Now that your students have made a TLUD from two 15 oz cans and have also made a safety can, it is time to make some biochar. But first:

1. Safety precautions;
2. A list of materials you will need.

It's very important to take fire safety measures when you work with TLUDs. Even a small TLUD can generate temperatures in excess of 1,000 degrees F. For your safety, and the safety of your students, read the following steps before operating your TLUD.

Safety Precautions:

Step 1: Keep students at a safe distance from operating TLUDS. No running around.

Step 2: Wear close-fitting clothing - no scarves or skirts. Long hair must be tied back and up.

Step 3: Make sure nothing flammable is nearby. Be sure to check under the TLUD as well.

Step 4: Have a fire extinguisher, a bucket of water, and a First Aid kit handy at all times.

Step 5: Make sure there's no dry vegetation nearby.

Step 6: Always operate the TLUD in its safety/windshield can.

Step 7: ALWAYS use insulated gloves and long handled pliers when handling TLUDs that are operating, or have recently been operated. Expect them to be VERY hot.

Step 8: Stand to one side when quenching the biochar. It can produce puffs of live steam. Live steam is dangerous.

Step 9: Before leaving or ending the session, quench in water the contents of ALL TLUDS that have been in operation Make sure there are no hot coals stuck in any of the TLUDs.

Step 10: Never operate a TLUD indoors - unless it is under a hood with excellent draft for capturing all of the stack gases. Operating TLUDs outdoors offers good protection from the stack gases that will be emitted by the TLUD.

Tips & Warnings

* Keep anything flammable away from fire and heat.

* Teach everyone how to put out a clothing fire - stop, drop and roll (If in doubt, please look up "How to Teach a Child to Stop, Drop and Roll)

* In the event of a fire, get all of your students to safety before attempting to put the fire out yourself. If the fire is spreading too quickly, get everyone away and call 911.

Materials you will need

1. Completed TLUD and its safety/windshield can;

2. 1/2 cup measure. This will give you about 60 grams of wood pellets;

3. Tablespoon measure;

4. Jar or can to make starter in;

5. 8 oz funnel and strainer to make starter with;

6. 91% rubbing alcohol for the pyrolysis starter;

7. Timer;

8. 1/2 cup of clean, dry wood pellets per TLUD to be used. This may be measured out and put in baggies in advance.

9. Small wooden matches;

10. Insulated gloves -- must be available for the operator of a TLUD;

11. Long handled pliers -- must be available for anyone quenching biochar;

12. Fire extinguisher;

13. Bucket of water;

14. Pan to quench biochar in, filled with 250 ml of cold water - one per TLUD

15. Large sieve to separate biochar from the quenching water;

16. Containers for the finished, quenched, and rinsed biochar;

17. First Aid Kit

18. Note book to record the results -- ideally one per TLUD to be operated.

Getting Started

Once you have prepared a fire safe working area, either out doors or under a good ventilating hood, and have established emergency procedures and exit routes, then you are ready to prepare your TLUD for operation. This will involve a number of steps as illustrated below.

Measure out the half cup of biomass, in this case wood pellets, that will be pyrolyzed:

Next, from this half cup, collect a heaping table spoonful of pellets to use as the pyrolysis starter.

Dump this heaping table spoon full of pellets in the jar or can you have for making starter.

Cover the pellets with 91% rubbing alcohol.

Wait 4 - 5 minutes -- time this for repeatability.

Use this period to place the remainder of the pellets into the main part of the TLUD, as shown on the next page:

The main part of the TLUD is the can with the primary and secondary air holes in it.

When the time is up, strain the alcohol back into its bottle. See next page:

Before you do anything else, replace the cap on the alcohol bottle. It is important not to spill it all over the place. This will create a major fire hazard that must be cleaned up BEFORE any thing else is done.

Next, shake the pellets in the strainer to get rid of any excess unabsorbed alcohol. The goal is to only start the pyrolysis on the top of the biomass in the TLUD. Any alcohol that runs down into the pellets in the TLUD will allow the pyrolysis to start below the top layer. This should be avoid if at all possible.

Shaking excess alcohol from the wood pellet starter.

