

# 1G Toucan TLUD for Biochar Production

by Hugh McLaughlin, PhD, PE, Alterna Biocarbon Inc., January 2010 Version

## Introduction to Biochar and TLUD pyrolysis

Biochar is a new approach to improving soils based on the ancient practice known as “Terra Preta”, where soils in the Amazon were enhanced by the addition of charcoal. . Since any agricultural utilization of biochar starts with obtaining the biochar, and since biochar is not yet a widely available commercial product, one challenge is obtaining reasonable quality biochar. **This memo outlines a simple device and method for making small quantities of consistent, high-purity and easy-to-use biochar, suitable for home gardeners for use in potting soils and gardens.**

One method of making good quality biochar is called Top-Lit UpDraft pyrolysis, commonly referred to as “TLUD” (Tee-lud). The TLUD principles are explained in various resources (just Google “TLUD”), but also will be evident in the discussion that follows. TLUDs were developed as cook stoves, but can be operated to produce biochar.

The “1G Toucan” is one of the smallest and simplest TLUDs to make. It is made from two tin cans (hence the nickname “Toucan” – the large-beaked tropical bird that is used as the unifying nickname of the author’s TLUD designs). The “1G” designates that the main can is a clean empty one gallon paint can, available new for under \$5 at many hardware or paint-supply stores. Be sure to get the paint can lid and handle when you buy the paint can – you will need them. The second can is a #10 tin can described later.

## Constructing the 1G Toucan TLUD

The paint can is modified by perforating the bottom as shown in Figure 1. The openings are made with a can opener – the ones that create the little triangle-shaped openings, often called a “church key” and shown at the top of Figure 2. The outer ring of 20-30 small triangle openings are made by piercing about half way with the can opener. The 20-30 interior slits are made by pressing the point of the can opener or punching a flat blade screw driver directly through the bottom of the paint can – the metal is thin. The goal is to create a uniform pattern of openings for the primary air for the TLUD. The number of openings is not critical and more is not necessarily better – additional openings can be added later, but too many holes is hard to eliminate.

The other part of the 1G Toucan is called the “Crown” and made from a #10 can, which is the big tin can size used for institutional cooking, like tomato sauce for schools, etc. They are also the big “coffee can” size, nominally 110 ounces and 6 inches in diameter. The tin can section of a recycling center usually has several empties, hopefully rinsed out.



**Figure 1: Can bottom**

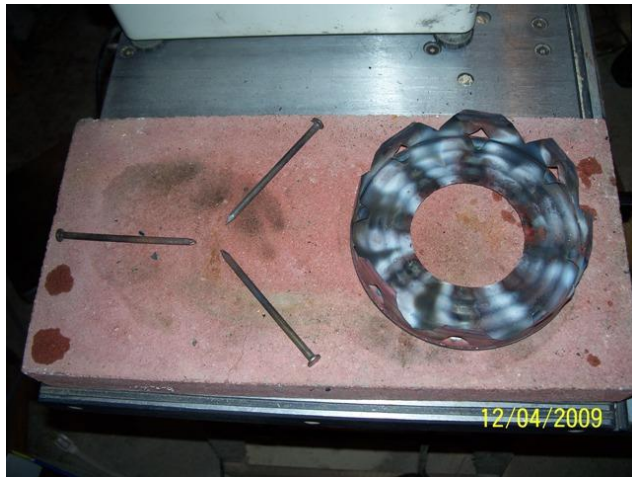


**Figure 2: Crown marked for trimming**

The #10 can is cut down to about 2 inches high – using tin snips and gloves (absolutely required – tin cans can slice you in the blink of an eye). First, cut off most of the excess side material, then more carefully trim one groove nice and uniform. On the sides of the Crown can, near the base, mark eight evenly spaced locations, and draw a 3-inch diameter circle in the center of the bottom, which is usually the innermost stamped ring in the bottom. Also mark eight larger equilateral triangles in the sides, reaching to about one inch of the top of the can, as shown in Figure 2.

