The Benefits of APL's Biochar Process

Decisions about biochar machines should not be made strictly based on efficiency of yield. Optimizing the efficiency of yield is optimizing for the wrong thing, because biochar's biggest impact is as a soil amendment, and many of the qualities that multiply the agronomic value of the char are obtained by processes which have somewhat of a lower yield. If increasing the yield means failing to capture the biggest value multipliers, the lost value is not worth the increased yield.

The following is a summary of the major differences.

Yield rates vs. processing temperature

As biomass is exposed to increasing temperature, more and more volatile material comes off of the fixed carbon. You can see this from the following graph.

Temperature and Yield Profile for Biomass Pyrolysis

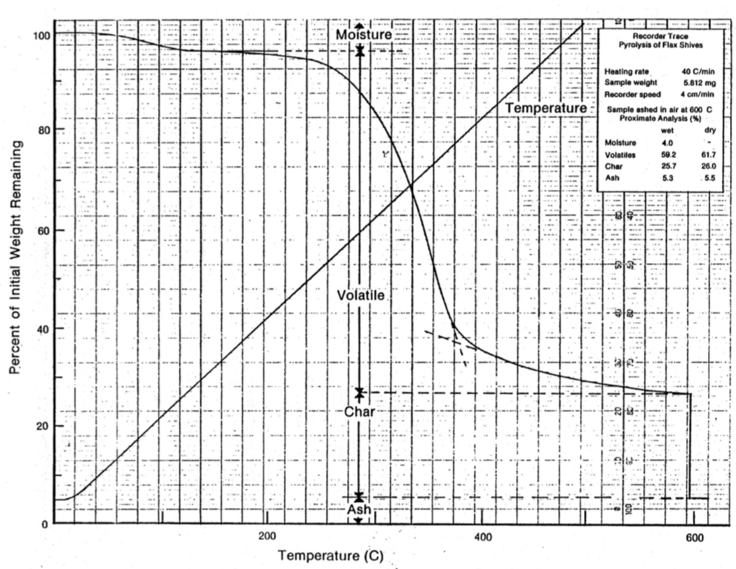


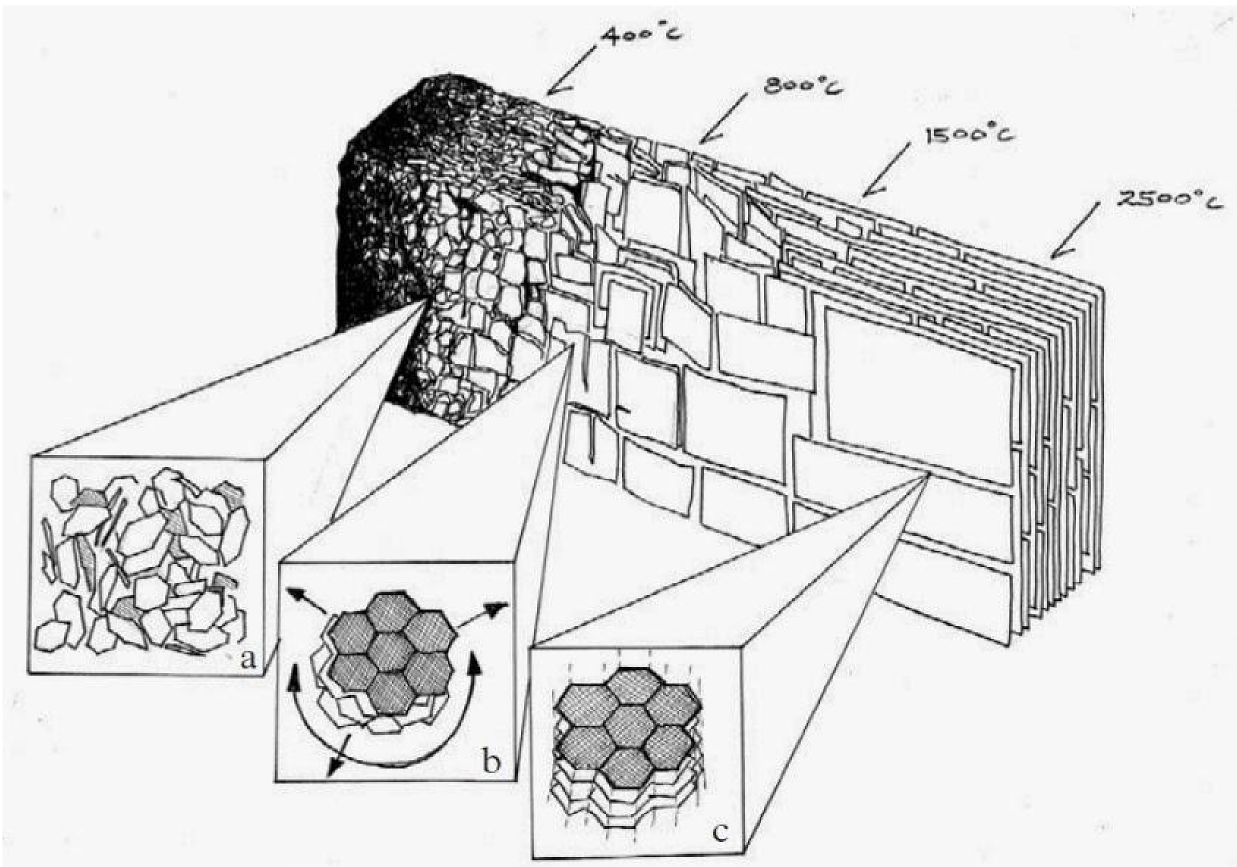
Figure 5-2. A Typical Dynamic TGA Result Obtained with Flax Shives and Showing Moisture, Volatile Matter, Char, and Ash Content

