SMALL SCALE BIOCHAR PRODUCTION

David Domermuth Ph.D. Appalachian State University

INTRODUCTION

This paper explains the factors and methods of small scale biochar conversion. It is written in a conversational tone and represents the study and observations of Dr. David Domermuth from seven years of research at Appalachian State University in Boone, NC. This paper is basically a Frequently Asked Question synopsis.

Biochar (Charcoal) is to wood what coke is to coal. Chemists call this conversion process dry distillation. What you are trying to do is heat up the wood and gasify everything except the carbon. This has to be done in the absence of oxygen/air. If oxygen is present it will combine/combust with the very hot carbon to form carbon dioxide. The carbon that is left is a specific form of charcoal. The difficulty of this process is making the most biochar with the least amount of expended energy.

HOW TO MAKE BIOCHAR, SIMPLE VERSION

The simplest but least efficient way to create biochar is with a camp fire. Make any size fire with any type of wood and burn it until you create a bed of embers/coals. Separate the coals and extinguish them. You can extinguish them with water or by collecting them in a metal can and sealing the lid. You can also smother them with dirt in your garden. In any event oxidation must stop, more on that later. The remaining coals are a crude, but effective form of biochar. This process requires no equipment so it is arguably the best way to start with biochar, providing you like to make fires and have scrape wood or brush available. The biochar will function but is not the same grade that can be created in a temperature regulated kiln. Worldwide and historically, most agricultural biochar is made this way. Farmers burn crop residue in the fields in ditches then extinguish with dirt. This eliminates the crop residue while eliminating potential insect infestations and diseased plants; the volatile organic residue is eliminated and the char remains where it was produced, eliminating costly transportation. Most people should start with this process. Make some biochar and start using it then move to more sophisticated methods later if you become enamored with the concept of biochar. Too many potential users get caught up with the minutia of creating and inoculating biochar instead of harvesting its effects.

HOW TO MAKE BIOCHAR, COMPLEX VERSION

The next method for making biochar is elaborate compared to a camp fire but is much more efficient for long term production. Efficiency is measured by biochar produced compared to heat energy expended. The efficiency is increased by insulating the cooking process with a kiln. The total energy expended, including muscle, fuel, and natural resources is questionable, but this process produces a high grade of commercially acceptable biochar. The first fact you must realize; biochar production is highly endothermic, it requires a lot of heat energy to dry the wood and then drive off the volatile components of the wood – to result in a pure carbon skeleton. This porous carbon skeleton is described later in “how biochar functions”.

Using dry wood saves energy by reducing the heat required to vaporize water. Ideally biochar is made from wood chips or small pieces of wood that have been sun dried for a season. Then the chips are distilled in a steel barrel or can. The difficulty and dangerous way to do this is in a barrel with a sealed lid and a vapor pipe. The author tried this for years and gave up. The simple and safe method is to invert a barrel with a mesh lid to retain the chips. A minimum of air will enter an inverted barrel because the wood is off gassing and pushing the gas down against air. The screen cover can be made out of a square of expanded metal with the corners folded up to clamp around the open end of the barrel (expanded metal is thick steel sheet with diamond shaped openings). This screen lid is sort of snapped on and off the barrel and held in place while the barrel is careful tipped/inverted. The barrel is filled with chips with larger chips on top so they won’t sift out through the expanded metal after converting into char. Now the inverted barrel is careful placed above the fire to cook. The barrel has to rest on a metal stand above the fire. A 20-30 gallon barrel is ideal, one to two feet above the ground. As the wood chips heat up they first dry and give of their moisture.

So far this process is easy, a barrel with a heavy screen lid, inverted over a fire. But this won’t work efficiently. The barrel has to be heated to 900 degrees Fahrenheit before the dry distillation is complete, about two hours. You can build a huge fire but is will use a truck load of wood; solution is surrounding the barrel in an insulated box or kiln. The kiln holds in the heat so that a small fire can heat the barrel. When the barrel reaches the 212 degree Fahrenheit, the moisture becomes steam. Around 454 degrees Fahrenheit other vapors emits from the wood and ignite in the fire. These vapors are called wood gas and aid the heating process. Eventually around 900 degrees Fahrenheit the dry distillation is complete. There are many ways to build a kiln ranging from a dirt hole in the side of a hill to expensive firebrick. The biggest problem with all the kilns is the door.

KILN SCIENCE

Wood ignites at 451 degrees Fahrenheit, so wood sided kilns though convenient are problematic, they will burn up. But a carefully built metal box can use wood for supports. The support wood might char, (ablation), a little bit and then it will stop burning. Or you can use angle iron for support. But metal is not a good insulator, in fact it is a great conductor of heat. So the metal box has to be surrounded with insulation, like fiberglass. Then the fiberglass has to be protected with a covering, like plywood; and then the kiln has to be protected from rain and wind with something like and open shed. The shed needs to be open to allow the smoke to escape. Thus the char making process has progressed from a camp fire to an insulated steel box in a shed and the cost of char production might be prohibitive. And we haven't even discussed the hardest feature, a door. This is one reason why biochar is not more prevalent, it is not an easy production proposition. The next few paragraphs will describe ways to keep the cost down and the difficult door. But first let's examine the yield and economics of small scale commercial biochar production.

