Review Article ____ *Chapter – 4*

BIOCHAR- PROCESS, PROPERTIES AND UTILIZATION: A REVIEW

Vinay Chamoli

Abstract

Biochar is a residue that is black in colour and light in weight, composed of carbon and ashes that are left behind after biomass is subjected to pyrolysis, a process that involves heating organic matter like biomass in the absence of oxygen. The ideal temperature for creating biochar is between 400 and 500 °C, and temperatures exceeding 700 °C are known to favour the yield of liquid and gas fuel components. Biochar has the potential to enhance soil fertility, and possesses several key properties, including high surface area with many functional groups, high nutrient content, and slow-release fertilizer. Soil mineral depletion is a major issue that arises mainly due to soil erosion and nutrient leaching. The addition of biochar can be a viable solution to prevent this problem, as it has been shown to improve soil fertility, promote plant growth, increase crop yield, and reduce contaminations. Biochar can be utilized as a Carbon Sink, Soil Amendment, Water Retention Aid, and Fertilizer. By using biochar, it may be possible to improve the overall health of the soil, and it could also have a positive impact on crop productivity and environmental sustainability.

Keyword:- Biochar, Pyrolysis, Carbon sink, Soil amendment, Water retention Aid

Department of Seed Science and Technology, H.N.B. Garhwal University (A Central University), Srinagar Garhwal, Uttarakhand -246174
E-mail: chamolivinay.44@gmail.com

Introduction

The term "biochar" has its roots in the Greek language, with "bios" meaning life and "char" being an abbreviation of charcoal. Essentially, biochar is a form of charcoal that serves specific purposes. Specifically, it is a type of charcoal that is created through thermal decomposition of biomass, but without the need for oxygen. Its primary application is as a soil conditioner, providing both carbon sequestration and soil health benefits. Given its properties, biochar is an effective tool in the fight against climate change. Biochar can also be defined as a material that resembles charcoal, produced from plant matter such as agricultural, forest, and grass residues. These are decomposed at high temperatures, often during the process of renewable energy production. Biochar derived from animal waste contains more nutrients than that produced from wood. During production, the physical and chemical properties of the plant matter are altered, resulting in a highly porous, stable, and carbon-rich material that is known as biochar. Biochar is a residue that is fine-grained and high in carbon, produced through direct thermal decomposition of biomass without the use of oxygen in the process. The process generates an amalgamation of solids, liquids, and gases as end products. The quantity of the yields attained is contingent on various factors including temperature and heating rate. These variables can also be harnessed to generate energy. The optimal temperature range for the creation of biochar is between 400 to 500 °C, whereas temperatures exceeding 700 °C are conducive to the production of liquid and gas fuel components. It is essential to maintain these temperature ranges to ensure the desired outcome of the process. The reliable and consistent achievement of these parameters is critical in optimizing the yield and quality of the final products. The ability to regulate these parameters is crucial in the successful implementation of this process.

Sources of Biochar

Biochar can be produced from various organic materials and biomass sources. Some common sources of biochar include:

1. **Agricultural Waste**: Crop residues are frequently utilized as raw materials for biochar production, with corn stalks, rice husks, sugarcane bagasse, and straw being commonly employed. These waste materials are readily accessible and plentiful due to their abundance in agricultural activities. As a result, they are a cost-effective and eco-friendly approach to generating biochar.

2. **Forestry Residues**: Wood chips, sawdust, and other byproducts of forestry can be employed for the purpose of biochar production. These materials are usually sourced from logging activities or the timber processing industry. The utilization of such waste materials for biochar production can provide an eco-friendly solution for managing forestry residues and promote sustainable practices in the forestry sector.

3. **Manure and Animal Waste**: Livestock manure and other forms of organic animal waste present a viable option as feedstock for biochar production, a process that can effectively manage and utilize these waste materials in a sustainable manner. This

approach can help reduce the environmental impact of such waste while simultaneously providing an opportunity to generate value from it. The use of biochar can also enhance soil quality and carbon sequestration, thereby contributing to the overall sustainability of agricultural practices.

4. **Green Waste**: The organic matter produced from horticultural and landscaping practices, such as yard trimmings, grass clippings, and other green waste, can be transformed into biochar, a valuable soil amendment.

5. **Food Waste**: Organic matter stemming from food processing and discarded food can serve as a viable biochar source, thereby enabling the recycling of organic waste and curbing landfill buildup. By converting this waste into biochar, not only is a valuable soil amendment produced, but also the carbon is sequestered, reducing the release of greenhouse gases and mitigating climate change. It is therefore imperative to implement such practices as a means of sustainable waste management and environmental conservation.

6. **Algae**: Certain varieties of algae, such as microalgae and macroalgae, possess the potential to generate biochar. This innovative technique can serve as a promising solution for tackling the issues of algae blooms and water pollution that afflict aquatic ecosystems while simultaneously creating a valuable output. The utilization of algae for biochar production has the potential to revolutionize the field of sustainable agriculture and environmental conservation.

