Biochar Production and Soil Application

NEW MEXICO AGRICULTURE SUSTAINABILITY WORKSHOP
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BE BOLD. Shape the Future.

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Biochar

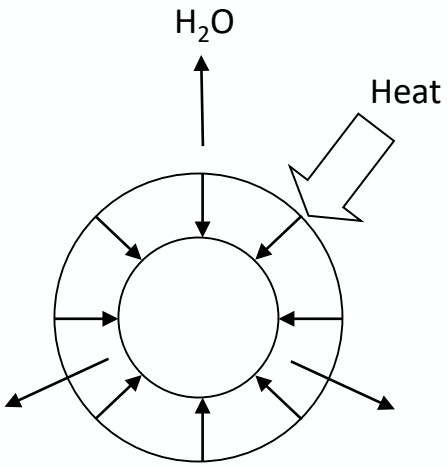
Biochar is a solid material obtained from the carbonization thermochemical conversion of biomass in an oxygen-limited environments.

In more technical terms, biochar is produced by **thermal decomposition** of organic material (**biomass** such as wood, manure or leaves) under **limited supply of oxygen (O_2)**, and at relatively low temperatures **(<700°C)**. This process mirrors the production of charcoal, which is perhaps the most ancient industrial technology developed by humankind. Biochar can be distinguished from charcoal—used mainly as a fuel—in that **a primary application is use as a soil amendment** with the intention to improve soil functions and to reduce emissions from biomass that would otherwise naturally degrade to greenhouse gases.

International Biochar Initiative (https://biochar-international.org/faqs/)

Making Biochar (2 of the Steps of Combustion)

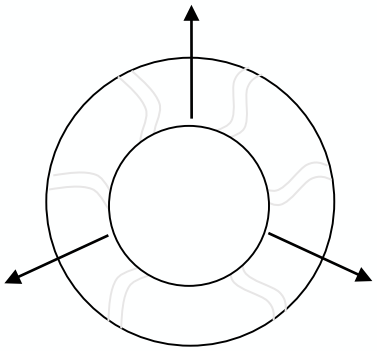
Heating/Drying



Thermal front penetrates particle

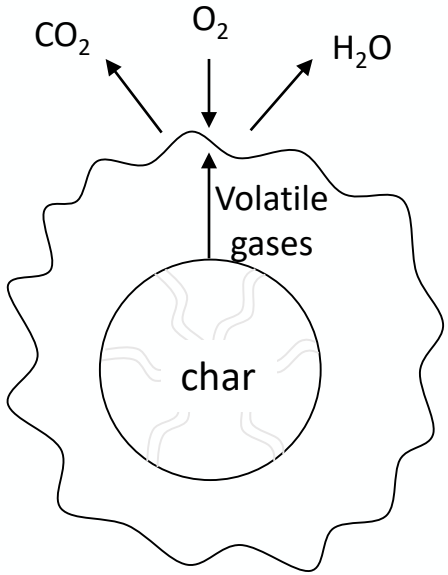
Pyrolysis

Volatile gases:
CO, CO_2, H_2, H_2O, tar, light hydrocarbons



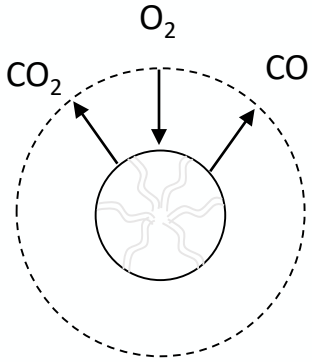
Porosity increases

Flaming Combustion



Flame front

Char Combustion



Shrinking core

Figure: Robert C. Brown

Uses for Char

Fuel/ "Charcoal"

- Combustion
- Heat and power
- Gasification
- Metallurgy

Sorbent/ "Activated Carbon"

- Water treatment
- Gas purification
- Site remediation

Biochar

- Carbon sequestration
- Soil amendment

Char as Fuel

- Has a high energy density
- Ignites and burns cleanly
- Is safe to handle
- Is easy to grind
- Is inexpensive

Self-Heating

Higher Heating Value

Moisture Content

Ash Content

Particle Size

Friability

Volatiles vs. Fixed Carbon

Density

Char as Sorbent

- Has high surface area
- Has surface chemistry tuned to adsorbate
- Has high capacity and selectivity
- Enables fast separation
- Is inexpensive

Porosity

Equilibrium Capacity

Surface Functionality

Particle Size

Pore size

Friability

Regeneration

Isotherm

Char as C Sequestration

- Has high carbon content
- Is recalcitrant to microbial decomposition
- Is resistant to abiotic oxidation
- Is measurable
- Is inexpensive

H:C vs. O:C

Carbon Stability

Half-Life

Models

Pyrolysis Temperature

Labile Carbon

Skeletal Density

Kinetics

Char as Soil Amendment

"BIOCHAR"

Char as Soil Amendment (Not Fertilizer)

