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UNDERSTANDING WOOD WASTES AS FUEL

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PREFACE

This paper is one of a series published by volunteers in Technical Assistance to provide an introduction to specific state-of-the-art technologies of interest to people in developing countries. The papers are intended to be used as guidelines to help people choose technologies that are suitable to their situations. They are not intended to provide construction or implementation details. People are urged to contact VITA or a similar organization for further information and technical assistance if they find that a particular technology seems to meet their needs.

The papers in the series were written, reviewed, and illustrated almost entirely by VITA Volunteer technical experts on a purely voluntary basis. Some 500 Volunteers were involved in the production of the first 100 titles issued, contributing approximately 5,000 hours of their time. VITA staff included Marjorie Bowens-Wheatley as editor, Suzanne Brooks handling typesetting and layout, and Margaret Crouch as project manager.

VITA Volunteer Jon Vogler, the author of this paper, is widely published in the

field of
recycling. His book Work From Waste, published by the Intermediate Technology development
Group, Ltd., London, England, describes how to recycle paper, plastics, textiles,
and metals. Mr. Vogler, an engineer, worked in Oxfam's "Wastesaver" program in developing
countries. He has done much research in the field of recycling waste materials.

VITA is a private, nonprofit organization that supports people working on technical problems
in developing countries. VITA offers information and assistance aimed at helping individuals
and groups to select and implement technologies appropriate to their situations.
VITA maintains an international inquiry Service, a specialized documentation center, and a
computerized roster of volunteer technical consultants; manages long-term field projects;
and publishes a variety of technical manuals and papers.

UNDERSTANDING WOOD WASTES AS FUEL

by VITA Volunteer Jon Vogler

I. BACKGROUND

We can define wood wastes as wastes arising from human operations
on wood; extracting it from forest, woodland, and plantation;

converting it into planks and other "stock"; fabricating these into products--buildings, furniture, tools, and thousands of other items; and finally, discarding these when broken or even just "out of fashion." To this definition may be added "nature's wastes," such as leaves, twigs, and branches that fall from the tree due to natural causes such as aging, wind, lightning, or animal disturbance.

With that broad definition in mind, tree and wood wastes can be categorized as follows:

Forest Wastes Conversion Wastes User Wastes

Thinnings(*) Bark Sawdust
Reject Trees Sawdust Shavings
Leaves Slabs(*) Sander Dust
Bark Edgings(*) End Trim(*)
Branches(*) Rejects(*) Off Cuts(*)
Topwood Veneer Clippings
Stumps and Roots(*)

The use of waste wood is as old as humankind. During early civilization, stone-age people likely used wood waste to fuel fire since greenwood is very difficult to burn. Manufacture of items from wood also began very early. Wood was used for tools and weapons and, no doubt, cut-offs from the production of long implements were used for short axe-handles or pegs, while chips and shavings served as kindling.

This paper describes a number of uses of wood wastes as fuel, which is how the greatest proportion of wood wastes are used. Non-fuel uses of wood wastes, for example in building materials, industry, and agriculture, are described in another paper, "Understanding the Non-fuel Uses of Wood Wastes." The issue is acute, because the poor throughout the world, both urban and rural, continue to consume fuelwood and charcoal faster than it can be renewed. Meanwhile, an insatiable demand for paper made from wood pulp, wooden building components, furniture, and other goods also contributes to deforestation. Economical use of wood wastes instead of new wood helps to preserve forests and woodland in developed countries and is becoming essential to survival of the poor in many parts of the Third World, as fuel becomes more scarce.

(*) widely used directly as domestic fuel, as kindling, and as the raw material for charcoal.

This paper concentrates on three main uses for wood wastes as fuel:

o Burning solid wood wastes or sawdust;

o Using sawdust and tiny wood pieces to make small compact fuel pellets (briquettes) that can be burned in a manner similar to solid wood;

o Making charcoal, a widespread (mainly cottage) industry for converting wood wastes into a lightweight, smokeless fuel.

Some experts describe certain wood waste processes as having singular applications. Many procedures for processing wood wastes, however, can also accommodate a wide variety of agricultural waste products such as husks and hulls.

II. BURNING SOLID WOOD WASTES

COMBUSTION IN WOOD-BURNING STOVES

All wood contains moisture; even kiln dried wood has an eight percent moisture content. When the kindling is first lit, white smoke, containing a large percentage of water, rises from the wood. As the fire begins to burn, long tongues of yellow flame indicate that the volatile substances, natural oils, and resins within the wood have been released. This chemical breakdown of the wood into "char" and volatile gases occurs at 150-200 [degrees] C. The gases do not all actually ignite until a temperature of 540 [degrees] C. has been reached. In an open fire, these volatile gases are given off into the air in the rising smoke and hot air and do not reach their flash point. Thus much of the fuel value is lost. Following this, the wood burns with small white flames and hard, clear outlines as the remaining fibrous matter (lignin) and carbon ignites.