7. **Poultry Litter**: The utilization of poultry litter, which comprises of a mixture of chicken faeces and materials used as bedding, for the production of biochar is a viable alternative.

8. **Municipal Solid Waste (MSW)**: The sustainable management of municipal solid waste can be achieved through the processing of its organic components into biochar.

9. **Biodegradable Materials**: Biodegradable substances such as waste paper, cardboard, and bioplastics can be transformed into biochar.

Mechanism of Biochar

Making biochar involves a process called pyrolysis, which is the thermal decomposition of organic materials in a low-oxygen environment. Here's a simple method for making biochar:

Materials Needed

1. Organic Biomass (e.g., wood chips, agricultural waste, yard trimmings, etc.)
2. Metal Container or Drum with a lid (to create the low-oxygen environment)
3. Firewood, kindling, or other ignition material
4. Shovel or Tongs (for handling the biochar)

Steps to Make Biochar

Select Biomass: To proceed with the production of biochar, the initial step involves the selection of the appropriate organic material for conversion. The organic material can comprise of various sources such as wood chips or agricultural waste, or any other form of biomass that is deemed suitable for conversion. The selection of the organic material is a crucial step as it determines the quality and properties of the biochar obtained.

Prepare the Container: It is necessary to procure a metal container or drum with a firmly secure lid. The container selected must possess the capability to endure high temperatures. It is imperative to ensure that the container has small apertures or openings to allow the escape of gas, but they must be restricted to maintain a low-oxygen atmosphere, which is crucial for the process to proceed successfully. Therefore, it is vital to exercise caution while selecting the container to ensure that it meets the requirements for a successful outcome.

Load Biomass into the Container: To ensure uniform heating within the container, it is recommended that the chosen biomass is finely chopped and uniformly distributed. In order to achieve this, larger pieces of biomass can be broken down into smaller chunks, which will facilitate the uniform distribution of heat throughout the container. By following these guidelines, the biomass will be more effectively utilized, resulting in a more efficient and productive process overall.

Ignite the Biomass: To initiate combustion of the biomass, it is imperative to position the container on a non-combustible surface, such as an exposed area of soil, and ensure that there are no combustible objects in the vicinity. Proceed by kindling a small fire within the container, utilizing either firewood or kindling, with the objective of inciting the biomass within the container.

Limit Oxygen: To create a low-oxygen environment within the container, it is essential to rapidly place the lid on the burning biomass. The lid should form a tight seal to restrict the entry of oxygen. This will limit the oxygen supply within the container and promote the desired low-oxygen conditions.

Pyrolysis Process: When biomass is burnt under low-oxygen conditions, it undergoes pyrolysis, a process that releases gases while leaving behind biochar. The combustible gases generated during the pyrolysis can be harnessed for various applications, provided that they are collected in a proper manner. By capturing and utilizing these gases, we can derive additional value from the process of biomass pyrolysis and potentially reduce our reliance on conventional fossil fuels.

Cooling Down: It is imperative to wait until the container has cooled down entirely before attempting to open it. This practice is of utmost importance to prevent any potential accidents or injuries. Once the container has cooled, the biochar should display a dark and brittle appearance, indicating that it is ready for use.

Collect the Biochar: After the cooling process has concluded, it is recommended to utilize either a shovel or tongs to retrieve the biochar from the container.

Store the Biochar: To ensure that the biochar remains free from moisture prior to use, it is recommended that it be stored in a container that is both dry and covered.

Properties of Biochar

Biochar is a substance that possesses varying properties that are heavily influenced by the feedstock from which it is derived. The quality and attributes of biochar are controlled by the settings of pyrolysis, which include factors such as maximum temperature, oxygen, pressure, and heating time.

Biochar has numerous distinguishing features that are worth discussing in detail:

- From a physical standpoint, its porous structure results in a low bulk density, and the pore size ranges from nanopores to macropores, which gives it a high specific surface area and a high water retention capacity.
- From a chemical perspective, the most noteworthy characteristic of biochar is its poly-condensed aromatic structure, which is caused by dehydration during thermochemical conversion, and this leads to the substance's black coloration.
- In general, the elemental composition of biochar consists of carbon, hydrogen, nitrogen, and lower nutrient elements, such as magnesium, sodium, calcium, and potassium. Additionally, the basic ash components result in a high pH value, which is another critical attribute of biochar.
- Biochar is the non-combustible constituent of the feedstock (ash) that is present as a product of pyrolysis and gasification, regardless of process temperature and feedstock. It is noteworthy that biochar is rich in nutrients such as calcium, potassium, and phosphorous content, while volatile nutrients like nitrogen decrease at the highest temperatures.

Overall, these properties and attributes of biochar highlight its potential as a valuable resource with numerous applications in various fields.