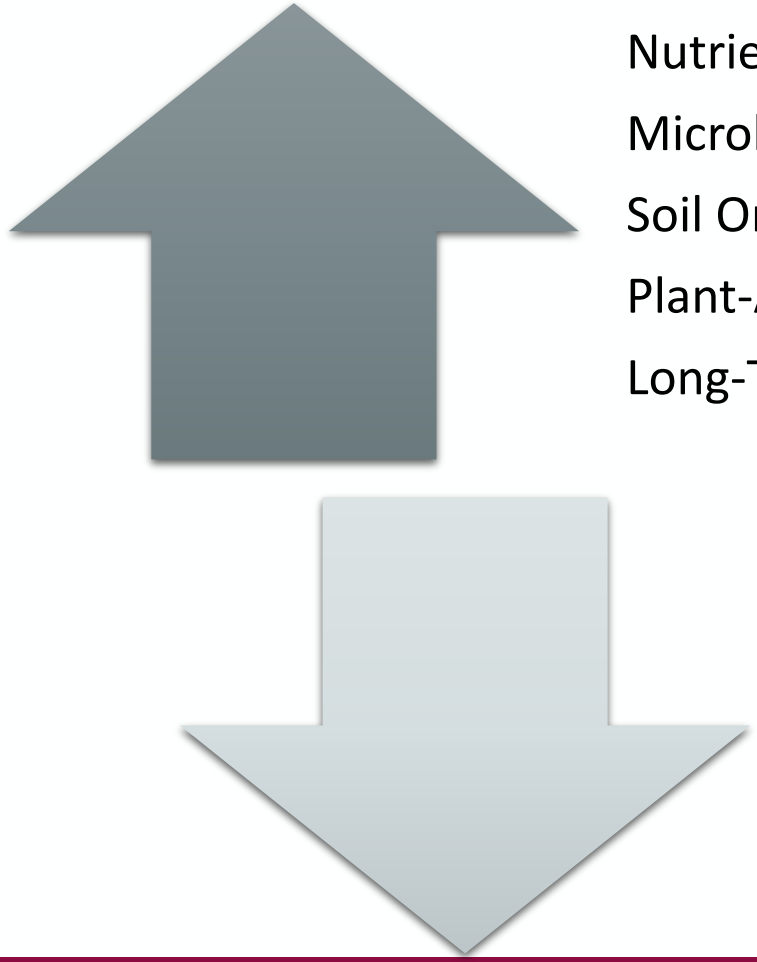
Soil Amendment

- Changes soil properties which can improve plant growth
- Has some short-term effects, but more often, long-term impacts
- May contain some nutrients

Fertilizer

- Provides plants with available macro- (N, P, K) and/or micro-nutrients (Ca, Mg, Fe, Zn, Cu, Mn, etc.)
- Is expected to result in effects in the short-term/growing season

Biochar Impacts in Soils



Nutrient Use Efficiency

Microbial Activity

Soil Organic Matter

Plant-Available Water

Long-Term Crop Yields

Fertilizer/Irrigation Needs

Greenhouse Gas Emissions

Nutrient Leaching

Soil Bulk Density

Biochar Quality

NO TWO CHARS ARE THE SAME

High quality biochar is:

- Black in color
- Consistent
- Not greasy
- Not smelly
- Friable
- Made from clean feedstock (free of heavy metals)
- Tailored to the application

Potential Pitfalls

Undercooked char	Nutrient immobilization in the soil inhibiting plant growth
Poor volatiles management	Smoke/air pollution; condensed volatiles on char surface inhibit germination/growth
Contaminated feedstock	Heavy/toxic metals in soil that leach into environment and/or plants
Poor oxygen control	Low biochar yields and/or low retention of biomass carbon in char
Small particle sizes	Dust—and lots of it
Insufficient cooling	Combustion of newly-made char upon exposure to air

Zhang, et al. 2016, *Agriculture*, 6 (1), DOI: 10.3390/agriculture6010010

Potential Pitfalls

High ash content	(Undesirable) increase in soil pH
High sodium content	Increased risk for soil structure problems and plant stress
High salt content	Increased risk for plant stress due to soil salinity
High purchase costs	Uneconomical relative to short/long-term benefits
Insufficient field study information	Guidance applicability limited to specific soils, biochars, and crops

Zhang, et al. 2016, *Agriculture*, 6 (1), DOI: 10.3390/agriculture6010010

Biochar Soil Studies at NMSU

- Multiple feedstock soil incubation (2014-2016)
- Spacecraft waste pyrolysis (2015-2018)
- Pecan residue utilization (2016-2017)
- Halophyte biochar leaching (2016-2018)
- Hybrid poplar tree growth (2018-2019)
- Pinto bean field study (2017-2022)
- Leyendecker long-term soil health (2022+)

Zhang, et al. 2016, *Agriculture*, 6 (1), 10.
Idowu, et al., 2017, *Comm. Soil Sci Plant Analysis*, 48 (15), 1781-1791.
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