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Biochar: A Source of Nutrient

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In the search for sustainable substitutes to synthetic fertilizers, biochar is increasingly being explored by agricultural researchers as a soil amendment. Excessive use of chemical fertilizers raises production costs and contributes to long-term soil degradation and environmental harm. Growing concerns about food safety and ecological health have encouraged the adoption of organic biofertilizers. In this context, biochar has gained attention for its ability to improve soil quality, support plant growth and enhance crop productivity. Studies indicate that biochar derived from plant residues and animal manures can supply essential nutrients due to its unique physicochemical properties.

Introduction

In recent decades, the use of biochar as a soil amendment has gained increasing interest among researchers. Studies have highlighted its economic viability and environmental benefits, including its role in carbon sequestration and the restoration of polluted soils.

Biochar affects soil nutrient dynamics through multiple mechanisms: firstly, it serves as a direct source of nutrients for plants and soil microorganisms; secondly, it functions as a nutrient reservoir that regulates nutrient mobility and availability; and finally, it acts as a soil amendment that modifies soil physical and chemical properties, thereby influencing nutrient transformations and cycling within the soil.

What is Biochar?

The term bio means living while, char means output from disintegration of organic and inorganic materials. Biochar and charcoal have been synonymously used but can be differentiated by their use, because charcoal is used for energy; whereas, biochar is considered for carbon sequestration and environmental applications. Biochar is also called as 'pyrochar,' because it is produced by the pyrolysis of biomass.

Biochar is a solid mate rial obtained from the thermochemical conversion of bio mass in an oxygen-limited environment. Biochar is a carbon-rich, porous material produced by heating organic biomass (such as crop residues, wood, manure or agricultural waste) in the absence or limited presence of oxygen, a process known as pyrolysis.

Steps in preparation of Biochar

1. Raw Material Selection: The process begins with selecting rice straw, an abundant agricultural residue, as the main biomass source. Its lignocellulosic nature makes it suitable for biochar production while providing an eco-friendly solution for crop waste management.

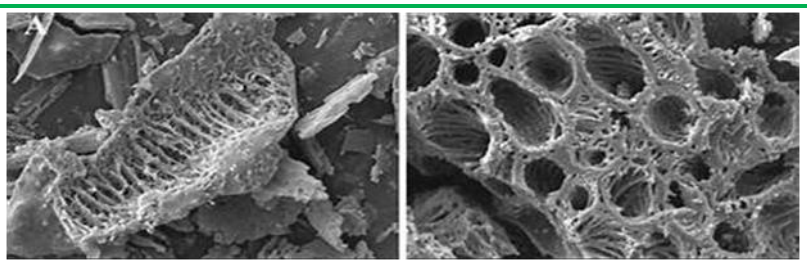
2. Thermochemical Conversion: Rice straw is converted into biochar through thermochemical methods such as pyrolysis, carbonization, or gasification under limited oxygen conditions. Pyrolysis (300–700 °C) produces stable and porous biochar. Carbonization (400–600 °C) increases fixed carbon content, whereas gasification (700–1,000 °C) enhances surface reactivity but results in lower biochar yield. These processes remove volatile compounds and form a carbon-rich structure.

3. Biochar Modification: The produced biochar is further modified using chemical or physical treatments to improve its adsorption capacity. These modifications enhance pore structure and introduce functional groups like hydroxyl, carboxyl, and amine groups, increasing its reactivity.

