Sustainable Materials and Technology

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Biochar

A Sustainable Approach

Springer

Sustainable Materials and Technology

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Contents

Production, Characterization, and Properties of Biochar

Zainab Ngaini, Nur Aqilah Makshut, Rafeah Wahi, and Showkat Ahmad Bawani

Abstract Biochar-based research has been widely studied due to its superb physiochemical properties and versatile applications. Numerous carbonization techniques of biomass have been introduced to form unique properties of biochars through thermochemical decomposition from the conventional to the latest technology (i.e., muffle, microwave, and tube pyrolysis) with higher porosity. During pyrolysis, the biowaste materials steadily transformed themselves into porous structured spherical shape particles with smaller particle sizes and higher surface area distributions. Nanostructure biochar showed a distinctive and ideal material for transdisciplinary usage due to its outstanding chemical, physical, and biological elements. Biochar has adaptable applications as fertilizer for soil amendment and also as an adsorbent for the removal of organic pollutants, dyes, and heavy metals. This chapter also describes the advancement in technology for the bioconversion of agricultural wastes into value-added products, which provides an eco-friendly alternative for a sustainable waste management system and benefits mankind.

Keywords Adsorption · Biomass · Lignocellulosic · Pyrolysis · Porosity

1 Introduction

Biochar is a black composite discovered in 3000—500 years BP in the Amazonian basin [1]. The Amazonian Black Earth or *Terra Preta do Indio* has intrigued the interests of researchers to discover the versatility of biochar due to the significant fertility of the soils compared to other tropical soils [2]. Naturally, biochar is found in the soil as a result of wildfire and the decomposition of organic matter after a long period [3]. In other words, biochar is a carbon-rich pyrogenous material which

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commonly produced from the thermal degradation of organic materials, such as biomass and agricultural wastes under a limited oxygen supply [4].

Biochar is a versatile material that is widely used for the treatment of contaminated soil, catalysis, energy storage, and many others [5]. The wide application of biochar has been reported in agriculture as a soil amendment. The addition of biochar to soil can enhance its pH, ability to store moisture, cation-exchange capacity, microbial flora [6], as well as concentrations of phosphorus and total nitrogen. A wide range of biomass is used to produce biochar, such as seaweed (*Gelidiella acerosa*) [7], Foxtail palm trunk (*Wodyetia bifurcata*) [8], coconut shell [9], and Bermuda grass [10]. The carbonization of biomass is producing biochar with the desired properties for various applications, such as an adsorbent for water-soluble pollutants in the wastewater as well as gaseous pollutants in the air [11].

Nowadays, biochar from agricultural resources is commonly used as the precursor to produce activated carbon by introducing acid or basic activation with activators, such as zinc chloride ($ZnCl_2$), phosphoric acid (H_3PO_4), sodium hydroxide (NaOH), and potassium hydroxide (KOH) followed by physical treatment (carbonization process) to produce activated carbon. The formation of activated carbon from these sources aids in economic management due to its low-cost production, easily produced, environmentally friendly, and versatile usage [12].

2 Production of Biochar

2.1 Biochar Precursors

The precursors for biochar production are commonly obtained from agricultural wastes or biomass. Biomass is a biological and non-biological solid product generated from living organisms that have no known values and applications, thus classified as waste materials [13]. Biomass is considered a sustainable renewable energy feedstock and an ideal source for the production of biochar [14]. Plant-based agricultures, such as sago bark [15], sago pith [16], corn cob [17], and Bermuda grass [10], have been reported as biomass sources due to abundance availability and highly composed of structural components (lignocellulosic materials) and non-structural components (extracts), such as starch, tannins, and metal oxides.

The lignocellulosic materials, such as cellulose, hemicellulose, and lignin, act as the building structure of plant-based biomass. The biggest component of lignocellulosic biomass, accounting for 38–50% of its weight, is cellulose while hemicellulose is the second largest fraction that contributes 20–40% by weight of biomass. Hemicellulose is responsible for the hygroscopicity of the biomass. Lignin is the amorphous compound associated with the sturdiness of biomass and contributes 15–25% of the biomass fractions [18]. Other trace materials or the extracts contribute the least percentage by weight of biomass and are not related to the structure built of biomass.

2.2 Carbonization Methods of Biomass

There are many methods reported on the carbonization of biomass to produce biochar namely hydrothermal treatment [19], steam gasification [20], torrefaction [21], and pyrolysis [22]. The hydrothermal treatment utilizes water as the medium of temperature regulatory between 120 and 350 °C [19]. This is a common process for the preparation of biochar which involves a simultaneous reaction of hydrolysis, decarboxylation, condensation, and dehydration that breaks the lignocellulosic structure of biomass [23] (Fig. 1). The biochar produced from hydrothermal treatment emits high carbon fractions, reduced volatile matter, and high calorific values that make it suitable for solid fuel [23, 24].

Another method reported in the preparation of biochar is via steam gasification [20] and the torrefaction process [21, 25] (Fig. 2). Steam gasification requires a high temperature to heat the gasifier (800–870 °C) and produced high-density biochar with numerous pore structures and high biochar yield [26]. The carbonization of biomass requires two connected fluidized bed reactors for gasification and heat generation during gasification treatment [20]. The torrefaction process is another process to produce biochar. It is a mild pyrolysis method that is similar to conventional pyrolysis with a lower temperature and pressure. The torrefaction method of biomass has been reported to have high energy density and low oxygen content which makes it a good feedstock for the production of activated carbon [27].

Pyrolysis is another carbonization method of biomass to produce biochar. It is the most reported method for thermal degradation of biomass [22]. Biomass pyrolysis is extensively studied employing different carbonization conditions and reactors. It is a thermal degradation process of lignocellulosic materials under high temperature and oxygen-starved atmosphere [28].

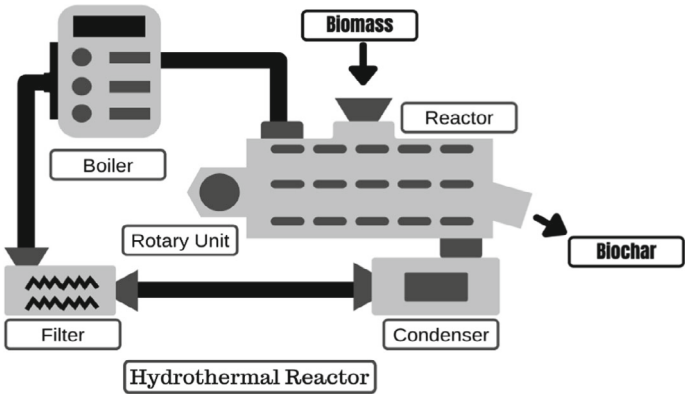

Fig. 1 Preparation of biochar using hydrothermal reactor