ECONOMICS AND THE BIOCHAR BUSINESS

This analysis is based on using a thirty gallon barrel to make char. Thirty gallons of wood chips will be reduced to about 15 gallons of char, so the char yield is roughly 50% by volume. The yield is similar on a weight basis if you start with dry wood. Assuming soil requires 10% char to a depth of 4 inches, than the half barrel of char, 15 gallons will treat 60 square feet of garden. This equates to 726 batches of char to the acre. Some sources recommend twice this concentration, and the depth of application varies for different root structures. For this analysis the 726 batches would take about 2 years to produce at one batch per day. The batch weighs about 20 pounds and is worth $26 or $18,876 for the 726 batches. If you made 4 batches a day the kiln would be generating about $100/day or $25,000/year for a 50 week year, 5 days per week; enough to treat 1.4 acres. So where is the market for biochar, who will buy it and what, is the potential scenario; also, how to make 4 batches of char per day?

SMALL SCALE BIOCHAR BUSINESS

Small scale biochar production cannot satisfy the quantity demands or be an economical commodity for soy bean or corn farmer, but it could be suitable to supply hobby gardeners; especially in a farmers market arena. A small scale producer could sell local biochar to the gardeners in the semi rural fringe surrounding a metropolitan area, I.E. every city in America. Or supply a circuit of small towns with a delivery to local retailers or on consignment. To meet this demand and create an income requires keeping the kiln up to temperature and handling hot barrels of char. A hobby biochar maker can load and unload a barrel of cool char, building a fire once a day or as they please; but a small-scale-commercial production requires two barrels and continuous operation. A finished barrel comes out and a fresh barrel goes in during the day. The last barrel cooks through the night and is changed out cold in the morning. Then the cycle repeats, ashes out, a fresh fire, and hot barrels changes every 3 to 4 hours. This necessitates and easy to use door and a way to safely exchange a hot barrel of char with a fresh barrel of chips. This can be done by sliding the barrel in and out of the hot kiln, on a track with a set of tongs or a pole with a hook: The door opens, the hot barrel comes out, the new barrel goes in, door closes, wait two hours, unload the cooled char, reload the barrel with chips, and repeat the process. This smooth process all hinges on the door.

KILN DOOR

Anyone can build a kiln box with a roof but a tight sealing door is tough, and a good door has to interface with a good kiln. The kiln has a number of functions to perform with parameters to be optimized. It needs to be kept dry and blocked from too much wind, has to be easily accessible, and safe. It has to be durable able to be bumped and repeatable handle high heat. Combustion air needs to be let in while smoke is let out with the maximum amount of heat retained. The door needs to seal reasonably tight, be insulated, not too heavy, easily removed and installed. Ideally smoke should be piped out of the back of the kin and high enough to keep out of the operator eyes. Tending the fire needs a separate opening, another short door incorporating an air inlet dampener. The barrel door doesn’t have to be hinged. It can be a large panel that lifts or slides off. It must have a metal edge that contacts with either a metal or masonry edge on the kiln. It must be insulated, not too heavy or expensive. One solution for this is to face the kiln with hard fire brick creating a door jamb; a metal facing can also be used.

The kiln is shaped like a milk carton with a short door in the front to tend the fire and the barrel door on the side. The barrel door opening has to be higher than the fire. The bottom of the door opening is level with two metal rails that support the barrel above the fire. So the door opening is two feet above the ground, two feet wide and three or four feet tall depending on the barrel dimensions. The door is a simple prismatic slab made out of sheet metal, 18 or 20 gage thick; the metal facing the fire. The sheet metal has 4 inch folded edges stiffened with wood or angle iron. You can use wood if it is away from the opening. Here again, the wood might char but phenomena called ablation will potentially stop the burning once a char layer forms. Angle iron is safer but more expensive and harder to fabricate. The door is a large sheet metal pan with a shielded wooden frame; this is filled with foil faced fiberglass insulation. The outward facing side of the door is protected with ½ inch plywood, plastic, or metal. The 20 to 30 pound door is equipped with handles so that it can be rotated or slid open. It can be secured in place with anything from a bungee cord to a receiver slot on one side and a latch on the opposing side. Simplicity, low cost, lightweight, durability, and non-warping, all will optimize the door.

HOW BIOCHAR FUNCTIONS

Biochar is a habitat for microscopic organisms. The organisms live in the tiny openings in the cellular carbon skeleton of the wood char. They absorb nitrogen and then slowly release it to the plant roots. It takes two years for this process to become fully established. The biochar needs to soak in inoculants like animal waste prior to use. Application of 10% by weight or volume is sufficient for a garden; to a depth of up to a foot deep but 4-6 inches is sufficient to start. The char should be ground to a consistence of course sand. This is the basic information for the casual char user. There are numerous articles online explaining this science in great detail. The char also lowers the PH, holds moisture, and filters containments among many additional virtues.

The quality of the char can be tested by smell and rub. Char cooked sufficiently long at 900 degrees Fahrenheit will vaporize its tar, the smelly component. The char will have no smoke smell. The smoke smell comes from the tar. Good char will not leave a tar residue on your fingers when it is rubbed and crushed, black greasy film. Good char will powder and blow away leaving the hands clean with no smoke odor.