MODERN "AIR-TIGHT" STOVES

Many years ago, stoves were made of cast iron panels bolted together. More recently, welded steel sheet has replaced cast iron. Cast iron holds heat better, but is prone to cracking under mechanical or thermal shock. Although fire cement is sandwiched in the joints, a cast iron stove is never as air tight as a sheet steel stove. Sheet steel cannot crack, but may warp if overheated unless made of thick (13 guage) plate. Sheet steel stoves are easier to move, being much lighter, and require little maintenance. The welded seams remain airtight for the life of a stove.

Fire Control in Air-Tight Stoves

Control of the rate of burning is achieved by controlling the amount of air escaping, and the speed and amount of air that passes through the mass of fuel. Various features of stove design affect this:

o The fuel rests on a grate that allows air to pass through it from below. Simple grates are usually parallel steel bars, close enough to prevent fuel from falling through the spaces between them.

o An important requirement is an air-tight firebox constructed so that all air admitted is controllable, by one of the following:

- Air intakes positioned below the grate control the quantity of air entering and fuels passing through the firebox. This may vary from no air to a strong draft that causes the fire to blaze.

- Opening and closing the stoking doors varies the air supply to the fire, but the doors are usually above the grate level, so air passes over, not through the fuel and the draft is not effective.

- Dampers regulate the draft by varying the size of the chimney opening. The damper is a hinged flap in the flue, the pipe from the firebox to the chimney.

- Baffle plates: the volatile gases are given off at 150-200 [degrees] C. If these hot gases escape up the chimney their fuel value is lost. Baffle plates of steel or cast iron obstruct the gas flow, and ensure the gases are heated to their flash point and radiate additional heat before escaping. During "secondary combustion" the gases given off from the heated fuel-wood are drawn away from the main fire. A secondary inlet admits air and the gases spontaneously ignite if they are at a sufficiently high temperature.

o Heat exchangers, sometimes called smoke chambers or radiators, extract the maximum amount of heat from the hot fire gases. They are additional chambers that can be bypassed during kindling. By moving a valve, the hot gates may be directed through them when the fire has reached a certain temperature. Heat exchangers and other parts of the fire boxes of stoves are often wrinkled or patterned in order to provide an increased surface area for transferring heat. This is one of the functions of the patterns and traditional scenes that are cast into the surfaces of many Scandinavian stoves.

o Heat output can be increased by forced draft provided by an electric fan running in a steel tube. This increases both the supply of air for burning and the rate at which heat is removed (transferred to the surrounding area).

Advanced Stove Designs

Five basic designs have evolved for wood-burning stoves, though there are as many variations as there are stove manufacturers. The main differences concern how air moves through the stove.

1. Updraft Stoves allow air to enter through inlets at the bottom, move up through the grate into the burning wood, and flow out of the flue. Many updraft stoves have secondary air inlets above the wood for secondary combustion of the gases when the stove is burning well.

2. Air enters the bottom of Diagonal stoves then moves diagonally through the fuel to the fire in the back of the stove. A secondary air inlet above the wood assists secondary combustion. Heat exchangers are often fitted.

3. Air enters near the bottom of Crossdraft stoves and leaves near the bottom at the back of the stove. Secondary combustion of gases occurs in the main fuel bed.

4. Downdraft stoves force air and combustion gases down through the burning fuel. Air enters at or near the top of the stove and travels down through the grate to leave through a flue at the bottom. These stoves are smokey when not burning properly, unless fitted with a flap valve to allow the smoke to leave at the top of the stove until the fire is burning fully.

5. Front end combustion or "S" draft stoves. In this model, logs burn from front to back much like a cigar. The primary draft enters through the front and passes over the fuelwood, which then burns towards the back. Baffle plates force the hot volatile gases to double back over the fire in order to reach the chimney flue. They encounter secondary air and burn with high efficiency if the stove temperature is high.

Water Heating

Many wood-burning stoves are jacketed. That is, the firebox is surrounded by a jacket of water, which, when heated, convects (moves upwards because hot water is less dense or lighter than cold water) or is pumped away to be used. Back boilers are also common. Water to be heated flows through a chamber (usually made of copper) behind the flue. Water heating reduces the heat radiated from the stove itself; however, the heated water may be passed through radiators to heat areas away from the stove.

WOODBURNING IN THE THIRD WORLD

Fuelwood accounts for at least half of all the wood used in the world each year and for more than 85 percent of wood used in Third World countries. No other source of energy is available (or seems to be) on a scale large enough to satisfy the billion people who depend upon fuelwood. Demand is now outstripping supply and the situation worsens with constant population growth, as fuel must be collected or purchased at a constantly increasing expenditure of labor or money--a burden that falls mainly on women.

