Biochar Production from Mulberry Residues: A Step Towards Circular Economy

P. Priyadharsini[1]*, Anna Kaushik[2]*, R. Kowsalya[3], A. Thangamalar[4] and G. Swathiga[5]

Department of Sericulture, Forest College and Research Institute, Tamil Nadu Agricultural University, Mettupalayam - 641301, Tamil Nadu, India.

Corresponding Author
P. Priyadharsini
Email: priyadharshini.p@tnau.ac.in
Anna Kaushik
Email: annatamannakaushik@gmail.com

OPEN ACCESS

Keywords

Mulberry residues, Pyrolysis, Biochar, Carbon sink, Soil fertility

How to cite this article:

Priyadharsini, P., Kaushik, A., Kowsalya, R., Thangamalar, A. and Swathiga, G. 2025. Biochar Production from Mulberry Residues: A Step Towards Circular Economy. *Vigyan Varta* 6 (10): 23-26.

ABSTRACT

Improper disposal or burning of mulberry residues, contributes to the release of harmful greenhouse gases like carbon dioxide (CO2) and methane (CH4), exacerbating the global climate crisis. Biochar is a form of charcoal produced from biomass through a process called pyrolysis, where the material is heated in limited or no oxygen conditions. It is a highly beneficial material for enhancing soil fertility, sequestering carbon, and providing various other advantages. Converting organic waste, such as mulberry residues, into biochar through pyrolysis process holds great potential for increasing carbon sequestration, minimizing agricultural waste, and enhancing soil quality.

INTRODUCTION

Mulberry, known for its silkworm rearing utility, provide a variety of biomass resources, such as branches, shoots, leaves, stalks, and fruits which makes them prolific producers of renewable biomass. However, the management of residues from mulberry cultivation, particularly those generated during silkworm rearing, finds significant challenges. For instance, pruned mulberry shoots, leaves, and disinfectant-laden silkworm bed waste are often discarded, leading to potential environmental hazards. These materials decompose slowly and can harbour harmful pathogens, posing a threat to subsequent crop cycles. According to estimates by the Food and Agriculture Organization (FAO), a single hectare of mulberry farming generates approximately 12 metric tons of waste annually, including leaves, stalks, silkworm litter, and soft twigs. Farmers used to burn this waste for accelerating decomposition and minimize the risk of infections. Unfortunately, this method not only increases greenhouse gas emissions but also results in the loss of essential nutrients and valuable biomass that could otherwise benefit soil health.

Improper disposal or burning of mulberry residues, contributes to the release of harmful greenhouse gases like carbon dioxide (CO2) and methane (CH4), exacerbating the global climate crisis. However, innovative waste management techniques, such as pyrolysis and anaerobic digestion, offer promising alternatives. These processes not only facilitate the recovery of energy from waste but also contribute to the establishment of a complete nutrient cycle, which supports environmentally friendly farming practices. Pyrolysis, in particular, has garnered attention for its ability to convert biomass into biochar, a stable carbon-rich product that can be used as a soil amendment. This process offers a threefold benefit in addressing climate change: it allows for the long-term storage of carbon in soils, reduces CO2 emissions, and mitigates methane emissions.

Recycling of mulberry stalks

Mulberry stalks and leaves, often discarded as waste, can be transformed into a valuable resource, biochar. through pyrolysis. This process involves heating organic materials in a low-oxygen environment, resulting in the formation of biochar, bio-oil, and syngas. The yield and characteristics of biochar are influenced by several factors, including the feedstock type, pyrolysis temperature, heating rate, and residence time. Biochar produced at higher temperatures tends to have a higher fixed carbon content, greater recalcitrance, and increased hydrophobicity and aromaticity. Additionally, the pH of biochar typically increases with pyrolysis temperature, making it more alkaline. Conversely, biochar yield, electrical conductivity, cation exchange capacity, and the contents of nitrogen, hydrogen, and oxygen tend to decrease as pyrolysis temperature rises. These properties can be tailored to suit specific agricultural or environmental applications (Chandra *et al.,* 2019).

Biochar production

Biochar production through pyrolysis involves heating biomass with minimal or no oxygen, driving off volatile gases and leaving carbon behind. This process, historically used to produce charcoal, includes steps like moisture and volatile matter loss, conversion to volatiles, gases, and biochar, followed by a slow chemical rearrangement in the biochar. Pyrolysis temperature, feedstock type, and residence time significantly influence the composition of pyrolysis products, including syngas, bio-oil, and biochar (Lehmann *et al.,* 2011).

High pyrolysis temperatures reduce biochar production but increase the gas yield. Thus, optimizing pyrolysis conditions is highly essential to control biochar quality and quantity. Biochars produced at low temperature *via* slow pyrolysis have low hydrophobicity and aromaticity, high polarity and acidity, and increased ash content with higher pyrolysis temperatures.

The carbon content of biochar is inversely related to its yield; increasing pyrolysis temperature from 300 to 800°C decreases biochar yield from 67% to 26% and increases carbon content from 56% to 93%. The ash proportion in biochar rises with temperature, from 0.67% to 1.26% between 300°C and 800°C. The stability of biochar depends on the production procedure; charcoal produced at 400°C shows greater stability against oxidation by ozone compared to that produced at 1000°C, despite increased aromaticity at higher temperatures.