With the can opener, create the eight small triangles, and “pierce & twist” a hole in the middle of the bottom of the can to create an opening large enough to start the tin snips. Cut out the circle, which functions as a concentrator hole for the combustible gases and ensuing flames. Cutting tin cans does take a bit of practice, but is easy after a few tries (these are free discarded tin cans, after all). After trimming the smooth bottom edge of the side, the final eight larger triangles in the sides.

The eight tabs of the Crown (now turned upside down) are bent in slightly to allow it to seat easily in the top rim of the paint can. Figure 3 shows the completed Crown and the recommended platform for burning, a concrete block with three nails to support the TLUD. The completed 1G Toucan is shown in Figure 4. Figure 4 also shows how the Toucan sits on three nails (of reasonable size) to provide a small air gap to allow primary combustion air during the wood gasification burn phase, as will be discussed.



**Figure 3: Three-nail stand & Crown**

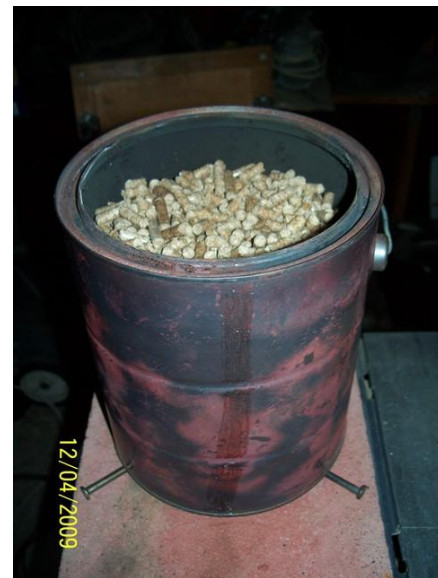


**Figure 4: Completed TLUD**

The last piece of the 1G Toucan is a chimney. A chimney ensures that sufficient secondary air is introduced through the side openings of the Crown and sweeps the secondary flames up through the center opening. It also improves the combustion by containing the flame in a turbulent vertical column. Figure 5 shows a 4" diameter by 24" tall chimney, using a piece of galvanized duct (from the hardware store). Alternately, a #5 can, 4" in diameter and 7" tall, can be used – this is the typical 46 ounce juice can size.



**Figure 5: 4" x 24" chimney**



**Figure 6: Ready to Top Lite**

## Operating the 1G Toucan TLUD

We are ready to light up the 1G Toucan, but first we need to talk about fuels. TLUDs can use a wide variety of biomass fuels, but good biochar requires uniform and dry wood or grass. Since the yield of biochar is only 10-20% of the weight of starting biomass, a denser fuel produces more useable biochar per burn. The preferred fuel is wood pellets, as are used in pellet stoves and widely available in hardware stores, etc. Dry wood chips or landscaping mulch can also be used, but it turns out that wood pellets are probably a better value, providing more weight per dollar for a store-bought fuel. If grass or straw is used, having it compressed into pellets or small uniform shapes helps pack a reasonable amount of grass in the TLUD. Most important is the fuel must be dry, not necessarily bone dry, but the drier the better. Wood pellets are about 6 percent residual moisture and they burn very nicely. Starting with wood pellets is recommended, if possible, to learn how to run the stove, then one can try other fuels to see how they work.

**A note about the First Time you burn a TLUD:** All metals these days, including paint cans and tin cans, may have protective coatings that don't withstand the heat and produce odors the first time they get hot. As such, new 1G Toucans should be fired up the first time outdoors and exposure to any noxious fumes avoided. After a few burns, the materials are accustomed to the heat, the fumes cease, and the odors abate. Even the galvanized chimney changes by developing a zinc oxide outer coating when heated, as shown in Figure 5.

Figure 6 shows the 1G Toucan loaded with wood pellets. As the name implies, TLUDs are “top lit”, which is done by either lighting the top of the fuel or making the top layer of fuel easier to burn. The top of the fuel can be directly ignited with a propane torch or by placing a layer of burning coals on the top of the fuel. Alternately, a small amount of the fuel can be wetted with charcoal starter, citronella oil (tiki torch fuel), or alcohol (be careful – pure alcohol is very flammable). 91% isopropyl alcohol, from the first aid section of the drug store, also works very well and is quite inexpensive. First mix a bit of the biomass fuel with one third as much starter fluid in a separate container, then spread it over the top of the remaining fuel, touch it off with a match and the top lights uniformly every time. It is important not to pour any liquid directly on top of the fuel, since it could drain down through the fuel, causing the combustion interface or pyrolysis zone to short-circuit and disrupt the uniform “top lit” burning pattern.

