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Turning Silkworm Waste into Treasure: Sustainable Solutions through Hydrothermal Carbonization

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This article explores the application of hydrothermal carbonization (HTC) in converting silkworm waste into valuable hydrochar, offering a sustainable approach to waste management. HTC efficiently transforms silkworm excrement, discarded cocoons, and leftover mulberry leaves into carbon-rich hydrochar, reducing waste volume, recovering energy, and sequestering carbon. The produced hydrochar enhances soil quality, promoting sustainable agriculture, while the mild operational conditions of HTC minimize environmental impact. By addressing waste disposal challenges and contributing to climate change mitigation, HTC presents a promising solution aligned with circular economy principles, delivering environmental, agricultural, and energy-related benefits.

Hydrothermal carbonization

Hydrothermal carbonization (HTC) is a thermochemical process that converts biomass into hydrochar through subcritical water conditions. It involves heating wet biomass at temperatures typically ranging from 180°C to 250°C under high pressure (up to 30 bar) in an aqueous environment, promoting hydrolysis, dehydration, and carbonization reactions. This process mimics natural coal formation but occurs within hours to days, making it a rapid method for biomass conversion. HTC produces hydrochar—a carbon-rich material resembling brown coal or peat—which can be used as a solid fuel, soil amendment, or precursor for activated carbon production due to its high carbon content and energy density (Funke & Ziegler, 2010). The versatility of HTC extends to wastewater treatment, where it effectively removes pollutants while producing a valuable carbonaceous material for various applications (Libra et al., 2011). Thus, HTC offers a sustainable route for biomass utilization and environmental remediation.

Wastes generated from silkworm rearing

Silkworm rearing generates significant amounts of waste, primarily consisting of silkworm excrement (known as frass), discarded cocoons, and leftover mulberry leaves (Bharathi, 2019). This waste presents both challenges and opportunities for sustainable management. Here is a breakdown of the types of waste produced and their potential uses:

1. **Silkworm Excrement (Frass)**: This organic waste is rich in nutrients and can be utilized as an excellent organic fertilizer. It enhances soil quality by improving its water retention and nutrient content.
2. **Discarded Cocoons**: These include various types of cocoons that are not suitable for silk production, such as double or pierced cocoons. They can be processed into biodegradable materials or used in crafts and decorations.
3. **Leftover Mulberry Leaves**: After feeding silkworms, the remaining mulberry leaves can be repurposed as livestock feed, contributing to the agricultural ecosystem. They also contain valuable nutrients that can be composted or fermented to produce biogas.
4. **Pupal Waste**: The pupae left after silk extraction can be used as a protein-rich feed for livestock or fish, further integrating the silkworm rearing process into the agricultural supply chain.

Environmental benefits of using hydrothermal carbonization for silkworm waste

The hydrothermal carbonization (HTC) of silkworm waste offers several environmental benefits, making it a promising approach for waste management and resource recovery. Here are the key advantages:

Waste Reduction: HTC significantly reduces the volume of silkworm waste, which includes excrement, discarded cocoons, and leftover mulberry leaves. By converting this waste into hydrochar, the process mitigates the environmental issues associated with waste disposal, such as landfill overflow and pollution.

Energy Recovery: The hydrochar produced through HTC has a higher energy density compared to the original biomass. This transformation allows for the utilization of silkworm waste as a renewable energy source, providing an alternative to fossil fuels. The process captures approximately 60%-90% of the calorific value of the input material, making it a viable option for energy generation.

Carbon Sequestration: HTC not only recycles carbon present in the biomass but also sequesters it in a stable form. The carbon recovery rate during the HTC process can be around 90%, which contributes to reducing greenhouse gas emissions by preventing carbon from being released back into the atmosphere (Maniscalco et al., 2020). This characteristic makes HTC a valuable tool in climate change mitigation efforts.

Soil Improvement: Hydrochar can be used as a soil amendment, enhancing soil quality by improving its physical and chemical properties. The addition of hydrochar can increase nutrient retention, water-holding capacity, and microbial activity in soil, thereby promoting sustainable agricultural practices and enhancing food security (Petrović et al., 2024).

Reduced Resource Input: The HTC process operates under mild conditions and utilizes wet biomass without the need for extensive drying. This efficiency reduces the energy input required for processing, leading to lower overall environmental impacts compared to traditional biomass conversion methods, such as pyrolysis or incineration (Satira et al., 2021).

Pollution Mitigation: By converting silkworm waste into valuable products like hydrochar, HTC helps reduce environmental pollution. The process repurposes waste that would otherwise contribute to landfill issues or water contamination, thus supporting a more sustainable circular economy.

Conclusion

Hydrothermal carbonization (HTC) of silkworm waste offers a multifaceted solution for sustainable waste management and resource recovery. By converting silkworm excrement, discarded cocoons, and leftover mulberry leaves into hydrochar, HTC significantly reduces waste volume, mitigates pollution, and recovers energy with high efficiency. The carbon sequestration potential of hydrochar contributes to climate change mitigation, while its application as a soil amendment enhances soil fertility and agricultural sustainability. HTC operates under mild conditions, reducing energy input and environmental impact compared to traditional methods. Overall, HTC aligns with circular economy principles, providing environmental, agricultural, and energy benefits.

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