Source: T. Milne 1979

Processes which optimize for biochar yield try to produce char at temperatures around the "knee" of this graph, around 400˚C, resulting in yields close to 35-40%. Processes which take the char all the way up past 600˚C (or even higher) are left with a char yield of around 20%. However, they gain the benefit of conductivity.

Conductivity

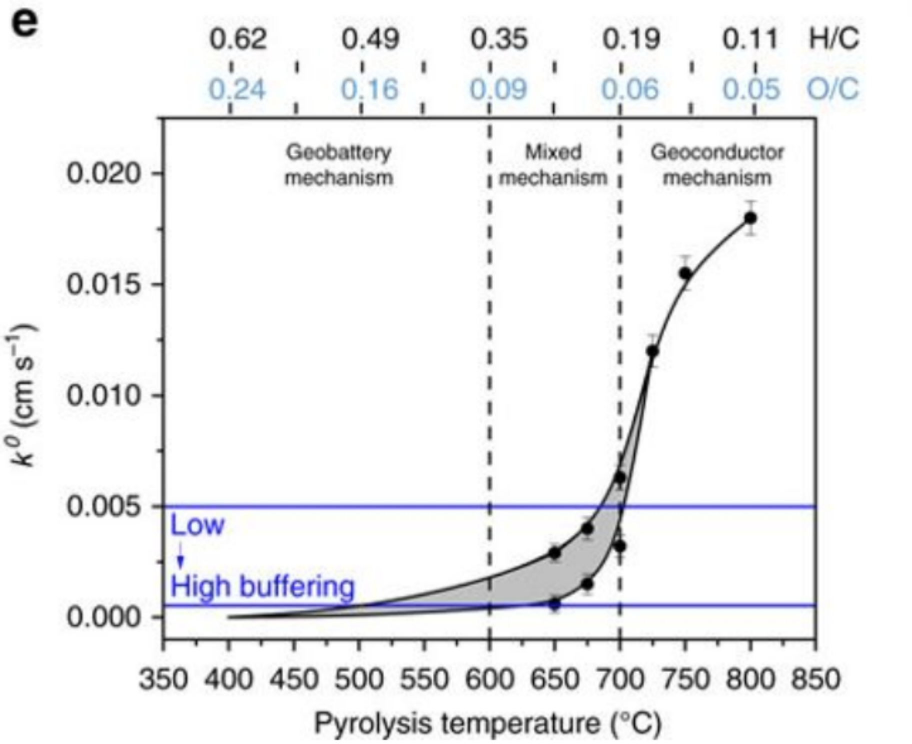
As fixed carbon gets exposed to higher and higher temperatures (above 600˚C, but much more so at 700˚C and above), the unstructured carbon begins to align and form graphene-like sheets, which are conductive. At the very highest temperatures (>1200˚C), the char will actually change into graphite, which is very conductive, but is not necessarily beneficial to plants:



