Biochar: A Valuable Soil Amendment

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ARTICLE ID: 009

Introduction

Biochar is charcoal that is produced by pyrolysis of biomass in the absence of oxygen. According to the International Biochar Initiative as "The solid material obtained from the thermochemical conversion of biomass in an oxygen-limited environment". The word "biochar" is derived from the Greek word βίος, *bios*, "life" and "char" (charcoal produced by carbonisation of biomass). It is recognised as charcoal that participates in biological processes found in soil, aquatic habitats and in animal digestive systems.Biochar results from processes related to pyrogenic carbon capture and storage (PyCCS). During the 21 century, biochar has become a focal point because of its special characteristics, broad application and promising development prospects.

Another form of biochar is charring that means partially burning so as to blacken the surface. Charring is a chemical process of incomplete combustion of certain solids when subjected to high heat. Heat distillation removes water vapour and volatile organic compounds (syngas) from the matrix.The residual black carbon material is char.

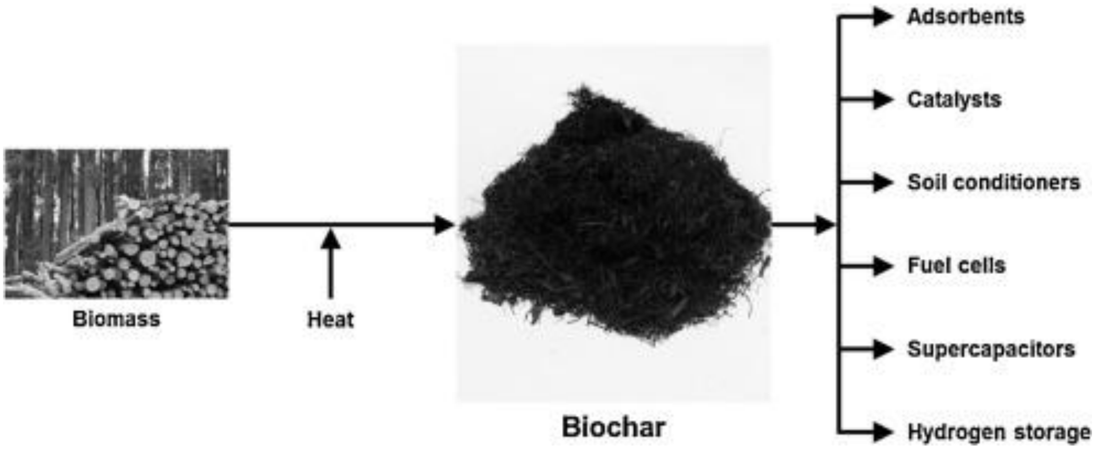
Properties of Biochar

- Properties can be categorized in several respects, including the proximate and elemental composition, pH value, and porosity.
- The atomic ratios of biochar, including H/C and O/C, correlate with the properties that are relevant to organic content, such as polarity and aromaticity.
- In the carbonization process, both the H/C and O/C ratios decrease due to the release of functional groups that contain hydrogen and oxygen.
- Scanning electron microscopy (SEM) is often used to describe the physical structure of biochar. The macroporous structure (pores of approximately 1 mm diameter) of

biochar is potentially important to water holding and adsorption capacity of soil (Day et al., 2005).

- Surface area measured by gas adsorption that is influenced by micropores (nm scale), biochar created at low temperature may be suitable for controlling release of fertilizer nutrients, while high temperatures would lead to a material analogous to activated carbon (Ogawa et al., 2006).
- Low temperature biochar is stronger than high temperature products, it is brittle and prone to abrade into fine fractions once incorporated into the mineral soil.

