

Charcoal making from agricultural residues

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Charcoal making

Traditionally, charcoal is made from forest wood cut into pieces and partially burnt. However, charcoal can be made from agricultural residues such as stems and twigs that would otherwise be left in the field and burnt away as waste. Some of the common crops whose stems are suitable for charcoal making are soyabean and red gram. Any kind of wood can be used to make charcoal. However, if softwood is used, it will make soft charcoal and therefore burn more quickly. Also, the method used for softwood would not be applicable for hard wood as the latter is denser and tends to burn slowly. The process described in this article is one that uses the heat given off from the wood or residues as it becomes charcoal to make the charcoal itself. The rate of combustion is controlled by regulating the amount of air allowed into the burning chamber, and when all the volatiles have been given off and the charcoal itself begins to burn, the process is stopped by keeping out all the air. This process is developed from the age-old method used by colliers to make charcoal in a pit, pile (clamp) or, more recently, in metal or masonry chambers (kilns).

In this direct burning process of converting agricultural residues, the charcoal produced weighs about 20–25% of the weight of raw material. Many factors are responsible for the quality and yield of the char, such as initial moisture content, composition of the biomass, and ambient temperature and humidity. The resulting charred biomass generally consists of small black pieces of very lightweight and low density charcoal which are compressed into briquettes. The charcoal burns hot and clean; and it can be easily ignited.

The combustion process

When wood is burnt in the open, with an adequate supply of air, its constituents, mainly, carbon, hydrogen and nitrogen, get oxidised, giving out

heat and light. The smoke consists of volatile and particulate matter. The resultant product of such uncontrolled combustion is generally ash, which is rich in potassium carbonate. Charcoal is made when the fuel is not completely burned – called *incomplete combustion*. In this process, all the volatile matter in the woody matter is driven out and only carbon, in the form of charcoal and a small quantity of ash, is retained.

When woody matter is heated to a temperature of 259°C or higher, it decomposes to yield gases, vapours and solids. Incomplete combustion of wood is achieved by restricting the supply of air, and volatile elements are driven off as smoke. The smoke consists of non-condensable gases and condensable vapours. The principal gases are carbon monoxide, oxygen and nitrogen. The vapours are water-acids, alcohols, tars, oil and other organic compounds. A small amount of these gases and vapours remain in the charcoal. Controlled and proper burning of the woody matter can yield charcoal comprising 75% to 95% of carbon. With the escape of most of the gases and vapours in the smoke, a charcoal fire is a clean, efficient and safe source of heat, both from the environment and health points of view. Conversion to carbon starts at a temperature of 250°C: in the case of fire where the air is not controlled, the

temperature may rise to nearly 400°C and carbonisation and subsequent conversion to ash is very rapid.

Construction of a charcoal kiln

In designing the kiln, both the requirements of a controlled rate of combustion and the need to stop the process when all of the agricultural residues have been converted to char have been addressed. The charcoal kiln consists of a cylinder made of mild steel (ms) sheet or modified from a ready-made oil drum. The schematic is shown in Figure 1. At one end the cylinder, an L-shaped chimney is formed from two pipes of diameter 100 mm, joined at an elbow and attached close to the top. The other end of the cylinder has a fixed lower half and the upper half is a hinged door. The lower half of this end has a small opening of 50 mm diameter to accept a bent pipe, which serves as the air inlet for the lower portion. The 50 mm bent pipe has a number of holes drilled along it, and this perforated section is pushed some way into the kiln to permit the entry of air into the fuel mix (see Figure 2). The other end is bent away and juts above the surface of the soil when the kiln is buried, as described below.

The whole unit is buried in soil so that only the chimney and the air inlet pipes jut out. In this manner, the unit

