INTERPRETING BIOCHAR LAB REPORTS

Learn about

- Biochar properties
- Interpreting a test report
- Tests recommended for different applications
- How to collect samples

Biochar's physical and chemical properties control its effectiveness in different applications. Properties are determined by:

- **feedstock**
- **production conditions**
- **pre- or post- processing**

Biochars differ greatly in their properties so laboratory analytical data provides a way to predict biochar's effectiveness.

Biochars are variable in their physical and chemical properties. These properties are generally determined by feedstock type and production temperature. For example, biochar feedstocks vary in their particle size (increasing along the top arrow), while feedstock and temperature can influence ash content (increasing with bottom arrow). Biochar properties influence how biochar interacts with soil or other media, which influences performance. A lab report assesses these properties. A sample report is shown inside.

Physical properties

1 Moisture content

Moisture content is the amount of water in the sample at the time of analysis. If the report indicates that the moisture content is 30%, then 100 lbs of biochar would contain 30 lbs of water. Moisture content is important to reduce dust. All other biochar analytical data are reported on a dry basis (content per unit dry mass).

2 Bulk density

Bulk density is a required value for converting between volume-based units such as cubic yards and weight-based units such as tons. The mass of biochar per unit is substantially lower than the bulk density of soil. When applied to soils, biochar typically reduces soil bulk density.

3 Surface area

Surface area, typically reported in square meters per gram (m^2/g), indicates the total area of the biochar surface. Biochar with high surface area typically has greater potential to absorb environmental toxins, metals, and nutrients, so the surface area of biochar is especially important when used in environmental remediation applications.

4 Particle size distribution

Particle size distribution indicates the mass percentage of a biochar sample that falls within specific size classes. When used as a soil amendment, particle size distribution influences biochar:soil interactions including impact on soil pH, leaching potential, and soil water dynamics. Particle size distribution is also a critical parameter for filtration applications and when used in granulated products.

Chemical properties related to carbon

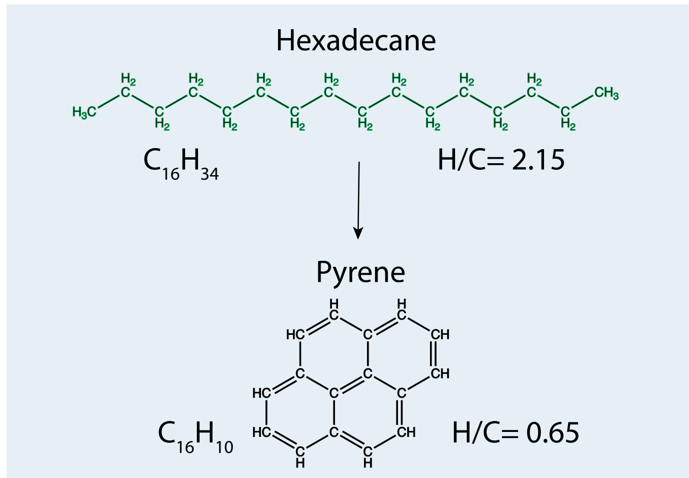
5 Organic carbon (C_{org}) and carbonates (as $CaCO_3$)

Total carbon analysis measures both organic carbon and inorganic carbonates, the latter of which is contained in the ash fraction (typically in the form of carbonates). Most laboratory reports separate total carbon into organic carbon (C_{org}) and carbonates (as $CaCO_3$). Both values are important, so confirm that the laboratory separates these values.

Manure biochars tend to be lower in C_{org} than wood-derived biochars, and for all feedstocks C_{org} generally increases with increasing production temperature. The carbon sequestration potential of biochar is directly related to C_{org}, and this analysis is required under all existing carbon removal methodologies for biochar and for use as a soil amendment under USDA incentive payment programs for biochar such as USDA Natural Resources Conservation Service (NRCS) Conservation Practice Standard (CPS) 336.

6 H:C ratio and fixed carbon

The ratio of hydrogen (H) to carbon (C) atoms, abbreviated as H:C_{org} (sometimes reported as H:C or H/C) ratio, is an indicator for biochar stability. Lower H:C ratios generally correspond to stronger bonds between carbon atoms, reducing susceptibility to microbial and chemical decomposition, therefore indicating a greater long-term carbon sequestration potential. Many biochar standards and carbon removal methodologies require an H:C ratio less than 0.7.