Biochar in Soil Amendment

Soil degradation is a critical issue that poses a major threat to global agriculture. This problem includes reduced fertility and increased erosion, which is caused by acidification and depletion of soil organic matter. As a result, it is essential to develop effective methods to sustain soil resources through various remediation strategies. The use of organic materials such as manure, compost, and biomass waste is a promising approach, but there has been a significant focus on stable forms of organic carbon, such as biochars. The use of biochar as a soil amendment has been found to be highly beneficial in improving the chemical and physical properties of soil. Biochar has proven to be an effective solution in enhancing the soil structure, increasing porosity, and reducing bulk density. It also helps to increase aggregation and water retention in the soil, as it is hygroscopic, capable of absorbing and holding water from the surrounding environment.

Moreover, the use of biochar can significantly enhance the soil's biological quality by improving the physical and chemical soil properties. It is a sustainable method that can help to restore soil fertility and mitigate the effects of soil degradation. Therefore, the incorporation of biochar as a soil amendment can play a crucial role in maintaining soil health and productivity. It can help to reduce the need for chemical fertilizers and pesticides, which can have harmful effects on the environment. Additionally, the biochar can improve the soil's capacity to store carbon, which is beneficial for mitigating climate change. Overall, the use of biochar is a promising solution to address the challenges of soil degradation and ensure sustainable agriculture.

Biochar a Rich Source of Nutrient: Biochar can be used as fertilizer by plants and microorganisms, as it contains organic matter and inorganic salt such as humic-like and fluvic-like substances, as well as available N, P, and K. Studies show that biochar produced from Acacia saligna and sawdust contained humics, while biochar made from Lantana camara contained available nutrients such as P, K, Na, Ca, and Mg. Biochar also has the potential to release large amounts of N and P, and its nutrient content is greatly affected by the feedstock source, pyrolytic temperature, and soil pH. Although total nutrient content in biochar may not reflect actual availability, pyrolysis temperature can affect nutrient availability, with N losses beginning at about 400 °C, and total P and K content increasing with higher temperatures.

Carbon Sequestration: The combustion or natural decomposition of biomass inevitably leads to the emission of significant amounts of carbon dioxide and methane into the Earth's atmosphere. Conversely, biochar also discharges these elements into the atmosphere, but its carbon content is relatively stable. Therefore, biochar offers an appropriate means of carbon storage in the soil, which has the potential to mitigate atmospheric greenhouse gases (GHG), while concurrently enhancing soil fertility and agricultural productivity. Consequently, biochar provides a promising solution for addressing climate change and food security issues.

Wastewater Treatment: Biochar possesses significant potential as a filtration medium for the purpose of wastewater treatment. The adsorbent qualities of this material enable it to eliminate various types of impurities, including heavy metals, organic pollutants, and contaminants, from water. This makes biochar a highly sustainable and cost-efficient option for the purpose of treating wastewater.

Livestock Feed Additive: In certain instances, biochar is integrated into livestock feed as an adjunct. Its utilization has the capacity to enhance digestion and nutrient preservation in animals, thereby resulting in superior feed efficacy and decreased discharges of methane, an influential greenhouse gas, from animal excreta. As such, biochar could be regarded as a potential solution for improving the sustainability of livestock farming.

Climate Change Mitigation: Biochar assumes a pivotal function in the process of carbon sequestration. Its implementation in agricultural soils has the potential to significantly mitigate greenhouse gas emissions, with a particular focus on nitrous oxide and methane, both of which have been identified as powerful agents of climate change. This highlights the potential of biochar as a valuable tool in the fight against climate change.

Biochar as a Potential Habitat for Microorganisms: Soil microorganisms are highly reactive to a range of environmental, climatic, and management variables, including organic matter inputs like biochar. Biochar, in addition to enhancing soil physicochemical qualities, has been found to modify soil biological properties. The biochar's permeable structure, vast internal surface area, and capacity to adsorb soluble organic matter, gases, and inorganic nutrients provide a setting for microorganisms to colonize, grow, and reproduce. Fresh biochar may be an extremely selective habitat compared to non-pyrolized carbon (C) substrates because the pore space of pyrolyzed biomass increases during pyrolysis by several thousand times and is related to the pyrolysis temperature and feedstock materials' nature. The influence of biochar on soil microbial communities is still a subject of research, and it is possible that the biochar's impact on microbial communities varies based on the soil characteristics and biochar application rates. As a result, further research is needed to better understand the effect of biochar on soil microbial communities.

Reference

Iwona Gruss , Jacek P. Twardowski , Agnieszka Latawiec , Jolanta Królczy and Agnieszka Medy´nska-Juraszek. 2019. The Effect of Biochar Used as Soil Amendment on Morphological Diversity of Collembola., *Sustainability* , 11 (5126) : 1-13

Janice E. Thies, Matthias C. Rillig and Ellen R. Graber. 2015. Biochar effects on the abundance, activity and diversity of the soil biota. *Biochar for Environmental Management.*13 (327-389)

Yang Ding, Yunguo Liu, Shaobo Liu, Zhongwu Li, Xiaofei Tan, Xixian Huang, Guangming Zeng, Lu Zhou, and Bohong Zheng. 2016. Biochar to improve soil fertility. A review., *Agron. Sustain. Dev.* (2016) 36:36

https://byjus.com/free-ias-prep/biochar