Part of the solution is, of course, to grow more trees. Part is to make better use of the fuelwood resources that remain. The introduction of cooking stoves that use less fuel than open fires or traditional stoves can reduce the labor of fuel gathering and conserve fuel, so as to extend the time available for long-term measures (tree planting) to take effect. However, the "advanced" stoves described above are too costly for most Third World users. Research programs have therefore been launched over the past few years to develop better stoves than those in common use, yet still simple, robust, of low cost, and suitable for local manufacture and unskilled use.

Some Typical Improved Stove Designs

Early efforts concentrated on the development of massive stoves made from mud. Later more durable designs known as "pottery insert" stoves were made from pottery by skilled artisans. These can be coated with an outside layer of mud to increase stability, durability, and insulation. These high mass stoves were, however, found to suffer from a number of design flaws. The stoves themselves absorbed tremendous amounts of heat, which while useful for space heating in some areas, used up excessive amounts of fuel. The mud or clay walls disintegrate in rain or high humidity, and the individual construction of the stoves precludes effective quality control unless the builder is very well trained. As a result, many high mass stoves use more fuel, not less, than traditional stoves. Because of these and other problems, subsequent research focused on smaller, portable metal and ceramic stoves based on traditional designs. The result of scientific research by VITA and others has been a series of guidelines for the design of such stoves. Critical points include close matching of pot to stove to ensure maximum contact with the fire, insulation to minimize heat loss, a grate to ensure good combustion, and control of the air supply to regulate burning. These portable stoves also lend themselves to quality control and mass production, as exact templates can be put into the hands of artisans who are trained in their use.

Portable metal cooking stoves are proving to be much in demand, especially in some urban areas of developing countries. This type of stove efficiently burns scraps that could not be effectively used on an open fire. Its fuel economy is excellent. Because it contains the heat well, the cook can remain seated close to the stove while cooking. This is not possible with the open fire or traditional coal-pot stove. With improved stoves, smoke is reduced. They are also more stable than the traditional coal-pot, and the pot can be stirred vigorously without the risk of upsets.

The charcoal-burning metal stove, known in Kenya as the "Jiko," is over 90 percent inefficient. To replace it, the Umeme Stove has been developed by UNICEF's Appropriate Technology Section in Nairobi. It is designed so that the cooking pot sits inside the stove. There is a sloping inner chamber made of metal, which is insulated from an outer metal cladding by a layer of ash. A newer model, known as the Kenyan Ceramic Jiko, uses a fired clay liner in the metal cladding.

VITA's work in Somalia and in West Africa has also yielded improved stoves based on traditional designs. In Somalia, soapstone stoves carved to rigorous specifications to increase efficiency are finding a ready market. And in Burkina Faso, Mali, Guinea, and elsewhere, traditional metal designs have been upgraded and artisans trained in their production. The use of templates in these areas has permitted the manufacture of large numbers of high quality stoves, thus bringing down the unit cost and making them more attractive to purchasers.

Commercial stoves, including an American product known as the Zip Stove, are also currently being promoted in developing countries. The Zip Stove, manufactured from light weight galvanized steel, comprises a cylindrical combustion chamber with a removable grate and an outer casing, with a layer of refractory (heat resistant material) insulation between them. This stove, and others like it, is much more costly than the improved traditional stoves that are produced locally, and may not be any more efficient.

Dangers of Simple Stoves

Fuel efficiency is not the only concern in the design of simple stoves. Burning any carbon fuel produces poisonous carbon monoxide. In an enclosed room this can be very dangerous. Simple stoves are not very safe in this respect. For example, the average carbon monoxide content of gases emitted by traditional charcoal stoves ranges from 0.9 percent to 0.3 percent. By contrast, European safety standards recommend carbon monoxide emissions should be not more than 0.0005 percent in any enclosed area. Even so called improved stoves are no better in terms of gas emissions. The average carbon monoxide flue gas composition of the Zip Stove for burning wood is 1.3 percent and for charcoal 2 percent. When damp wood is burned, the production of carbon monoxide increases 1.8 percent with considerable quantities of smoke.

At present, there are no reliable measurements of carbon monoxide and other emissions from open fires, but indications are that the women who cook with these fires and improved stoves suffer respiratory damage that is equivalent to smoking several packs of cigarettes a day.

The solution to this problem lies in creating designs with a chimney to remove gases from the room, the lethal carbon monoxide in particular, and an air-tight firebox with baffles to achieve more efficient burning of the combustion gases.