7 Total ash

The ash fraction of biochar contains mineral carbonates and oxides that can react in soil to increase pH, provide nutrients to plants, and bind metals and phosphorus. The ash fraction is comprised of elements that do not volatilize (calcium, potassium, magnesium, silicon, phosphorus and trace metals) at typical biochar production temperatures. Some of these elements are discussed in detail under soil fertility.

8 Volatile matter

Volatile matter is composed of compounds that volatize from the biochar in the absence of oxygen at 950 °C. Volatile matter may contain gases like carbon monoxide and methane; organic hydrocarbons, acids, and tars; and some inorganic compounds. Volatile matter can be an important food source for microbes, which can improve soil fertility.

Typical lab report

Laboratory analytical reports for biochar vary depending on which laboratory performed the analysis, however each report should contain similar information including parameters analyzed, analytical methods used, and results. A typical report is shown below.

International BioChar Initiative (IBI)
Laboratory Tests for Certification Program

		Dry Basis Unless Stated:	Range	Units	Method
1	Moisture (time of analysis)	56.9		% wet wt.	ASTM D1762-84 (105c)
2	Bulk Density	9.9		lb/cu ft	
5	Organic Carbon	77.8		% of total dry mass	Dry Combust-ASTM D 4373
6	Hydrogen/Carbon (H:C)	0.68	0.7 Max	Molar Ratio	H dry combustion/C(above)
7	Total Ash	1.2		% of total dry mass	ASTM D-1762-84
9	Total Nitrogen	0.38		% of total dry mass	Dry Combustion
10	pH value	6.76		units	4.11USCC:dil. Rajkovich
12	Electrical Conductivity (EC20 w/w)	0.074		dS/m	4.10USCC:dil. Rajkovich
11	Liming (neut. Value as-CaCO3)	7.6		%CaCO3	AOAC 955.01
5	Carbonates (as-CaCO3)	0.2		%CaCO3	ASTM D 4373
	Butane Act.	0.8		g/100g dry	ASTM D 5742-95
3	Surface Area Correlation	157		m2/g dry	G

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All units mg/kg dry unless stated:		Results	Range of Max. Levels	Reporting Limit (ppm)	Method
Arsenic	(As)	**ND**	13 to 100	0.37	J
Cadmium	(Cd)	0.26	1.4 to 39	0.15	J
Chromium	(Cr)	0.73	93 to 1200	0.37	J
Cobalt	(Co)	**ND**	34 to 100	0.37	J
Copper	(Cu)	2.4	143 to 6000	0.37	J
Lead	(Pb)	0.26	121 to 300	0.15	J
Molybdenum	(Mo)	**ND**	5 to 75	0.37	J
Mercury	(Hg)	**ND**	1 to 17	0.001	EPA 7471
Nickel	(Ni)	0.6	47 to 420	0.37	J
Selenium	(Se)	**ND**	2 to 200	0.74	J
Zinc	(Zn)	32.3	416 to 7400	0.74	J
Boron	(B)	8.2	Declaration	3.7	TMECC
Chlorine	(Cl)	22.7	Declaration	20.0	TMECC
Sodium	(Na)	**ND**	Declaration	370	E
Iron	(Fe)	65.1	Declaration	18.5	E
Manganese	(Mn)	118	Declaration	0.37	J

Particle Size Distribution (4)	Results	Units	Method
< 0.5mm	18.4	percent	F
0.5-1mm	4.1	percent	F
1-2mm	7.5	percent	F
2-4mm	18.6	percent	F
4-8mm	37.5	percent	F
8-16mm	13.9	percent	F
16-25mm	0.0	percent	F
25-50mm	0.0	percent	F
>50mm	0.0	percent	F

Basic Soil Enhancement Properties		Results	Units	Method
Total (K)	13	2072	mg/kg	E
Total (P)	14	186	mg/kg	E
Ammonia (NH4-N)		11.9	mg/kg	A
Nitrate (NO3-N)		3.6	mg/kg	A
Organic (Org-N)	9	3767	mg/kg	Calc.
Volatile Matter	8	27.9	percent dw	D

* "ND" stands for "not detected" which means the result is below the reporting limit.