If all of the safety items are in place, and the TLUD is in a fire safe location, you are ready to add the starter and start the pyrolysis. See the photos on the next page.

Note: if you have not already prepared a pan in which to quench the biochar, do it now. Fill the pan with about 250 ml of cold, fresh, water.

To put the TLUD into operation:

1. Add the alcohol soaked and well drained wood pellets to the top of the biomass already in the TLUD - the can with the primary and secondary air holes in it. Do not stir it in. You may use a long nail or screw driver to spread the starter pellets out evenly -- only if necessary.

2. Place the draft can on top of the basic TLUD can -- the can with the primary and secondary air holes. If the two cans do not lock together snugly, than place the basic TLUD in the safety can first. Then balance the the top can, the draft enhancer made from the second 15 oz can, on top of the bottom can. Lastly, center the two cans in the safety/wind/shield can. Now all cans, biomass, and starter are in place.

At this point, before starting the pyrolysis, **do a last safety check** to make sure all is well and safe to go. The teacher or instructor should give this approval BEFORE the students start the pyrolysis. Students should not start pyrolysis without permission.

Now that the student is good to go, it is time to start the pyrolysis. This is a one match process.

Simply drop the match down the draft can and into the basic TLUD can below. The alcohol soaked starter pellets will light immediately. Start your timer NOW so you can time the run.

Warning: The initial flames will be quite blue and may be hard to see. They are there and they are hot. You can test this by carefully placing a hand well above the top of the cans. You will feel the heat, even if you do not see the flames.

The pyrolysis in a TLUD with 10 primary air holes of 9/64ths [3.6 mm] size will run for about 16 1/2 minutes, give or take a minute. Watch the flame patterns, colors, and flame height. Does the flame come out of the bottom can? The top can? Can you see any soot being ejected from the system?

When the last of the flames of the burning pyrolytic gases self extinguishes, the two can TLUD will smoke a bit. Let it smoke. Does it stop smoking in less than 60 seconds? 120 seconds? Waiting two minutes before you quench the biochar is enough. But make notes about the smoking. Did it diminish quickly? Was it gone in two minutes or less?

Before you can quench the biochar, you will have to remove the two TLUD cans from the safety/windshield. You should use insulated gloves and pliers to do this safely. See the photos below. Remove the top can, from the bottom can it is balanced on. Place it to one side, out of the way to cool down.

Remove the bottom can from the windshield / safety can in the same manner. It has some very hot charcoal in it so be VERY careful.

You are now ready to quench your biochar in cold water and then evaluate it.

Quenching the Biochar

Wearing insulated gloves, use the pliers to slowly pour the very hot biochar into the 250 ml of cold water in the quenching pot. Make sure ALL of the hot pieces of biochar get into the pot and that none are left in the TLUD. You may have to tap the bottom of the TLUD quite hard to jar any stuck bits free. Do a careful visual check of the TLUD to make sure it is completely empty.

Set the bottom can back inside the windshield/safety can to cool off. It will be hot for a few minutes.

Evaluating your biochar

The students have already done the first of seven evaluations.

Test #1: Smoke -- If the smoke at the end of pyrolysis last 60 seconds or less, this is a very good indicator that there is not too much residual "junk" left in the biochar. If the smoke greatly diminished in two minutes or less, this is also a good sign.

Test #2: Floaters -- Stir the pot with the biochar in it. Use a nail or a stick or a screw driver etc. There should be very few "floaters" in the water. Charcoal that floats is not as absorptive as biochar the sinks in very short order. Absorption is good and is the desired result. Discard the floaters.

Test #3: Brown bits -- Look for “brown bits” of incompletely charred pellets. This is an indication of incomplete and uneven pyrolysis. Discard the brown bits. But they are telling the student that not all may not be well.

Test #4: Clear water -- Is the quenching water clear or milky? Clear is good. Milky indicates the presence of too much ash. This suggests that the pyrolysis was too hot and too fast and some of the charcoal was actually burned down to ash. If this is the case, your harvest of biochar is less than optimal. It may also suggest that the pH of your biochar is not neutral.

Test #5: Smell -- Scoop out as much biochar as you can from the cool quenching water. Put it right up to your nose and smell it. It should have no oder. If it smells of old fires, creosote, then it is dirty and you may well want to discard it.