BURNING SAWDUST

Huge quantities of sawdust are produced in sawmills and carpentry workshops all over the world, but it is rarely recycled effectively. It cannot be used for paper making because the fibers are too short. It will not burn on an open fire, except in the smallest quantities. Its lignin structure makes it unsuitable for fertilizer, animal feed, or biogas production. Unless it contains very high proportions of resin, it is difficult to use in briquettes without expensive binders or very high pressures. Only large sawmills may find it economical to buy a briquetting press and possibly to carbonize (make into charcoal) the finished briquettes, let alone to recover the tar and combustible gases that are the by-products of the carbonization process. Nonetheless, there are several ingenious ways people have found to burn sawdust.

Tin Can Stove

The single chimney tin can stove is the simplest homemade stove to use sawdust for cooking. A hole is cut in the bottom of one side of a five-gallon can. A short length of broomstick is placed horizontaly in the hole so that it reaches just to the center of the can. Another stick is held upright in the center of the stove, with the ends of the two sticks touching. The can is filled with sawdust, tamped down with a wooden block during filling and sprinkled with water to keep the dust level down. The sticks are removed, some diesel oil or kerosene is dripped through the hole where the center stick was. The oiled area is

lighted with a burning rag through the air hole at the bottom. The mass will burn for six to seven hours. The burning rate can be controlled by obstructing the air flow through the bottom passage. A simple "trivet" (three-legged stand for cooking pots) can be placed on top of the can and a cooking pot or kettle can be heated on it. Food cooked on this stove will tend to smell and taste of wood-smoke.

Other Sawdust Stoves

The double drum stove is even larger and more complicated, but still inexpensive to construct. It consists of a 30-gallon steel drum, supported on a false floor inside a 55-gallon steel drum. A drawer, opening below the false floor, provides draft and catches dropping ashes, which are then easily removed. A hole in the center of the false floor and the inner barrel bottom lets air pass up to the fuel, and ashes fall into the drawer. A tightly fitting lid covers the outer barrel and two stovepipes exhaust smoke. It should stand at least two feet from any combustible material and be set on a fireproof floor pad. CAUTION: DO NOT

open the lid while the fuel is burning. A serious flare-up may result.

With dry sawdust and a good draft, one charge of this stove can heat a room 7 meteres square for six to eight hours with no tending. Wetter fuel heats less but lasts longer. During the first two hours of burning, there is enough heat at the center of the lid to boil water or cook. As burning progresses, the heat on the

lid is distributed more toward the rim. Stoves can also provide hot water. A coil of metal (preferably copper) pipe placed inside the stovepipe will heat water that is circulated through it.

Mexican Water Heater

A sawdust-fire water heater is widely used in Mexico. The sawdust is lightly sprinkled with petroleum or fuel oil and loosely packed in polythene bags that are sealed. The full bag is known as `combustible' and is sold by grocers and hardware stores. Two combustibles can heat enough water for a bath. The special water boilers have a grate at the bottom, on which the combustibles are burned. Above the grate is a chimney surrounded by a water jacket with a water inlet and outlet that are plumbed into the household hot water system.

III. COMPACTING WOOD WASTES

SAWDUST BRIQUETTES

The alternative to having a special stove for burning sawdust and small wood wastes is to compress these into a briquette--a small, compact fuel pellet. The average calorific value of briquetted wood waste or sawdust is 4,000 kilograms per cubic centimeter, so every 100,000 tons of briquetted wood waste will be equivalent to 42,850 tons of fuel oil, making it a valuable fuel that will repay substantial costs of manufacture and transport.

High-Tech Briquetting Processes

The process is based on the recognition that most wood waste is self-bonding at fairly high temperatures and requires no added binder. Sawdust is preheated to above 163 [degrees] C to destroy its "elasticity" and to eliminate moisture. This decreases the weight by about one-third and almost doubles the heating value per pound. It is then moistened and briquetted hot without a binder. Pressure is retained during cooling. The resulting briquettes are firm and strong enough to withstand rough handling and resist weathering to an extent that permits shipment and storage, if protected from rain.

To achieve briquettes of the necessary strength and hardness, the moisture content of the wood waste should be around 10 percent, although in some cases, machines are capable of handling dry wood chips. Dryers may take the form of rotating drums through which hot air is blown or steam-heated plates and pipes over which the waste is cascaded. A large proportion of the material may be needed to provide sufficient heat to dry the feedstock from a high moisture level. It is usually necessary to grind the waste to a suitable size and, before doing so, to strain it to remove stones, soil, or metal, which would damage the grinder.

Briquetting machinery must be robust and powerful. Attempts to produce simple, low-cost, low-power machines for small-scale operations have not been successful to date. Pressures of up to 1,000 kilograms per square centimeter can be involved. To keep die temperatures low and avoid burning the briquettes, dies need water cooling. Machines need motors giving between 25 and 100 kilowatts for every ton per hour of throughput, although not all this is absorbed during operation.