Method A Rayment & Higginson
D ASTM D1762-84
E EPA3050B/EPA 6010
F ASTM D 2862 Granular
G Butane Activity Surface Area Correlation Based on McLaughlin, Shields, Jagiello, & Thiele's 2012 paper: Analytical Options for Biochar Adsorption and Surface Area
J EPA3050B/EPA 6020

This typical laboratory report details the physical and chemical properties of biochar. Colored numbers correspond to the description of physical properties (green numbers), chemical properties related to carbon (orange numbers), and fertility and heavy metals (blue numbers).

Soil fertility

9 Nitrogen

Total nitrogen is the sum of organic nitrogen, ammonia, and nitrate. Even when raw biochar is applied at very high rates, it will not provide sufficient nitrogen for optimal plant growth.

Biochar is extremely effective at retaining nitrogen in soil and making it more available for plant uptake, which can increase the nitrogen use efficiency of applied fertilizers. If biochar is applied as a co-composted or nutrient-charged product, it can supplement other forms of nitrogen to meet crop demand. Pelletized and prilled biochar-enhanced fertilizers can contribute to crop nitrogen needs and improve fertilizer efficiency. Consult with your laboratory and crop advisor to estimate nitrogen contributions from raw, composted, or charged biochars to better understand the effect of biochar on nitrogen application requirements.

⑩ pH and liming

Biochars generally have alkaline pH (above pH 7), but acidic and neutral pH biochars can also be produced under certain production conditions. As the ash fraction of the biochar increases, salts, oxides, hydroxides, silicates, and carbonates also increase, which contributes to biochar alkalinity.

Biochar pH does not directly describe the potential of biochar to change the pH of soils. Soils have pH buffering capacity that allows soils to resist pH changes. Liming equivalent estimates biochar's ability to impact the pH of soil, soilless media, and other media blends.

⑪ Liming equivalent

$CaCO_3$ equivalence, the most common form of lime used by farmers, indicates the liming effect of a unit mass of biochar compared to pure $CaCO_3$. High ash biochars, such as those derived from manures, typically have higher lime equivalence than wood biochars. Higher temperatures tend to produce biochars with a higher pH and liming eqivalence.

The ash content of biochar may contain calcium carbonates ($CaCO_3$) and hydroxides. In soil, these compounds react with exchangeable hydrogen ions (part of the soil's reserve acidity) to form carbonic acid and water. Like agricultural lime, this reaction alleviates soil acidity because the strongly acidic exchangeable hydrogen ions are incorporated into weaker carbonic acid. In places where agricultural lime is scarce, biochar may be a good option for increasing soil pH. However, prior to application, the liming potential of the biochar (measured as liming equivalence) and the pH-buffering capacity (usually measured as SMP or Sikora) should be tested to ensure that the post application soil pH is within the ideal range for crop growth.

⑫ Electrical conductivity

Electrical conductivity (EC) measures soluble salt content in biochar. A low EC indicates that biochar is low in soluble salts and vice versa. The impact of biochar salts on salinity is typically short-lived in applications where water percolates through media. That is the case in stormwater treatment, nursery and seedling production, and most farming except in drier regions. Intentionally rinsing biochar with fresh water can be used to reduce biochar EC.

High amounts of salt can cause plant toxicity, especially in seedlings, transplants, and nursery crops. However, high EC may indicate that the biochar has high levels of plant nutrients, so higher EC biochar may be a good choice for established crops.

⑬ Total potassium (K)

Biochar produced from certain feedstocks, such as manure, can contain substantial amounts of potassium (K). Potassium in biochar is readily available to plants and can meet a portion of crop potassium needs.

⑭ Total phosphorus (P)

The P found in biochar is generally present as calcium and magnesium-phosphate complexes. In these forms, biochar can act like a slow release fertilizer, and allow plants to uptake available P. Their availability depends on which phosphate compounds are present in biochar but also on inherent soil properties, such as the minerology of the soil and dynamic soil properties, like pH. Some studies have shown that applying biochar produced from manures or biosolids can meet a significant portion of crop P demand.