Test # 6: Hugh McLaughlin’s “no soap test”. Take some of the freshly water quenched biochar from the quenching pot. it may be pleasantly warm.

The no soap test photos are by Lars Torres.

"Grind" the biochar into your skin as it you meant it to stay there forever.

Now rinse your hands off in the clean quenching water. Does the biochar come off with no soap? If yes, then it is not oily. This is good. If not, and it is oily, you may want to discard the biochar.

Test #7: pH -- Use a pH testing kit to see if the biochar is pH neutral or close to it. If it is not, you will probably want to discard it.

If your biochar passes all 7 tests, if is certainly good enough to use in the next section of this kit. If it fails more than three tests, it may be best to discard it and try again.

Saving your biochar for the next steps:

The last two step are to separate the biochar from the quenching water and to rinse the student's biochar to remove carbon dust and ash:

The cleaned and well drained biochar should be stored in baggies for use in the next section of this kit.

Optional Activity: Measuring your biochar harvest

Before you can measure your biochar harvest, you must first dry it in an oven. Biochar that has been quenched in water may take longer than an hour in a 350 degree oven to return to a moisture content of less than 2%. Dry it in a flat pan. Stir from time to time. Drying in the sun is an even better idea. Be sure to re-hydrate the biochar before you add it to compost or soil.

You will be looking for two numbers:

1. The volume of biochar as compared to the volume of the biomass you started with. It is normal for the pyrolysis process to reduce the starting volume by 50%.

2. If you weigh the dried biochar, if will probably be in the range of 12% - 20% of the weight of the biomass you started with. If it is more than 20%, it is likely that either the biochar is not fully dry or that it may be contaminated with tars etc. Ask the students to figure out what percent of the carbon in the biomass they were able to harvest.

Notes

Note 1: The length of time between starting the pyrolysis and the last flame self extinguishing, the run time for a given amount of biomass, can be informative. If it is too short, there is apt to be very clean biochar but perhaps too much ash. This results in an inefficient biochar harvest. If it is too long, it is too slow and cool and the biochar is apt to have residues, floaters, uncharred bits, and a bad smell etc. With experience with the types and sizes of cans your students use, you will quite quickly get a handle on the optimal run time, plus or minus a minute or two.

Note 2: Do not use too much quenching water as it will make it hard to see the milky state of the water if there is a lot of ash mixed in with the biochar.

Note 3: Once the students have had success with their TLUDs, consider challenging them to use locally sourced biomass such as hay, not yard clippings contaminated with fertilizers and pesticides, seeds such as acorns, cherry pits, gum tree seed pods, or twigs and small bits of wood -- but nothing with paint or preservatives. Pressure treated wood is to be avoided. It will be a good challenge to see how different biomass types, form factors, sizes, and moisture contents work. Sun dried biomass of less than 20% moisture content will be easier to use than fresh green wood chips. Such wood chips can, however, be made to work if you vary the primary and secondary air supplies appropriately. One of the benefits of pyrolysis is that it can use ‘light beer’ fuels. It does not require ‘champagne’ fuels such as stick wood or fossil fuels. Professional biochar reactors, for example, can work well even with simple chicken litter -- best if dried and pelletized.

Note 4: Cans that have had food in them are apt to be lined with plastics of one sort or another. These will burn off after one or two runs. But the first run will very likely have a plastic smell for at least the first part of the run.

Note 5: Never use a can that has had chemicals in it. Old paint cans should NEVER be used. Brand new paint cans can be purchased and used if desired. They are, like food cans, lined with plastic which will burn off.

Note 6: Biomass of uniform form factor, size and moisture content is best for pyrolysis, if consistent and repeatable results are desired. Smaller form factors are easier to handle and come out of the TLUD pretty much ready to be used with no further crushing etc.

Note 7: Have some fun! Try cooking marshmallows over the TLUD. Perhaps sections of hot dogs?

Note 8: Consider having the students take their TLUDs home with them. The TLUDS are not to be used at home without parental approval and supervision.

Note 9: You have seen that the process of making biochar also produces thermal energy. What uses for this thermal energy can your students think of?

The next lesson in this kit is: School Biochar Experiment

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