Many manufacturers of wood pulp and other wood products use sawdust and other wastes as fuel for their manufacturing processes. The wood wastes are briquetted in an ongoing process. One such process uses a machine that screws the waste wood (sawdust, shavings, and other scrap, ground to the size of oatmeal particles) first into a compression chamber at a pressure of 3,000 pounds per square inch (211 kilograms per square centimeter). At the outlet from this chamber, a secondary head cuts the compressed material into a spiral ribbon and forces it into a mold under a pressure of 25,000 (1757.7 kilograms per square centimeter) to 30,000 pounds per square inch (2109.24 kilograms per square centimeter). Friction at this extreme pressure generates enough heat to achieve self-bonding. The molds are parallel to the axis of the wheel. The mold is closed by a hydraulic piston that retracts as the mold fills. When one mold has been filled, the wheel rotates to align the next with the compression chamber. The molds are water cooled, and, by the time the wheel has moved full circle, the briquette is cool enough to eject. The machine produces 4 by 12 inch briquettes that are fed manually into the factory's furnaces.

For mechanical stoking an extruder is used that forces the waste through one-inch round holes as continuous rods, which are cut into one-inch lengths by rotating knives. The machine is small enough to be mounted on a truck and powered by a truck motor.

It is far less expensive to transport briquettes than loose waste, so briquetting machinery should operate where the wood waste arises. Briquetting presses are best located at sawmills, furniture factories, or oil mills. However, if these are far from populations or industrial centers where there are markets for fuel briquettes, transportation costs may not make the operation cost-effective. The finished briquette may need protection from reabsorption of moisture and should be stored in dry areas or packed in sacks. Packing in plastic film or cellophane may be necessary. Careful handling and transportation are needed to prevent crumbling.

Other processes include:

o Briquetting between rollers with cavities that produce egg-shaped briquettes in sizes between one and four centimeters.

o Pelleting where waste is forced by pressure rolls through the holes in a die-plate (product size 0.5 centimeter);

o Cubing--a modified form of pelleting (product size 2-5 centimeters);

o Rolling/Compressing--where fibrous material is wrapped around a rotating shaft to produce a high density roll or log (product size 10-18 centimeters diameter).

Simple Sawdust Briquettes

Various attempts have been made to devise methods by which people in rural areas can use sawdust to make briquettes. The simplest idea, for areas where dung is shaped by hand and sun dried for use as fuel, is that the dung cakes will burn longer if wood ash is added. Most efforts have been devoted to making simple machines.

Most hand-operated machines use a mechanical lever to apply greater compacting pressure than is possible with hand molding. The length of the lever arm determines the briquetting pressure and it is important that the mold be sturdy enough to withstand this. Approximately four to five hours work of by a competent blacksmith or welder are all that is needed for the simplest devices. A steel pipe provides a good briquetting mold.

Earth rams, simple hand-powered presses currently in use for making building blocks, can be easily modified to make briquettes. The Combustaram, similar to the CINVA-Ram and Tersaram, is commercially available or can be locally manufactured.(*) Another device consists of a piston that reciprocates in a cylinder on which there is a hopper to feed the sawdust (or other agricultural waste) to be compacted. The piston is driven by a hand-turned crankshaft, on which a flywheel is mounted. There is a simple device to eject the briquette, which is about 30 millimeters in diameter and 10 millimeters thick. Approximately 50 kilograms of briquettes can be produced in about eight hours.

A larger machine is powered by a single bullock. It consists of two sets of pistons and cylinders and turns at about four rpm to produce two briquettes per revolution. The capacity is around 150 to 200 kilograms of briquetted fuel per eight hours.

(*) Both machines were designed, fabricated, and tested by the School of Applied Research in India. Further details can be obtained from the National Research Development Corporation of India, 20-22 Zamroodpur Community Center, Kailash Colony Extension, New Delhi 110 048, India.

A Thai businessman, Sayan Panpinij, in collaboration with VITA, has developed an extrusion machine that transforms rice husks into burnable logs. Approximately 75 kilograms of rice husk fuel logs are produced per hour from each of twin extrusion heads, with a density almost double that of firewood. The machine is powered by a 20-horsepower electric motor and works best with husks that have been ground and dried to reduce moisture. The machine can be operated by one person who feeds the rice husks into the hopper on top of the machine, removes the fuel logs from below the extruder, and stacks these for cooling. It is estimated that three people will be necessary to operate four machines. The VITA extruder can also produce fuel logs from sawdust. These have a higher heat value than rice husk logs, produce less smoke and ash when burned, and reduce wear and tear on the machine. The device is relatively new and has not yet been manufactured outside of Thailand.