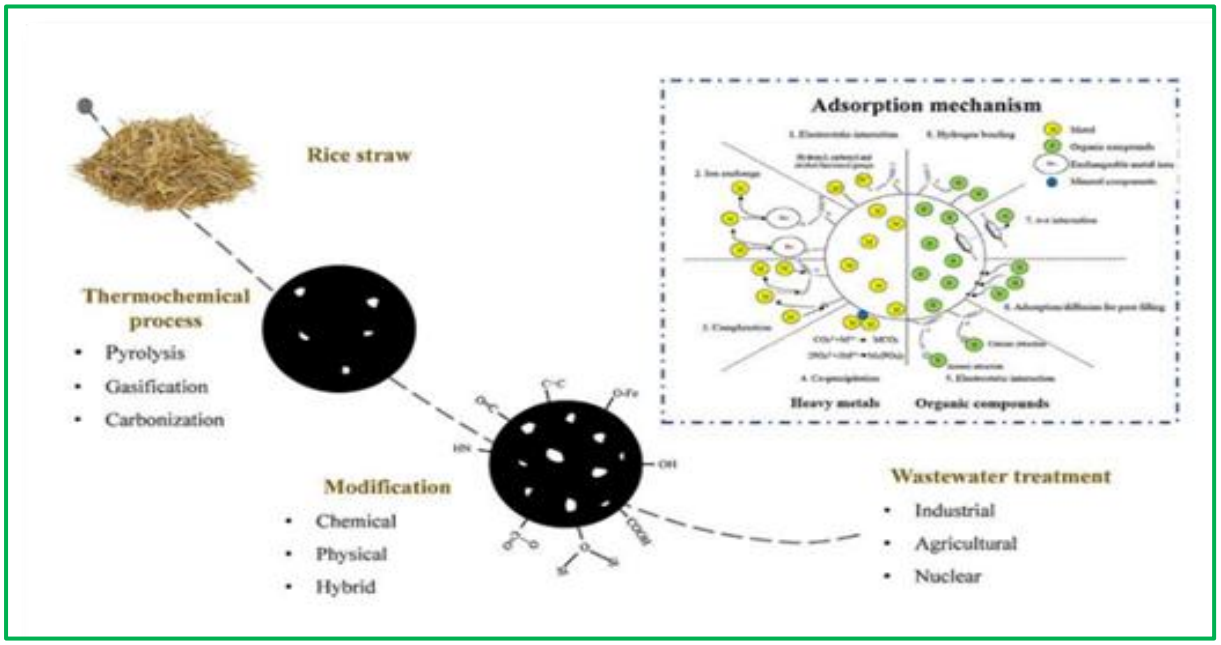
4. Adsorption Mechanisms: Modified biochar removes pollutants through various mechanisms. Heavy metals are retained by electrostatic attraction, ion exchange, complexation, and co-precipitation, while organic pollutants are removed through hydrogen bonding, π–π interactions, hydrophobic interactions, and pore filling.

5. Application in Wastewater Treatment: Engineered biochar is applied in wastewater treatment to remove contaminants from industrial and agricultural effluents. Its adsorption and immobilization properties make it a sustainable and cost-effective solution for wastewater management.

Biochar



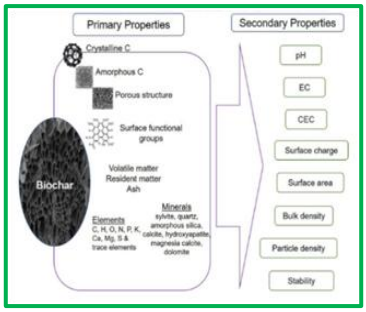
Scanning electron microphotographs of rice straw biochar



Biochar preparation process

Characteristics of Biochar

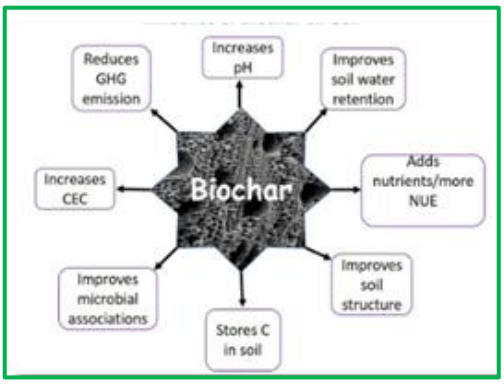
Biochar possesses both primary and secondary properties that determine its behaviour and effectiveness in soil and environmental applications. The primary properties are inherent to the material and include its carbon structure (crystalline and amorphous forms), highly porous nature, surface functional groups, volatile and residual matter, ash content, elemental composition (such as C, H, O, N, P, K, Ca, Mg and trace elements) and associated minerals like quartz, calcite, and silica. The secondary properties are derived from the primary characteristics and include pH, electrical conductivity, cation exchange capacity, surface charge, surface area, bulk and particle density and stability. Together, these properties influence biochar's ability to improve soil fertility, retain nutrients and support environmental remediation.



Characteristics of Biochar

Influence of biochar on soil properties

Application of biochar increases soil pH and cation exchange capacity, thereby improving nutrient retention and nutrient use efficiency. The porous structure of biochar enhances soil water-holding capacity and improves soil structure, leading to better root growth and aeration. Biochar also supports beneficial microbial activity by creating favorable habitats in the soil. In addition, it acts as a stable carbon sink, storing carbon in soil for long periods and helping to reduce greenhouse gas emissions. Together, these effects contribute to improved soil fertility, crop productivity and climate mitigation.



Influence of biochar on soil properties

Conclusion

Biochar serves as a valuable and sustainable source of nutrients in agricultural systems. Derived from organic biomass, it not only supplies essential elements such as carbon, potassium, calcium and magnesium, but also enhances nutrient retention and reduces losses through leaching. Its porous structure and functional surface groups improve soil fertility, microbial activity and overall soil health. Therefore, biochar represents a promising strategy for nutrient management and long-term soil improvement in sustainable agriculture**.**

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