Once the top layer of fuel is lit, the Crown can be placed on the paint can and the chimney added. Shortly, the combustion regime will split into a pyrolysis zone descending in the bed of fuel, converting the biomass to char via the process of carbonization. Simultaneously, the TLUD is producing wood gas via the process of “wood pyrolysis”. The wood gas rises through the charred fuel bed and is mixed with additional air by the Crown, which results in secondary combustion going upward through the concentrator hole. The flames can be seen at the top of the TLUD, as shown in Figure 7.

Figures 4, 6 and 7 show two **optional** ways of monitoring the TLUD, with either a magnetic stove temperature gauge or a strip of candle wax etched vertically on the side. Figure 7 shows the wax melted half way down the can and the thermometer reading 300 Fahrenheit, revealing the position of the pyrolysis front descending the bed of wood pellets, leaving a bed of char above the pyrolysis front.



When the pyrolysis front reaches the bottom of the fuel, two things happen; the flame turns from yellow to blue and the red pyrolysis front can be seen illuminating the bottom of the TLUD, as shown in Figure 8. At this point, all the biomass has been converted to char and wood pyrolysis ends due to the lack of additional wood fuel to gasify. For a 1G Toucan loaded with wood pellets, the wood pyrolysis (char-making) phase takes between 45 minutes and 90 minutes, depending on the height of the chimney.



**Figure 7: Half way through burn**



**Figure 8: End of Wood Pyrolysis**

Taller chimneys provide better draft and shorten the burn cycle. It turns out that shorter burn cycles also produce biochar with higher adsorption capacity, which is a desirable property. The 24" chimney is a bit much, but does produce nice biochar and completely contains the secondary combustion flames. The user can select a chimney height that produces the most aesthetically pleasing flames, especially if you plan on sitting around watching the 1G Toucan burn and, therefore, pretending you're doing something really important. Otherwise, put a tall chimney on it and check on it every so often.

If the TLUD is allowed to continue to burn after wood pyrolysis is completed, the char starts to gasify and the char is converted to ash. This "char gasification" is quite slow and the blue flames on top may well extinguish, allowing hazardous carbon monoxide (CO) to escape into the air. The char gasification will not stop, however, and eventually all the char will be converted to ash, reducing the production of biochar. Therefore, it is up to the user to halt the char gasification.

This is done by "quenching" the TLUD by sealing off the sources of air. The 1G Toucan is designed to be moved from the three nails and set on a flat heat-tolerant non-combustible surface to seal off the bottom (or just remove the three nails and set it down on the concrete block). The Crown is removed and the original paint can top is placed loosely on the top of the paint can, as

shown in Figure 9. Very shortly, all combustion will cease. If the TLUD has converted all the wood to char, there will be very little smoke, if any.

Although the combustion has stopped, the TLUD still has to cool and that may take several hours. Alternately, the hot char can be transferred to a separate “Quench Can”, with an airtight lid to allow the char to cool in the absence of oxygen. If one transfers hot char, please wear gloves and be careful. Notice how hot the char is at the end of the burn, as shown by the thermometer in Figure 8, which is indicating over 600 Fahrenheit. If the char is placed in a Quench Can, the Toucan fuel container will cool quickly and then may be refueled and relit.



**Fig. 9: Quenching char**



**Figure 10: 1G Toucan Biochar**

Once cooled, the Toucan can be emptied of biochar. The biochar is much less dense than the original wood pellets. Also, the wood shrinks during pyrolysis and the Toucan will produce about one half the original fuel volume as biochar. Figure 10 shows the finished biochar, which can be used “as is” or crushed. It is added directly to potting soils or gardens, typically at about 10-20% of the root soil volume. Remember to provide additional fertilizer at the same time with the biochar, or it will soak up all the available nutrients in the soil, and then slowly release them back to the plants. Alternately, add the biochar to an active composting process and it will be “good to go” when the composting is completed.