The life and maintenance of this extrusion machine is a primary consideration for the user. When the device is used for extruding rice, the screw will need to be replaced every 120 hours. The extrusion cylinder has a life of about 450 hours and will probably need to be rebored every 150 hours for its most efficient operation. When the device is used for extruding sawdust, however, the life of the machine is nearly double. Depending on temperature, quality of the heater unit, and the length of operation, the life of the heat unit varies between 240 and 350 hours. In a four-unit plant, it is estimated that capital and operating costs can be replaced within one year.

RETTING AND PRESSING

Partially decayed and processed cellulosic materials give a much higher heating value than if the materials are simply dried. For example, dried rice straw (10 percent moisture content) has a heat value of only 3,000 BTU/pounds (7 million joules/kilogram [J/kg] or 0.0698 gigajoules/kilogram [GJ/kg]), but this will increase to between 7,500 (17.4 million J/kg or 0.0174 GJ/kg) and 12,000 (28 million J/kg or 0.0279 GJ/kg) when the material has partially rotted before it is dried. In the Philippines, the MAPECON research group has set up a pilot plant producing such fuel, with 25 percent moisture content and an average of 10,000 BTU/pounds (23 million J/kg or 0.0232 GJ/kg) which they call `green charcoal,' at the rate of one ton per hour. The group reports that it is very competitive with other types of fuel.

Retting--soaking in water for several days or longer at normal air temperatures--allows chopped, moistened woody residues to be biodegraded (partially decayed). This process is used to produce mats that can be pressed into fiberboard, but a simple hand press can also be used to make briquettes from retted agricultural residue or wood wastes. The lever is made from steel pipe and the timber mold has holes on each side to allow water to escape during pressing.

BUNDLING

Tying brushwood into compact bundles for ease of transportation and use is the simplest means of densifying wood wastes. Twigs, straw, hay, dry leaves, and other woody wastes are bundled all over the world, using cord, vines, wire, or any locally available tying material. Where large-scale bundling is carried out, stands or racks have been developed to assist in the bundling process, and to allow for drying before use. Brush bundling machinery is also available, but indescriminate use can seriously damage ground cover, leading to soil erosion and loss of fertility.

IV. MAKING CHARCOAL FROM WOOD WASTES

In contrast to the heavy weight and high smoke level of the wood from which it is made, charcoal is a light, smokeless fuel of high calorific value.

THE CARBONIZATION PROCESS

When wood is heated in the absence of air, changes take place in several stages. At 100 to 120 [degrees] C, water is emitted into the air. Green wood contains between 50 to 70 percent water, which must be evaporated before the wood temperature can rise higher. Carbonization (conversion into carbon or charcoal) begins at 270 to 400 [degrees]

C. The reaction, technically named pyrolysis, gives out heat. The wood chars and gives off gases and vapors--carbon dioxide, carbon monoxide, hydrogen, methane, water vapor, methanol, acetone, tar, and pitch.

The yield of charcoal and its composition depend on the species of wood, the carbonizing temperature, and other factors. Yield is generally about 25-40 percent by weight of dry wood. Although low carbonization temperatures produce a higher yield (because the charcoal still contains matter that has not been given off as gas) the charcoal quality is poor. It smokes and flames. Temperatures that are too high, on the other hand, shorten the life of equipment, so care should be taken to keep carbonizing temperatures between 400 and 700 [degrees] C.

The energy value of the gases represents some 40 percent of all the heat value of the original dry wood. Some of the gases contain valuable chemical compounds. Unfortunately, production on an industrial scale is necessary before it is economical to recover these compounds. In small-scale processing, however, they help maintain burning in the kiln.

TYPES OF KILNS

Charcoal is made by placing wood in a kiln, igniting it in the air, and then, when it is burning thoroughly, reducing the supply of air almost completely. Many types of kilns are in use. Some are industrial size, some are much smaller. They will be described here in order of complexity, starting with the simplest.

The Earth Kiln

An earth kiln usually occupies about eight square meters of ground. Logs of wood are placed on the ground with space between them to allow air passage in the early stages. The pile is built to a meter high and covered with leafy vegetation 30 cm deep. Stakes are set in the ground around the pile to support a wall made with interleaved branches or scrap corrugated iron. The kiln is then lit and allowed to burn fiercely until smoke comes out at various places. The pile is then covered with earth and left to burn for about two days. Burning is complete when the kiln slumps down to half its original height. More soil is added to exclude air totally for three or four days until the kiln is cold. It is uncovered, allowed to cool for a few hours, then the charcoal is put into sacks for sale. It is reported that two experienced charcoal makers can produce about six tons of charcoal a month by this process, which needs no capital money just a sack, a spade, and an ax.