⑮ Metals

IBI[1] and NRCS[2] standards require that biochar be analyzed for a broad suite of metals. Many state departments of agriculture also maintain standards for heavy metal application rates via soil amendments, typically expressed as limits on total metals mass applied per acre. The IBI and NRCS standards for biochar include a range of maximum allowable concentrations for metals based on a review of regulatory values, however, state and local regulations may be more stringent than IBI and NRCS standards. A review of applicable regulations is recommended if heavy metal concentrations are above minimum values listed in the IBI and NRCS standards.

Some metals (e.g., arsenic, chromium, mercury) are phytotoxic and/or pose human health hazards, while other metals are plant micronutrients (e.g., nickel, zinc, boron) and contribute to the growth and health of crops.

What tests are important?

There are no federal standards for biochar specifications. However, to qualify for certain incentive payments, including the NRCS CPS 336[2], certain criteria must be met. These generally align with standards suggested by the International Biochar Initiative[3] (IBI). Biochar used for other end uses may need to comply with state, local or industry requirements including agricultural and environmental regulations, specifications in stormwater manuals and carbon removal credit methodologies (e.g., Puro.earth, Verro, and the European Biochar Certificate). Depending on the biochar end use, different lab tests are needed. A general framework for various end uses is presented below.

General testing framework

	Soil amendment NRCS, IBI*	Compost	Carbon credits Verra, Puro.earth, EBC*	Stormwater	Remediation	Concrete	Soilless media
Moisture content	always	sometimes	sometimes	sometimes	sometimes	sometimes	sometimes
Bulk density	sometimes	sometimes	sometimes	sometimes	sometimes	not	always
Surface area	sometimes	sometimes	not	sometimes	always	not	sometimes
Particle size	always	sometimes	sometimes	always	sometimes	always	sometimes
Organic carbon	always	sometimes	always	sometimes	not	always	not
H:C ratio	always	not	always	sometimes	not	not	not
Ash	always	not	sometimes	sometimes	sometimes	always	not
Volatile matter	sometimes	not	not	not	not	always	not
Nutrients (N, P, K)	always	sometimes	sometimes	always	sometimes	not	always
pH and liming	always	sometimes	sometimes	sometimes	always	sometimes	always
Electrical conductivity	always	sometimes	sometimes	sometimes	sometimes	sometimes	always
Metals	always	sometimes	sometimes	always	always	sometimes	sometimes

A framework indicating the importance of each analytical test for various end uses. The importance of each testing procedure is indicated by:

- **always recommended/required**
- **sometimes recommended/required**
- **not recommended/required**

**The regulatory agency or organization that developed the recommendations are listed under the related end use. If no agency is listed recommendations are based off the general scientific literature and standard practices.*

Collecting a composite sample

Use a composite sample collection approach to produce a representative biochar sample, which improves the reliability of the laboratory testing results. Collect 10-15 subsamples and combine them to create a composite sample. The weight of each subsample should be no less than the laboratory requested sample weight divided by the number of subsamples. If the biochar is moist double the weights. These are general guidelines. Always follow directions from the laboratory you are using.

If the biochar is stored in piles and thorough mixing of the pile is possible:

1. **Turn the pile at least 10 times to mix the biochar**
2. **Take samples from 15 different areas in the pile**
3. **Place all biochar subsamples into a 5-gallon bucket and thoroughly mix them, so they don't stratify**
4. **Collection the lab requested sample weight from the 5-gallon bucket. Mark the name of the biochar, sampling date and time, and place it in a reusable plastic bag.**

When piled biochar cannot be mixed:

1. **Select five random areas to collect subsamples near the top of the pile, five areas to collect in the middle of the pile and five areas from the bottom for a total of 15 subsamples.**
2. **See steps 3-4 above.**

When biochar is stored in containers/bags:

1. **Select five random biochar containers/ bags to be sampled**
2. **Open the containers and mix their contents thoroughly**
3. **Take three subsamples from a different depth in each container**
4. **See steps 3-4 of the scenario when mixing of the pile is possible**

Selecting a laboratory and analysis package

There are currently only a small number of laboratories that offer analytical packages specifically tailored for biochar analysis. Yet, many compost, soil, coal, and activated carbon analysis labs can perform all biochar analyses presented in this guide. A list of laboratories[1] is maintained by IBI, and these labs tend to offer different analytic packages. It is important to make sure the laboratory is using an acceptable analysis method for biochar. Confirm that they follow IBI testing guidelines.