**A note about Soot and Carbon Monoxide:** Soot is basically unburned wood gas, which upon cooling, condenses to form visible particulates, also known as smoke. Running properly, TLUDs should not produce soot or smoke. Carbon monoxide is principally a combustion product of char gasification, after the wood pyrolysis ends, as evidenced by blue flames. The major concern is if the blue flames extinguish, then unburned carbon monoxide can be emitted from the stove. For this reason, the 1G Toucan and all TLUDs should only be used in well-ventilated areas. A nearby household CO detector is a good idea for any location that will have repeated TLUD burns, such as in fireplaces or marginally ventilated areas such as garages.

**So, have fun with the 1G Toucan, or any other TLUD, make some biochar, and go play in the garden. It is good for Mother Earth and good for you.**

## Additional 1G Toucan uses

The lowly 1G Toucan is intended for introducing the user to TLUDs and generating small quantities of biochar for home use. There are, however, a few additional applications that may serve to amuse the casual TLUD practitioner.

**The Toucan Retort:** A retort is a container of biomass used to make biochar in the absence of oxygen. The Toucan's paint can, filled with biomass (likely either blocks of wood or wood pellets) and having the original paint can lid placed snugly on top, makes a fairly effective retort when placed in an active combustion regime – like a camp fire, fireplace, wood burning stove or fireplace insert. Just place the fueled Toucan, lid in place, directly in an active fire or on top of a bed of embers, bottom down or tipped slightly to see the vents on the can bottom. The retort, upon heating, starts generating wood gas, which exits the Toucan via the bottom vents and is burned upon mixing with additional air. Once all the wood gas has been released, the Toucan can be cooled and the biochar retrieved. Beware if taking a Toucan Retort out of a hot fire, since it may continue to produce and emit wood gas at a rate too low to support open flames, resulting in annoying smoke. Therefore, there are three options: 1) Be ready to place it in a large quench can, large enough to take the entire 1G Toucan “as is”, 2) Be outdoors where you can set the TLUD on a flat surface or ground until it cools, or dump out the hot charcoal into water or wet soil, or 3) Have a clear area inside the fireplace, to stand the Toucan Retort upright and leave the Toucan until the main fire goes out. Because it is operated as a retort with no active combustion inside, the mass yield is typically about *fifty percent more* than a similar scale TLUD operation, due to the absence of the TLUD pyrolysis front. Basically, retort chars retain and convert more volatile matter into char and have some different biochar characteristics than TLUD chars.

**The Toucan Fireplace Insert:** The Toucan can be burned in a traditional fireplace, fireplace insert or self-standing wood stove (if it fits) to generate comforting flames, some heat and biochar. Remember to provide the air gap at the bottom of the paint can and stop the char gasification when the flames turn blue or go out – or the biochar will be consumed and only ash will remain. There should not be additional burning embers or open flames inside the fireplace, since that may inhibit or disrupt the typical top-down pyrolysis of the TLUD.

**The Toucan Cook Stove:** The Toucan makes a very good camping stove, with a couple of caveats. Wood gas is a reasonable cooking fuel, but not as excellent as natural gas or propane. So be patient and hold the pan above the flames and capture as much heat as possible or construct a pot stand to hold the pot. Take caution that the cooking pot is well supported and stable – several quarts of boiling water are a much greater risk of injury than the open flames of the stove. One thing about cooking directly over an open flame of wood gas – the bottom of the pot can get black with soot. This is normal and implies that the heat being generated as the flames combust is getting transferred efficiently to the pot, but the bottom does get dirty.

**The Toucan Survival Stove:** The Northeast had a bad ice storm in December of 2008 and we all learned how to survive without electricity. Several stranded survivors noted “I wish I had one of those – then.” Applying techniques noted in #2 & #3 above, and assuming you don't run out of fuel (in which case, you are in a bad way), the Toucan will help get you through the worst of straits in a true emergency.