Importance of biochar –



Factors	**Effect of biochar application on various factors**
Soil fertility	Biochar can improve soil fertility, stimulating plant growth, which then consumes more CO_2 in a positive feedback effect.
Reduced fertilizer inputs	Biochar can reduce the need for chemical fertilizers, resulting in reduced emissions of greenhouse gases from fertilizer manufacture.
Reduced N_2O and CH_4 emissions	Biochar can reduce emissions of nitrous oxide (N_2O) and methane (CH_4), two potent greenhouse gases from agricultural soils.
Enhanced soil microbial life	Biochar can increase soil microbial life, resulting in more carbon storage in soil.
Reduced emissions from feed stocks	Converting agricultural and forestry waste into biochar can avoid CO_2 and CH_4 emissions otherwise generated by the natural decomposition or burning of the waste.
Energy generation	The heat energy and also the bio oils and synthesis gases generated

Factors	Effect of biochar application on various factors
	during biochar production can be used to displace carbon positive energy from fossil fuels.

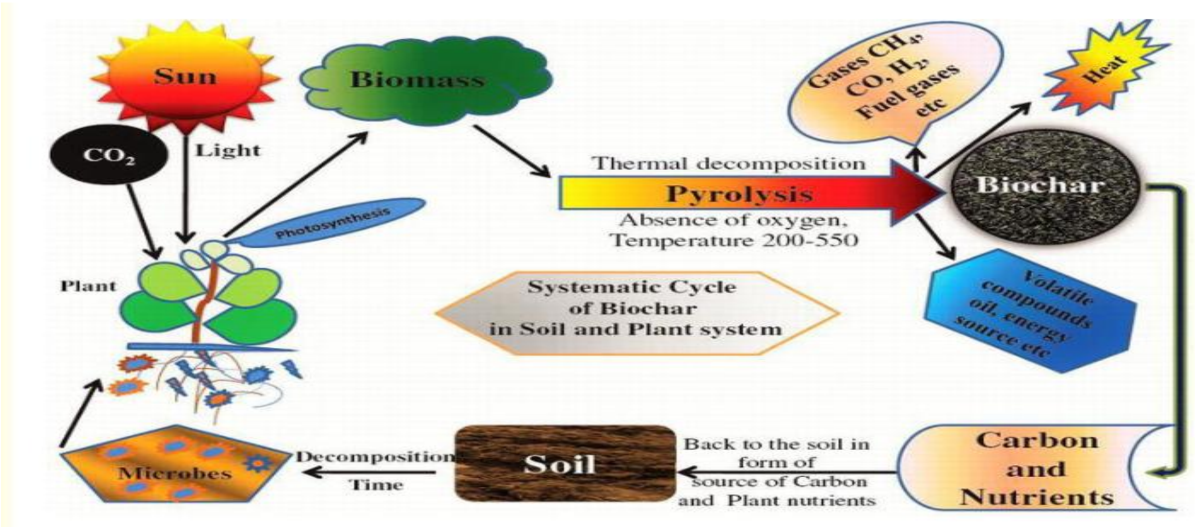


Figure: 1. Systemic potential mechanism of biochar in soil and plant system

Applications of Biochar

1. **Soil amendment:-** Biochar offers multiple soil health benefits in degraded soils, its porous nature is effective at retaining both water and water-soluble nutrients.For plants that require high potash and elevated pH, biochar can improve yield.Biochar reduce N_2O emissions by up to 80% and eliminate methane emissions, which are both more potent greenhouse gases than CO_2.Application rates of 2.5–20 tonnes per hectare (1.0–8.1 t/acre) appear to be required to produce significant improvements in plant yields.
2. **Carbon sinkBiochar** carbon remains in the ground for centuries, simultaneously, its presence in the earth can improve water quality, increase soil fertility, raise agricultural productivity, and reduce pressure on old-growth forests.Sustainable use of biochar could reduce the global net emissions of carbon dioxide (CO_2), methane, and nitrous oxide by up to 1.8 billion tonnes carbon dioxide equivalent (CO_2) per year.
3. **Slash-and-char**: - Slash-and-burn leaves only 3% of the carbon from the organic material in the soil. Slash-and-char can retain up to 50%. Biochar-enhanced soils can