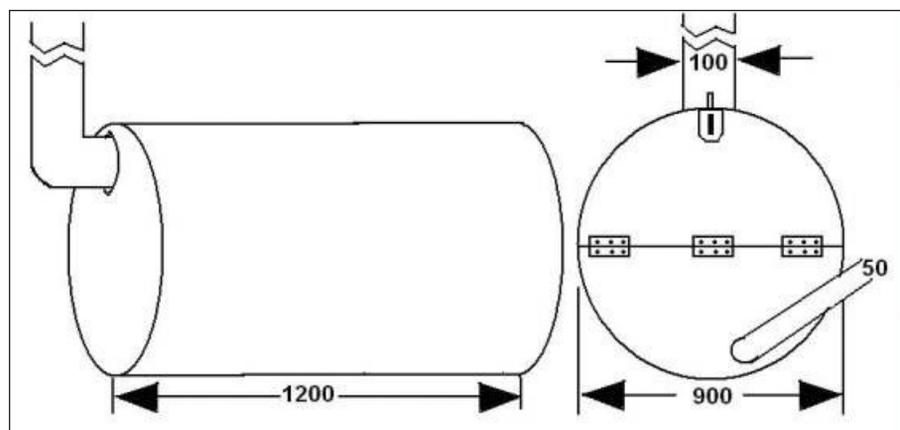


Figure 1 Schematic drawing of charring kiln for agricultural residues (dimensions in mm)

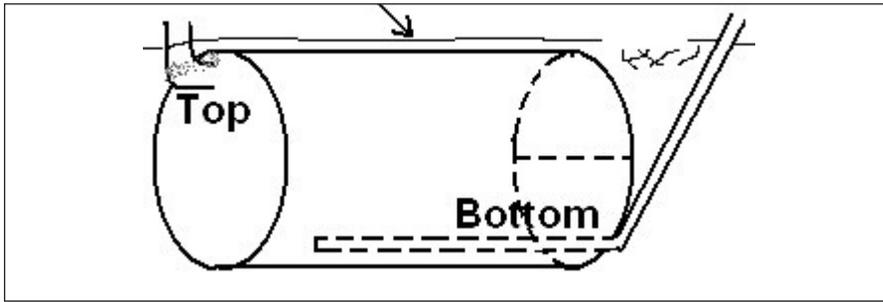


Figure 2 Schematic of the kiln buried ready for use

is insulated from all sides and the heat of combustion is conserved to a large extent. After burying the unit, a small slope is made on the hinged side so that the hinged door can be opened for easy feeding of raw material; this is left unfilled. The unit is ready for making charcoal out of agricultural residues. Wherever it is not possible to weld in the pipes (e.g. lack of electricity), it will suffice to make the holes using a chisel and hammer into which the pipes are pushed. To prevent leakage of air, the joint may be covered with thick mud paste. Since the whole unit is buried, problems of air leakage and over burning of the soft wood are minimised.

Some of the exposed portions of the kiln may become very hot and caution must be exercised to avoid burn-

ing one's hands and feet. The chimney should be extended to a height of 1500 to 1800 mm above the ground so that the operator is not directly exposed to the smoke emitted by the kiln. The extension pipe is made detachable so that the outlet can be covered once the burn process is completed. A spade with a long handle is needed to unload the charcoal once it is ready in the kiln.

Loading and firing the kiln

Agricultural waste in the form of dried stems and twigs are collected and kept ready. The semi-circular door on one side is opened and a small quantity of the agricultural waste is pushed into the kiln so as to cover the whole length. A piece of flaming paper or grass is lit and pushed into the kiln so that the material catches fire and starts burning. This is allowed to burn till all the material turns into red hot embers. This state is shown in Figure 3.

At this point, additional material is pushed into the kiln with the help of a stout pole till the drum is completely filled. It will be seen that the kiln starts to emit thick white smoke indicating the escape of volatile gases in the raw material. The hinged door is now closed and the kiln left to burn away the material inside it. Since the door is not fully airtight and the small air inlet pipe also allows some air into the kiln, air is available for the combustion process to continue, which can be seen from the smoke coming from the chimney.

For a fully loaded kiln with agricultural residues derived from red gram stems, it has been found to take between 90 to 120 minutes for complete conversion of the biomass into char. The right time for stopping the combustion process is determined



Figure 4 Fully loaded kiln giving white smoke (photo: CIAE)

from the colour of the smoke from the chimney. As the material inside the kiln burns away and the volatile matter escapes away as exhaust, the colour of the smoke turns from white to grey and then to black gradually. This state is shown in Figure 4.