The CUSAB or Oil Barrel Kiln

Kilns for carbonizing small wood pieces are made from oil drums, 45 gallons or 250 liters in volume. Each oil drum is fitted with holes of approximately five centimeters. Threaded pipe fitting the same approximate diameter are then welded to the holes. The screw connectors can then be fitted with plugs to cut off the emerging air. Holes should face the wind and a stick can be used to keep the openings clear of debris during the early hours of burning. It is reported that five to six kilns can produce four to five tons of charcoal per month. Although kilns have a short life, the pipe fittings can be reused, and the low cost of oil drums makes this a cost-effective technology.

The Steel Kiln

The steel kiln can produce an average of 500 kilograms of charcoal every two days from two and a half tons of wood, depending on moisture content and density of the timber used as feedstock. This represents up to 12 tons of charcoal per month. The kiln is simple to operate and does not normally require attention at night nor water for cooling purposes. It is, however, an expensive object and very hard work to transport across rough roads. Two strong men can barely handle two kilns, including loading, unloading, and moving to new sites. It has been designed to withstand rough usage and extreme temperature conditions. There are no underground fittings.

To operate, logs are placed, with kindling between them, in the lower cylinder, which rests on eight smoke boxes. The lower cylinder is then densely packed with logs. When full, its rim is filled with mud to form an air seal and the upper cylinder is mounted on top. The upper cylinder is also packed to a height such that the top cover does not quite meet the cylinder. Flaps of the smoke boxes are open for lighting. Then, when plenty of smoke is emitted, some flaps are closed. In approximately an hour, the cover will settle down onto its rim. Chimneys are then fitted to the smoke boxes. If blue smoke comes from a chimney, the chimney is removed and the smoke box below it is capped for fifteen minutes to reduce burning. After 16 to 24 hours, smoke will cease. Each chimney can then be removed and the smoke box closed. Cooling takes 8 to 12 hours.

Other Simple Kilns

There are many other simple kiln designs available. One version uses a drum lying on its side. It has been found very satisfactory by the Fiji Department of Forestry. In the Philippines tests have been made on various improved simple designs, mostly consisting of two drums welded together to increase capacity to 160 kilograms of wood. Improved air vents and chimneys can cut heating time to four hours, and yield up to 40 percent charcoal. In Papua New Guinea, two cylinders made from 44-gallon drums, lying on their sides over a stone or concrete fire trench, produce high quality charcoal. A group of drum kilns wired together will allow the heat to be distributed more efficiently and produce charcoal faster.

Retorts

Retorts are designed to use the gases (including condensed gases or liquors) more effectively. They give a higher yield because they carbonize all of the raw materials. Kilns on the other hand, burn away some of the raw material in order to provide the necessary heat. Heat for carbonization is provided by otherwise useless materials such as coconut shells, pigeon pea bushes, palm leaves, and woodworking scraps. A tar condenser may be fitted, in which the gases are condensed and the tars collected for use in road construction, preserving timber, or sealing flat roofs. Some retorts can recover gases that are directed to the firebox where they are burned to fuel the process during its later stages, saving solid fuels.

Industrial Processes

Increased sizes and complexities of kiln are available as follows:

Mobile Vertical Bath Kiln: This 19-foot-high kiln weighs nearly three tons and has a built-in crane to assist in erecting it on site, lifting and lowering the cover during operation. No concrete foundation is required. It takes only 48 hours to produce four tons of charcoal, which can be discharged directly from a chute into bags. Liquors (condensed gases) are recovered.

Demountable Vertical Kiln: This semi-permanent design can be set up in an area of forest. When cleared, it can be re-erected on a new concrete foundation in another area. It can be moved using large road vehicles. Skilled erection is, however, a requirement. This kiln can produce around 3,000 tons of charcoal per year.

Permanent Vertical Kiln: This is available in sizes to produce between 5,000 and 10,000 tons of charcoal per year. The material is handled mechanically and can be passed through a continuous dryer. Little labor is necessary.

Larger Kilns: These are usually horizontal and include continuous drying, briquetting, and bagging plants.

Fluidized Bed Kilns: Fluidization is a well known technique, a developing technology in such applications as coal conversion, packaged coal-fired boilers, and gas turbine power generation. Within the timber industry, wood-fired fluidized bed furnaces have become commercially available for steam raising. There is increasing interest in processing wood waste into upgraded fuels such as gas, charcoal, or oil fluidized beds.

Further details may be obtained from manufacturers.

BRIQUETTING OF CHARCOAL

If charcoal can be sold near the site where it is made, transportation and storage costs will not be high. If it is to be transported a long distance or sold later when the market price is better, it is desirable to compress it into small, dense briquettes. This also uses the fine dust, which cannot otherwise be sold or used. The disadvantage is the cost of a binding substance, such as starch from cassava. If no binder is used, a briquetting press with high working pressure is needed and such machines are expensive (about US$100,000), but easily obtainable and not difficult to operate or maintain. So far, no company has produced an inexpensive small briquetting press that produces sufficient pressure to make briquettes that do not crumble without a binder, so large presses have to be used. Some models need to be fed by at least eight steel kilns, which result in additional transportation costs.