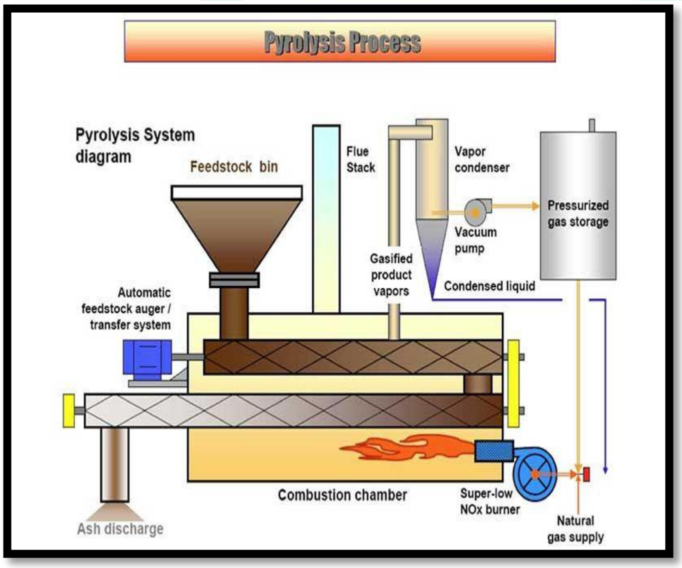
indefinitely sustain agricultural production, whereas slash/ burn soils quickly become depleted of nutrients, forcing farmers to abandon the fields, producing a continuous slash and burn cycle.

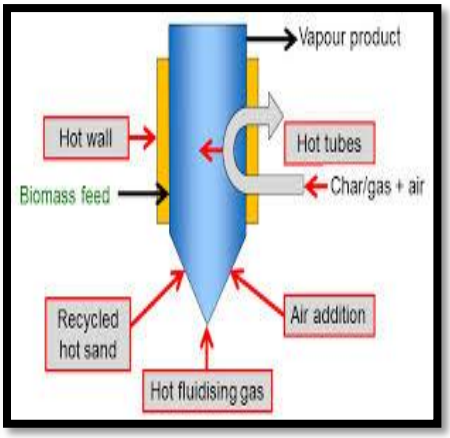
4. **Water retention: -** Biochar is hygroscopic due to its porous structure and high specific surface area. As a result, fertilizer and other nutrients are retained for plants' benefit.

Production of Biochar

Biochar is a high-carbon, fine-grained residue that is produced via pyrolysis; it is the direct thermal decomposition of biomass in the absence of oxygen (preventing combustion), which produces a mixture of solids (the biochar proper), liquid (bio-oil), and gas (syngas) products.

The specific yield from pyrolysis is dependent on process conditions such as temperature, residence time, and heating rate. Temperatures of 400–500 °C (673–773 K) produce more char. Pyrolysis occurs more quickly at higher temperatures.The increasing heating rate leads to a decrease of biochar yield. Typical yields are 60% bio-oil, 20% biochar, and 20% syngas.





Pyrolysis Reactors

Besides pyrolysis, torrefaction and hydrothermal carbonization processes can also thermally decompose biomass to the solid material. The carbon product from the torrefaction process contains some volatile organic components, thus its properties are between that of biomass feedstock and biochar.

Furthermore, even the hydrothermal carbonization could produce a carbon-rich solid product, The solid product from hydrothermal carbonization is defined as "hydrochar" rather than "biochar".