Stopping the process

It is necessary to have about 2–3 bags of sand for this operation, and the same amount can be held in reserve nearby. Insulated gloves are also needed. When all the material inside the kiln gets converted to red hot embers, the smoke completely vanishes and only colourless convection of hot gases can be seen. At this stage, all entry of air into the kiln is stopped. Firstly, the sand kept near the feeding end is pushed with a spade to cover the opening completely. The sand seals off the closed semicircular lid. The extension to the chimney is removed with the help of insulating gloves and the open end is closed with a slab of stone or a lid made especially for this purpose. The small air inlet



Figure 3 Initial burning of waste in the kiln (photo: CIAE)

pipe at the feed end is also closed off in a similar way. Thus the whole kiln is made airtight. If there is a leak around the kiln, all the material will turn into ash. It is left to cool for 5–6 hours. It is advisable not to open the kiln to remove the material whilst it is hot, as hot char may catch fire and cause accidents. After a few successful runs, it is possible to judge and operate the kiln without any difficulty. Sometimes, it may be necessary to chop the twigs into smaller pieces for easy feeding.

Char from the kiln

The woody content of dry agricultural residues contains about 50% carbon, and 15% moisture. In some cases, it may be drier. The remaining matter is unwanted tar, alcohols, lignin etc. Even when the kiln appears to be fully filled, there will be lot of space around the pieces of fuel. Therefore, after complete conversion, there will be considerable reduction in volume, as the long twigs will have crumbled to smaller pieces. Even after a successful burn, there will be a small portion that has been converted to ash and also some woody mass in the corners that did not get enough air or heat to convert to char. These can be separated at a later stage. Some of the charcoal will have turned to powder. These products are quite acceptable. The charcoal produced in this way is shown in Figure 5.

Briquettes

The charcoal produced in the above process is of very low density and very brittle with large quantities of powdery material. It does not burn efficiently or produce much heat in a stove in this state. Therefore, it is necessary to convert it into briquettes of a suitable size and shape with reasonable density. The charcoal obtained by the above process is ground to a powder using a small grinder. A *bonding agent* is needed to make the briquettes stick together, and this can be boiled starch or fresh cow dung. Starch is preferable for a more smoke-free fire, whilst fresh cow dung as bonding agent creates slight smoke during the initial 8–10 minutes. Nevertheless, cow dung is locally available and the briquettes are less smoky than the cow dung cakes used by the villagers for cooking. It has been found experimentally that no more than 5% by volume of binder is sufficient for adequate bonding that withstands handling without crumbling. Briquettes are made using a screw type extruder to which the char and binder mixture is fed gradually. A flow chart of the briquette making process is shown in Figure 5.

The wet briquettes are laid out in the open sun to dry out completely. Depending on the weather, it may take two to three days to dry all the way through. Thus no charcoal is wasted in the drying process, and the resulting briquettes have high calorific value.

The briquettes thus produced are quite convenient and occupy considerably lower volume than the original agricultural residues.

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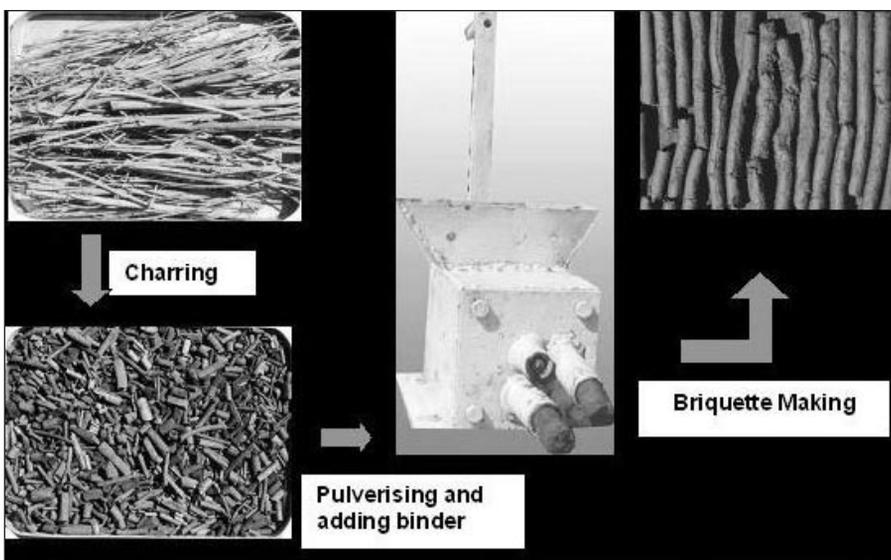


Figure 5 Flow chart of the charcoal briquette-making process