Charcoal Briquetting Processes

The production of charcoal briquettes may be accomplished either by preparing the charcoal first and then pressing it, or by preparing wood briquettes to be carbonized after forming. One method produces semicharcoal briquettes by preheating sawdust until the lighter gases have been given off and tar begins to distill. The partly charred sawdust, brownish in color, is then cooled to 100 [degrees] C, moistened with water, and pressed into a mold. Another method heats dry sawdust in molds, under low pressure, until it has partially carbonized, then applies a pressure of 350 pounds per square inch until carbonization is complete. The resulting briquettes are further heated to drive off gases that would create smoke.

Another process distills finely ground wood to produce granulated charcoal, which is mixed with the wood tar produced in the process and briquetted. The briquettes are reheated in a retort to drive off and recover the lighter fractions of the tar. The remaining particles may then be bound firmly together to form a dense briquette. This process is sometimes referred to as"coking." It is reported that these processes are commercially unsuccessful because the charcoal briquettes produced are too brittle to be used. An alternative is for finely ground charcoal or charcoal dust to be mixed with a suitable binder before being pressed into uniformly-sized, strong, dense briquettes, free from charcoal dust.

Practical briquetting operations entail four steps:

1. Preparation of charcoal fines. Lump charcoal is crushed, then milled using a screen with 1/10 inch or 1/8 inch holes to produce material with enough fines to fill the voids between the larger pieces and to prevent them from being crushed during briquetting.

2. Mixing to coat the charcoal particles with a film of binder. A kneader-type, double shaft mixer is often used. Another method, however, involves simultaneously feeding pre-crushed charcoal and cassava flour into a hammermill. The mixture is stirred continuously, then steamed until the flour forms a binding paste.

3. Briquetting the mixture between two cylindrical rolls that rotate in opposite directions. Each roll is designed with rows of hollowed half molds, aligned so the halves match. Hundreds of briquettes can be produced at every turn of the rolls.

4. Drying the briquettes continuously or in batches. Dryers are similar to agricultural dryers in operation. Briquettes produced with asphalt or pitch binders do not need artificial drying, only cooling.

Binders

To produce satisfactory briquettes economically, the binding substance must meet certain requirements. It must produce a briquette strong enough to withstand damage during transport, storage, and stoking. Exposure to weather must not cause crumbling or softening and, during use, the heat must not cause disintegration and loss of fine pieces through the grates. It must burn without smoke and unpleasant smell and not be too dusty. Ideally the binder should have as high a heat value as the charcoal.

Binders fall into three categories: inorganic materials, organic materials, and fibers.

o Inorganic materials, such as cement and silicate of soda are appropriate for wood fuel. These substances are poor because they give more ash, reduce the heat value, and fall apart while burning.

o Organic materials such as tar, pitch, resin, and glue usually increase the heat value and create no extra ash.

o Various types of fibrous material may serve as binding agents. The cheapest is hydrated wood fiber-wood waste--ground, pulped wood waste, which, when dry, binds together in the same way as paper.

Some binders permeate the material to be briquetted; others coat the surface. Starch binders, such as cassava, corn, and others are smokeless, but not moisture resistant. They are normally used in the proportions of four percent (dry basis). Tar, pitch, asphalt, and sugar cane molasses are used in less than 30 percent of the cases. They are moisture resistant but not smokeless. This is no drawback in industrial uses, such as smelting and heating, but would be inappropriate for home fuel or cooking.

Secondary distillation (heating a second time) can drive off the smokey gases, but increases cost and does not completely remove objectionable smells during burning. A good smokeless charcoal is one that contains at least 75 percent fixed carbon and not more than 24 percent "volatile" (able to be emitted as gases) matter.

Uses of Briquetted Charcoal

Briquetted charcoal has many industrial uses and can be used as domestic fuel as well. The product is a high quality industrial fuel for production of steel, cement, copper, rubber, gun powder, and other products.

In the chemical industry, very pure briquettes are used as activated carbon for air and water purification, for filtration, decolorization, purification of sugar, and as a chemical catalyst. Activated carbon commands prices five to six times higher than those of briquetted charcoal.

REFERENCES AND RESOURCES

Appropriate Technology International has several reports on the use of both charcoal and wood stoves. For information contact ATI, 1331 H Street, N.W., Washington, D.C. 20005, USA.

Intermediate Technology Publications (ITP) includes over a dozen titles on this subject in their catalogue. The catalogue can be ordered from I.T. Publications, Ltd., 9 King Street, Covent Garden, London, WC2E 8HW, United Kingdom.

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SOURCES OF HELP AND INFORMATION

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Box 343
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