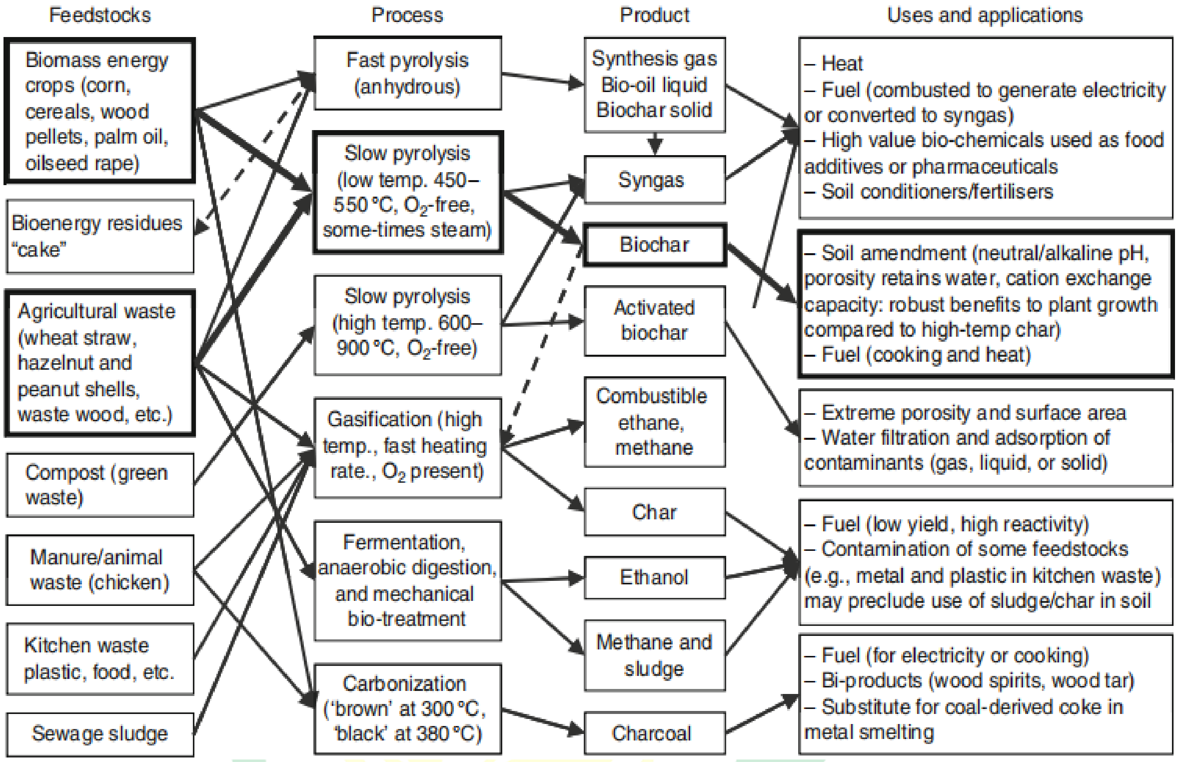


Figure 2. Biochar and other products of thermal conversion of biomass according to available technologies and feedstock

Centralized, decentralized, and mobile systems

In a centralized system, unused biomass is brought to a central plant for processing into biochar. Factors that influence the choice of system type include the cost of transportation of the liquid and solid byproducts, the amount of material to be processed, and the ability to supply the power grid.

Thermo-catalytic depolymerization

Thermo-catalytic depolymerisation utilizes microwaves, has been used to efficiently convert organic matter to biochar on an industrial scale, producing ≈50% char.

Barriers and limitations to biochar systems

- A market for carbon credits in which land managers can engage in deploying biochar does not exist.

- A lack of knowledge and awareness of bio-energy and carbon markets, how to access these markets, and particularly a way to accurately evaluate costs and benefits associated with the use of biochar in soil.
- No framework exists within which the carbon sequestered in biochar can be certified as a tradable commodity.
- There are significant organizational and institutional obstacles to the use of biochar in soil. Since biochar could be used on a large scale and cannot be removed from soil once applied, there is a need to carefully assess the potentially negative impacts on occupational health, environmental pollution, water quality, and food safety.
- The lack of mechanistic understanding as to the function of biochar, and its interaction with already complex soil processes.

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