Understanding Biochar Series

Measuring Biochar Properties – Focus On Ash Levels And Value

By Hugh McLaughlin, PhD, PE – CTO

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Biochar is a complex material, both chemically and physically. Any given biochar reflects properties inherited from the starting material, the pyrolysis process, and any post-processing actions, such as adding moisture to cool hot product. The purpose of this memo is to put some of the constituents in the final biochar in perspective - both in how they appear on the label and what various quantities may mean when the biochar is utilized.

One way to understand the properties of biochar is to break it down into broad classes of compounds that exist at the time the material is created. One simple partition is to consider the biochar to consist of water, organic compounds, and inorganic compounds (often referred to as "ash", but that glosses over the importance of what specifically is in the ash).

During the process that converted the biomass into biochar, the biomass was heated and several things happened to the biomass: the excess water is evaporated, the organic compounds that make up the previously living structures of the plant (the vast majority of which are composed of cellulose, hemicelluloses and lignin) are transformed by "pyrolysis" into the carbon-rich portions of the biochar, and the inorganic compounds are dried out, but remain, by and large, chemically unchanged when heated and cooled.

In contrast to the moisture and organic portion of the biomass, which are being removed from the original biomass, the inorganic portion is essentially inert and its amount remains essentially constant. The net effect is to increase the relative amount of inorganic mass compared to the decreased amount of remaining carbonized organics. Thus, when one compares the weight percent of inorganic compounds in biochar to the inorganic fraction of the original biomass, even on a moisture-free basis, the biochar is significantly higher due to the conservation of the inorganic material in the residual solids formed during pyrolysis and the concurrent loss of organic matter as volatiles.

The extent the inorganic portion increases, relative to the organic fraction, is basically a function of how much of the organic fraction decreases – due to removal of some organic mass via devolatilization. For biochar production processes that just heat the biomass in the absence of any oxygen, roughly three-quarters of the organic mass is converted to “wood gas” and lost as volatiles, leaving about one-quarter of the original organic mass as the organic portion of the biochar. Thus, for very clean woody biomass (no bark or leafy material in the biomass), the starting biomass has around 1 weight percent inorganic mass on a dry basis. The remaining 99 weight percent are organic matter, and that is reduced by three-quarters, or 74.25 weight percent, volatiles, leaving 24.75 weight percent organic biochar in the solids, in addition to the original 1 percent inorganics. Thus, on a dry weight basis, the biochar would be 1/(1+24.75) = 3.88 weight percent inorganics and 96.11 weight percent organic biochar. In addition, the yield of biochar would be 25.75 weight percent of the starting moisture-free biomass.

Higher levels of inorganics are possible if the carbonization process allows oxygen or air to consume some of the carbonized biochar by “char gasification”, the direct burning of the char by oxygen, such as happens in a charcoal grill when the black charcoal is burned in a red ember to produce heat and vapors (carbon dioxide and carbon monoxide). In one type of microgasifier stove known as the TLUD, some of the organic char is consumed during the conversion of the biomass fuel to biochar, and the typical total char yield is 10 to 20 weight percent of the starting dry biomass. Since there is less organic char and less total char, but the amount of inorganic mass remains constant, the relative ash level of the TLUD biochar is higher.

In large industrial gasifiers and boilers intended to utilize biomass as fuel, a significant portion of the char is combusted for additional heat production. Depending on the design and operating practices, anywhere from half to virtually all the organic material may be consumed. As such, it is possible for gasifier biochars to be everything from mostly carbon to mostly ash, with 40 to 60 percent ash by weight fairly typical of materials marketed as “High Carbon Wood Ash”.

High levels of inorganic matter, or “ash”, have several consequences on the utility and value of the biochar, and the effects are not necessarily bad. The best insight into the value of the inorganic portion of a particular biochar is the properties of the inorganic compounds found in the original biomass prior to conversion to biochar. As a rule, to the extent the inorganics in the starting biomass were plant-derived, those compounds will have a value and utility in the growing applications of the subsequent utilization of the biochar. For those compounds, the more germane issue is the relative levels of such plant nutrients in the biochar, and whether the introduction of a specific quantity of a specific biochar into an existing soil will alter the soil such that undesired conditions are created for the soil microbiology or the intended crops.

In contrast, if some of the inorganics are not plant-derived, as in the case of the manures of non-grass feed animals (chickens, swine), the non-plant derived portion of the ash may or may not have value in the soil. In particular, any salt in the diet of the animal may get concentrated in the ash, and impact the soil water upon wetting of the biochar, resulting in brackish groundwater. Another major non-plant constituent of ash is often “dirt”, representing the soil and other particulate residues that became entrained with the biomass and converted to ash in the biochar. In general, dirt is a benign inert, adding weight and volume, but little additional value to the biochar - but also doing no real harm.

Of the several major constituents in the ash, here are the major characteristics:

> Salt: This is literally the sodium chloride found in the diets of the animals, and subsequently found in their manure. Upon wetting in the soil, it dissolves and forms brackish groundwater. It can be measured by conductivity or TDS (total dissolved

solids). Excess salt flushes out with a few excess water events, which may be a short period of the growing season in some areas and a very long time if there is a drought or normal precipitation is minimal.

Alkalinity: This is the effect of the soluble ash on pH – mostly the tendency to raise the soil pH by reacting with any sources of acidity. Unfortunately, pH is a fairly sensitive measure of something that bounces around a lot in the soil. Limestone is a common additive to soils to counteract soil acidity due to decomposing detritus or added organic matter such as compost. In general, if lime is routinely added to the soil, then the limestone in any biochar should be viewed as another option for addressing the lime requirement.

Potassium and Phosphorus: These are beneficial plant nutrients and are usually welcome as part of the biochar. Since they are plant fertilizers, they are consumed by the crop and will not persist in the soil beyond a growing season or two. The potassium is generally immediately available in the soil, but the phosphorus may be in a form that requires soil biology to make it plant available, which is good because it prevents phosphorus leaching into field runoff.

Nitrogen: While nitrogen may be measured in biochar, it is usually not plant available. The pyrolysis conditions used to make biochar usually render the organic nitrogen fixed in the biochar graphite matrix, so the plants never get it. Chicken litter biochars often have impressive nitrogen levels; none of it is of consequence, since the plant cannot extract it from the biochar.

Dirt, sand, silicon dioxide, gravel, grit, etc: These are inerts, add weight, but not value. Some biochars have rock dust intentionally added, and they may provide trace micronutrients. However, if the micronutrients are not called out on the label, don’t expect too much of value.

Sulfates and Nitrates: While they are part of soils, they are not really part of biochars, so one wonders why they are there in the first place. At significant levels, they are an indicator of non-biomass waste, like plaster or sheetrock (drywall), in the biomass supply sources.

Heavy metals: Many heavy metals are plant micronutrients, but they really don't belong in pure biochar at any significant level. We can measure some level of anything these days, but the heavy metals should be present at levels well below any regulatory limits, or something is amiss.

Love: It is almost impossible to measure how much love is packed in a high quality biochar, but your plants and soil microbes will know it is there – and it is unconditional love, at that.

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