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Review

Thermochemical upcycling of food waste into engineered biochar for energy and environmental applications: A critical review

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ABSTRACT

Environmental issues caused by food waste are important concerns for human well-being and ecosystem health. Valorization of food waste into energy and carbon materials has been extensively investigated. Here, we reviewed the most recent advancements in the thermochemical conversion of food waste into engineered biochar. Synthesis routes and practical applications of the food waste-derived biochar was succinctly reviewed. Engineered biochar is a promising alternative for mitigating environmental pollution and alleviating energy crisis. The underlying relationships between engineered biochar properties and specific applications are still unclear, therefore, machine learning-aided engineered biochar design and process optimization was proposed. Moreover, before any industrial scale implementation, detailed assessments of the environmental benefits and economic feasibility must be conducted. In the context of carbon neutrality, thermochemical upcycling of food waste into engineered biochar for energy and environmental applications can significantly contribute to attaining sustainable food waste management, mitigating environmental pollution, and addressing the energy shortage crisis, and thus will eventually facilitate the fulfillment of United Nations Sustainable Development Goals (SDGs). Furthermore, the existing challenges in the practical valorization of food waste into engineered biochar are comprehensively discussed, and outlooks are proposed.

1. Introduction

Food waste is a global issue that brings serious environmental, economic, and social challenges [1–3]. Many countries have taken measures to reduce food waste and sustainable management of food waste separately collected from other wastes. Collected food waste can be processed to minimize its environmental impact and to maximize its benefits within a circular economy. Food waste, which is mainly composed of organics (e.g., carbohydrates, proteins, fats, and lipids), is hereby converted into high value-added products (e.g., methane, bioethanol, syngas, chemicals, and carbon materials) [4]. Recently, the upcycling of food waste into advanced carbon materials has been considered an emerging paradigm shift from landfilling and incineration. The major upcycling approaches include thermochemical conversions (e.g., hydrothermal carbonization (HTC), pyrolysis, and gasification) and biological conversions (e.g., anaerobic digestion (AD)) [4,5]. AD is extensively investigated for transforming food waste into value-added products, owing to its considerable advantages of cost-effectiveness, mild operating conditions, and relatively low energy consumption [6–9]. However, AD generally requires a long residence time and a high-quality feedstock [10].

Compared with the biological conversion mentioned above, thermochemical conversion is fast and achieves high yields of value-added products [11]. Pyrolysis, a high-temperature treatment in the absence

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