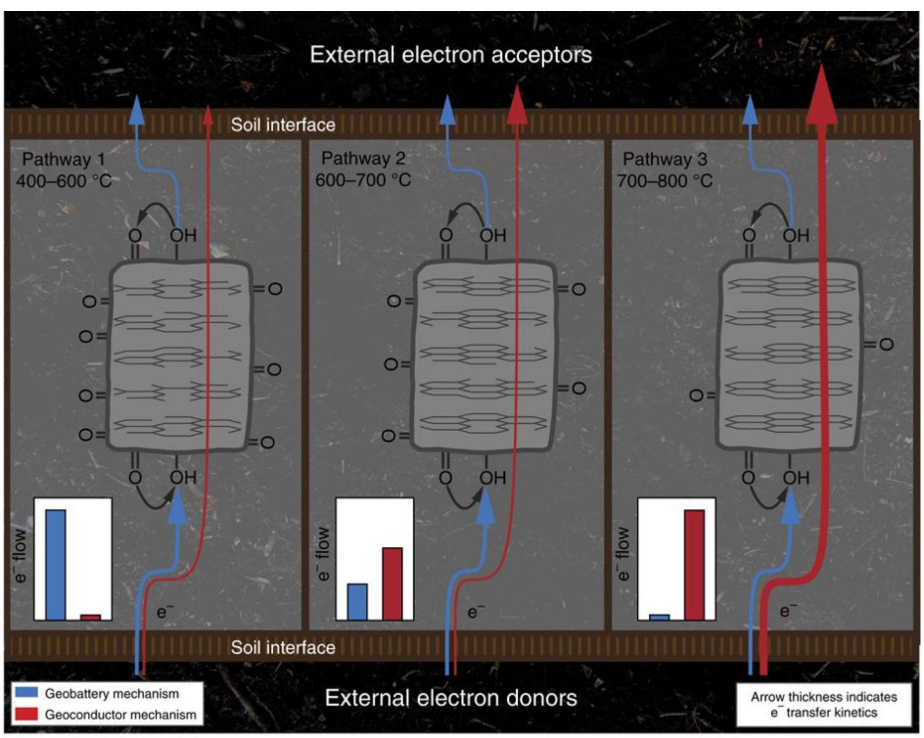
Why does conductivity matter?

Why does conductivity matter? Because nearly every microbial activity in the soil involves electron exchange. Speeding up this electron exchange speeds up the provision of many of the benefits of soil microbes, such as nitrogen fixation and the production of exogenous plant growth hormones.

This conductivity results in this biochar providing a soil service not found in lower temperature biochar: the *geoconductor* and *geocapacitor* soil services, which facilitate DIET (direct interspecies electron transfer) at rates which are far faster than the geobattery mechanism provided by lower temperature (<600˚C peak processing temperature) biochar—over 300% faster. In the following figure, from the scientific journal article that first reported this discovery, you can see that the rate of electron exchange through high temperature processed biochar is far faster than that of biochar produced at lower temperatures.



Here's the schematic from Figure 5 from the scientific journal article that reported this finding, linked below:



See the following articles. The first one is a science news article, which has the main points; the second is the actual scientific journal article, which is rigorous but lengthy and extremely technical.

Researchers discover high-def electron pathways in soil
https://phys.org/news/2017-04-high-def-electron-pathways-soil.html

Journal article:

Rapid electron transfer by the carbon matrix in natural pyrogenic carbon
https://www.nature.com/articles/ncomms14873

The items above establish the benefit of processing the biochar at high temperatures, but the quality of the char is not only a function of the temperature; the process also matters, because the various different methods that can produce char at these temperatures involve different processes which can impact the cleanliness of the char.