Selecting a biochar package, or suite of analyses depends on the end use of the biochar, but also on relevant regulations and standards that may apply. A summary of recommended and required laboratory analysis methods for different end uses is shown in "General testing framework" table.

References

1 International Biochar Initiative. 2023. Testing laboratories for IBI biochar certification. https://biochar-international.org/testing-laboratories-for-ibi-biochar-certification

2 USDA Natural Resources Conservation Service. Conservation Practice Standard. *Soil Carbon Amendment Code 336*. 2022. Available at: https://www.nrcs.usda.gov/sites/default/files/2022-11/336-NHCP-CPS-Soil-Carbon-Amendment-2022.pdf

3 International Biochar Initiative. *Standardized Product Definition and Product Testing Guidelines for Biochar That Is Used in Soil (aka IBI Biochar Standards) Version 2.1*. 2015. Available at https://biochar-international.org/wp-content/uploads/2020/06/IBI_Biochar_Standards_V2.1_Final2.pdf

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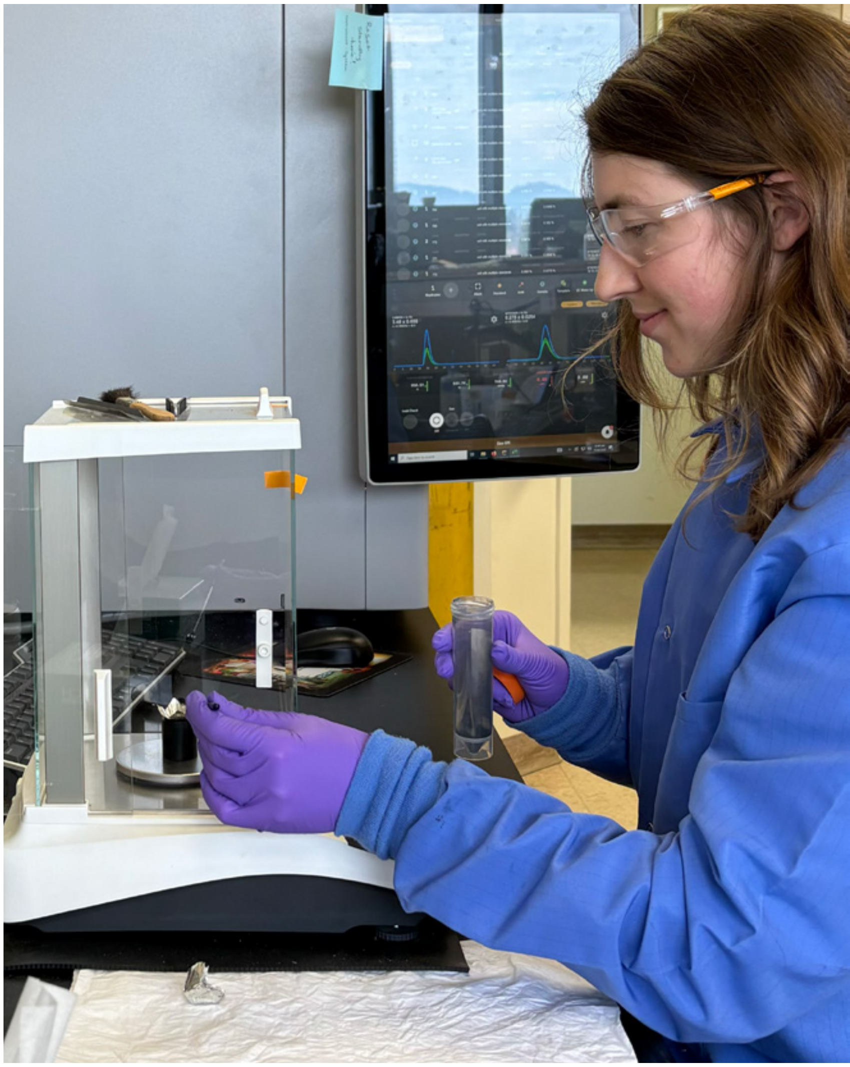

For more information, please visit
US Biochar Initiative: **biochar-us.org**

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