Biochars with high amounts of poly-condensed aromatic structures, produced at 400 to 700°C, have fewer ion exchange functional groups, limiting their soil nutrient retention capacity. Conversely, biochars produced at lower temperatures (250 to 400°C) have higher yields and more nutrient exchange sites due to the presence of C=O and C-H functional groups. These biochars also have a more diverse organic character, making them suitable substrates for mineralization by soil bacteria and fungi, which play a crucial role in nutrient turnover and aggregate formation.

Composition of biochar

Biochar is primarily composed of carbon (65-90%), with the remaining portion consisting of volatile matter and mineral matter. The ash content of biochar varies depending on the feedstock. For instance, biochar derived from wood typically has a very low ash content (less than 2%), whereas biochar from tire- derived char often exceeds 10% ash content. However, the exact composition and physical properties of biochar depend heavily on the source material used and the conditions employed during production.

Advantages of biochar

The most significant advantages of biochar is its ability to improve soil properties over the long term. Its porous structure allows it to retain water and nutrients, reducing leaching and improving the availability of essential nutrients to plants. This makes biochar a more reliable nutrient source than other organic soil amendments, which can degrade rapidly in tropical climates. In addition, biochar's high carbon content, which can reach up to 90% depending on the feedstock, makes it highly effective at capturing and storing carbon in the soil, contributing to carbon sequestration efforts and helping mitigate climate change (Mehmood *et al.*, 2017).

Role of mulberry biochar in soil carbon sequestration

Biochar as a carbon Sink

Biochar has gained recognition as a potent strategy for carbon sequestration, with numerous studies highlighting its ability to enhance soil carbon storage and mitigate CO2 emissions. According to Lehmann *et al.* (2011), biochar application to soils can substantially increase carbon sequestration when compared to simply burning plant residues or directly adding them to the soil. When plant residues are converted into biochar through pyrolysis- a process that subject biomass to high temperatures in a low-oxygen environment- carbon becomes stabilized in a form that resists degradation, potentially remaining in soils for thousands of years.

When plant residues decompose rapidly, they release a significant amount of carbon back into the atmosphere in the form of CO2. However, when the same residues are transformed into biochar, this carbon is "locked" into more stable forms like aromatic structures. These forms are less susceptible to microbial decomposition, reducing carbon loss from the soil. Even though some CO2 is released during pyrolysis, it is much lower than the amount that would be emitted if the residues were allowed to decompose naturally.

Impact of pyrolysis temperature on carbon stability

- The temperature used during pyrolysis is one of the most critical factors influencing the quality and stability of biochar, particularly in terms of its carbon sequestration potential and its effectiveness in improving soil properties.

- ❖ Pyrolysis temperatures determine the chemical composition of biochar, notably the balance between aromatic and aliphatic carbon fractions, as well as the degree of aromatic carbon condensation.
- ❖ Biochar produced at higher temperature, typically above 400°C, is richer in aromatic carbon structures. are more stable, reducing the rate of biochar degradation in soil, enhances the biochar's ability to act as a long- term carbon sink (Chandra *et al.,* 2019).
- ❖ Higher pyrolysis temperatures not only increase the concentration of aromatic carbon but also decrease the proportion of volatile organic compounds and oxygen-containing functional groups in biochar.
- ❖ The presence of highly condensed aromatic structures makes high-temperature biochar resistant to microbial degradation, allowing it to persist in soils for centuries to millennia.
- ❖ Low-temperature pyrolysis, on the other hand, produces biochar with a higher aliphatic carbon content and lower aromaticity. These biochars are more susceptible to breakdown and release of carbon back into the environment (Yeboah *et al.*, 2020).

CONCLUSION

The biochar helps to stabilize carbon and reduce its release into the atmosphere which makes it an essential tool for reducing global carbon emissions. Furthermore, the specific impact of mulberry stalk biochar, not yet extensively studied, but its use in agriculture could not only help to sequester carbon but also improve soil health, water retention, and nutrient cycling, all of which are vital for enhancing the sustainability of agricultural systems.

REFERENCES

Chandra, Subhash, and Jayanta Bhattacharya. 2019. "Influence of temperature and duration of pyrolysis on the property heterogeneity of rice straw biochar and optimization of pyrolysis conditions for its application in soils. Journal of Cleaner Production, 215:1123-1139.

Lamani, D, Prakasha, H.C, Naveen, D.V., Kalyana Murthy, K.N. and Rinku Verma. 2024. Effect of mulberry stalk biochar, FYM and humic acid on growth, yield and quality of mulberry (*Morus alba* L.). International Journal of Plant & Soil Science, 36 (4):174-183.

Lehmann, J, Matthias, C., Janice, T., Caroline, A., William, C. and David Crowley, D. 2011. Biochar effects on soil biota–a review. Soil Biology and Biochemistry, 43 (9):1812-1836.

Mehmood, Khalid, Elizabeth, C.G, Michael, S., Brenton, L., Claudia, K., Nicole, W, Christina, S., Jose, M, Estavillo and Mariluz, C. 2017. Biochar research activities and their relation to development and environmental quality. A meta-analysis. Agronomy for sustainable development, 37:1-15.

Yeboah, E., Gideon A., Patrick O., Ben, A. and Kwaku, O.S.U. 2020. Method of biochar application affects growth, yield and nutrient uptake of cowpea. Open Agriculture, 5 (1):352-360.