).

Preparing the binder

Once you have a fine charcoal powder, binder must be added to it. This holds the powder together, and makes strong briquettes. A number of different binders can be used; we describe using cassava root to make a porridge, but any starchy porridge is ideal.

- Peel and grate one large cassava root for each batch of charcoal.
- Mix it with hot water, to form a thick, gummy porridge.

Approximately 1 cassava root and 1.5 litres of hot water are required to make enough porridge for one drum of charcoal.

- Mix the fine charcoal powder, with this warm porridge, in a basin. Mix it well so that all of the charcoal has some porridge on it.

You can test if the charcoal mixture is ready for briquetting with your hands. Grab a handful of charcoal powder, and crush it in your palm to make a rough ball. If the ball falls apart when you let go, the charcoal needs more binder. If the ball keeps the shape of your hand, it is ready to make briquettes.

Making the briquettes

After the binder and charcoal are well mixed together, you can make briquettes. You need the briquette press, and a hammer, or wooden mallet.

- Figure 3 shows the briquette press. With the ejector resting in the bottom of the cup, scoop up a full cup of charcoal powder.
- Place the plunger in the cup.
- Hit the piston hard with the hammer 3-5 times, to compress the powder (figure 16).

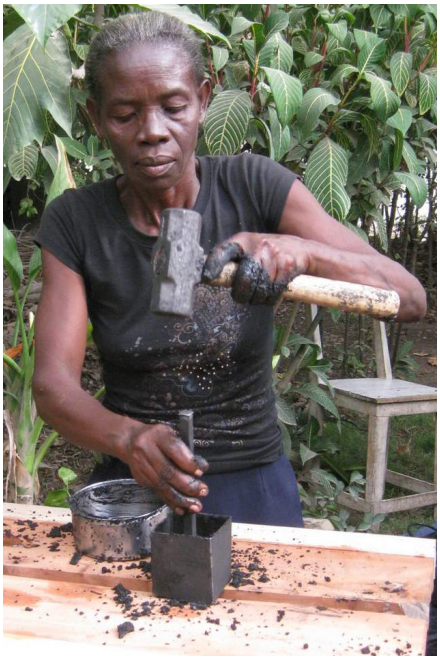

Figure 16: Using the briquette press
Photo credit: Fuel from the Fields.

- Hit the bottom of the press on a hard surface (e.g. the surface of the hammering station). This pushes the ejector pin upwards, and lifts the briquette upwards.

- Repeat until you have made briquettes with all the material.

A lot of charcoal mixture will fall on the ground during this process; if you put a plastic sheet or tightly woven cloth down where you are working, you can use it to collect the charcoal mixture to use it to make one final briquette, so it isn't wasted.

Drying the briquettes

These briquettes, now formed, will need to dry in the sunshine, to fully harden.

- Leave the briquettes to dry in the sun for at least 2 days. If rain is likely, make sure they are protected from the water.

Hardening the briquettes (optional step):

After briquettes have dried in the sun, they may still be soft. To harden the briquettes, you can fire them in an oil drum, while making another batch of charcoal. Put the briquettes in a wire mesh basket, and gently toss the basket in a burning oil drum, just before you put the lid on and seal it. When you open the drum after 2 hours, the briquettes in the mesh basket will have baked, and hardened.

Figure 17: Charcoal briquettes, ready to use.
Photo credit: Fuel from the Fields.

Complete

These fully formed briquettes (figure 17) are now ready for use. They can be used in a normal stove, or can be transported and sold at market.

Conclusion

Household fuel use is a major energy problem in the developing world. Cooking with biomass (which is free) is associated with childhood pneumonia; the leading cause of childhood death across the world. Wood charcoal made traditionally is a clean alternative, but can be expensive, and is also associated with deforestation.

The FftF technique allows clean-burning charcoal to be made from previously unused agricultural waste, either for personal use, or to sell at market. It allows poor farmers to make a profit from previously worthless crop waste. The technology is simple, cheap and quick, and uses locally available materials. We have outlined the process required, to allow field-workers to produce charcoal of their own and to run training sessions.

Further information

For more information, contact charcoal@mit.edu
Video available at: http://www.youtube.com/watch?v=LqI63IEg3MM

For more information on the health impact of indoor air pollution, see:
Smoke – the Killer in the Kitchen. Practical Action (2003)
http://practicalaction.org/smoke/report_home#Download

For more information on the use of biomass as a cooking fuel, see:
Biomass as a Solid Fuel. Practical Action Technical Brief: (2009)
http://practicalaction.org/practicalanswers/product_info.php?cPath=21_64&products_id=417&attrib=1

This document was written by Manpreet Singh, Ryan Stanley, Jessica Vechakul, Amy Smith, Amy Banzaert, and Shawn Frayne in February 2010. With thanks to the rest of the FftF team, and our partners in Haiti, Rwanda, and elsewhere.

The Fuel from the Fields project was set up in 2002, by D-Lab at MIT, to create a way for rural farmers to make charcoal from agricultural waste. The technology has been designed developed in collaboration with Haitian technicians. In 2007, the team won a World Bank Development Marketplace grant, which has been used to create a sustainable training programme in Haiti. To date, over 1000 farmers have been trained in Haiti, with a secondary focus in Rwanda, and additional trainings in more than 10 other countries.

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