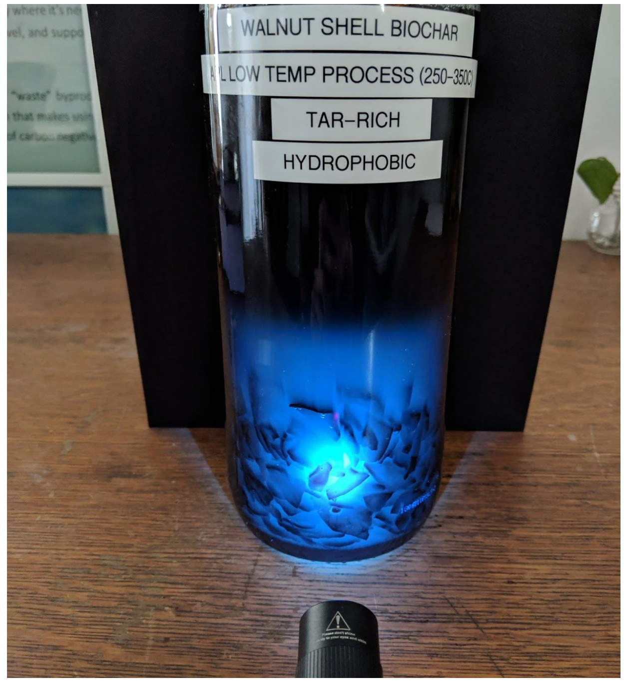
Cleanliness

The production of tar is intrinsic to the production of charcoal. Tar can be classified into three primary classes: *primary tars*, which are just chunks of molecular components of cellulose and lignin; *secondary tars*, which are transformations of these chunks, and *tertiary tars*, which are produced as these tars change and react with each other to form PAHs (polycyclic aromatic hydrocarbons). PAHs are toxic and even carcinogenic. The process of microbe mediated decomposition and oxidation during composting can break down low concentrations of PAHs, but concentrations of PAHs above 10mg/kg are considered harmful.

The same high temperature processes which produce conductive biochar can result in the production of tertiary tars; the alternative pathway that destroys tar is the combustion of these tars and the cracking of the remaining tar gases, which is what our gasifier does, since nearly half of the gas comes from cracked tar. Additionally, our gasifier produces char under a constant flow of gas; the charcoal is blazing hot when the gases are pulled up and away from the char. The result is that our char is remarkably clean among high temperature char, and even compared to some low temperature chars:

In the test shown above, two samples of char, one from our high temperature process, and one from a low temperature high-yield process, are soaked in water. The high temperature char is not only incredibly clean, but it also turns out to be hydrophilic. It aggressively absorbs water, becoming waterlogged, and sinks. In contrast, the low-temperature processed char is full of tar, and is initially hydrophobic, floating because it refuses to wet.

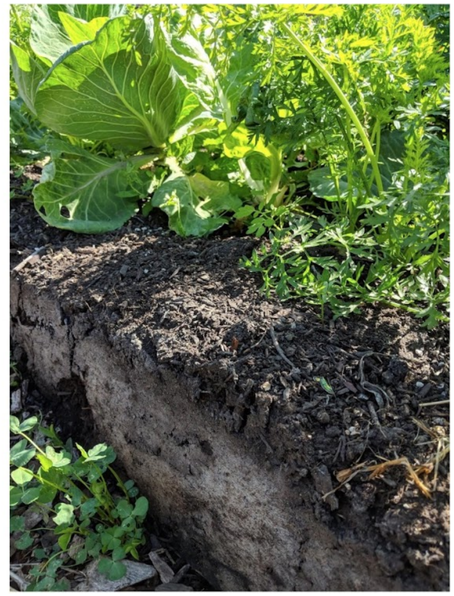
The following photos show a test is a 365nm wavelength UV test for detecting the presence of PAHs. PAHs are toxic, carcinogenic compounds found in tar, and are not desirable in biochar. PAHs fluoresce under this kind of UV light. Even though glass blocks UV light, it doesn't block so much that this powerful UV flashlight can't get through the glass. You can see the dirty char is full of PAHs, whereas the high temp low-tar biochar does not fluoresce, at least not noticeably.



Results

Here are some of the results we're seeing from the use of our biochar. Compost that has 10% of our biochar added to it composts much hotter. We believe this is due to the massive acceleration of microbial activity:

The resulting compost lasts longer and is more stable, due to more thorough decomposition:



In the photo on the left, there are two raised beds, one on each side of the walk way. The one on the right, which was amended with conventional compost, has flattened out and shrunken away as the compost continued to decompose, whereas the one on the left has remained stable. The compost that was composted with biochar seems to have decomposed into a stable solid. Compost such as this is much longer lasting.

The fertility this biochar imparts to the plants is amazing:

In the example above, it appears that plant pathogens survived the composting process for the compost used on the artichoke on the left, whereas the biochar compost used on the artichoke on the right was free of pathogens.

This pair of pumpkin plants showed an absolutely astounding difference in the rate of growth. In spite of being planted at the same time, the one that received the biochar compost exhibited a rate of growth and a level of vigor that utterly dwarfed the one that merely received compost.

The broccoli plant that received plain compost is not unhealthy nor deprived by any measure, but its growth is completely dwarfed by the broccoli that received co-composted biochar.