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Biochar

A Sustainable Approach

Springer

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Modifications of Surface Properties of Biochar by Different Treatment Methods

Rafeah Wahi, Muhammad Imran-Shaukat, Zainab Ngaini, and Nur Fakhirah Qurratu'ain Zuhaidi

Abstract Biochar is a value-added product of biomass which is thermochemically synthesized. Application of biochar covers different processes/activities including environmental remediation, water purification, catalysis, tissue engineering, additive in organic waste compost, electrode material and modifier, and so on. Biochar is modified with respect to the target application. Different types of physical and chemical modifications have been reported. For application as adsorbent, pristine biochar exhibits lower surface area in comparison with the commercial activated carbon and this shortcoming necessitates appropriate treatment to make the biochar an effective adsorbent with larger surface area and improved surface properties. Modification process can be physical, or chemical, or a combination of both the treatment. Physical treatment entails enhancing the porosity, surface area, pore volume, and other physical features of biochar by activating its surface morphologies and properties. Chemical modification involves the use of solvents, acids/bases, or other substances to change and improve the functionality, pore structure, and surface area of biochar and can entail both one-step and two-step modification procedures. The current chapter highlights recent advances in physical and chemical treatment of the biochar, outlining major effects on the surface properties of the biochar.

Keywords Biochar · Biochar modification · Chemical activation · Physical activation · Biochar properties

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1 Introduction

Biochar is a light, highly porous carbonaceous material produced by the thermochemical breakdown or pyrolysis of biomass in the absence of, or with a restricted supply of, oxygen [1, 2]. Biochar research has gained popularity in recent years due to its diverse applications [2]. Biochar can also be utilized as feedstock for a variety of processes, depending on its physicochemical properties [3]. Utilization of biochar has been reported in the production of activated carbon, catalysts, carbon nano-filaments, and hydrogasification [2]. For soil amendment, biochar is used to increase soil fertility and growth media by raising soil pH, improving soil aeration, and modifying soil structure owing to changes in physicochemical qualities [4]. Biochar is modified into activated carbon through different physiochemical treatments [5]. Biochar and the resultant activated carbon, which has a high degree of porosity, a larger surface area, and functional groups, such as C–O, C=O, COOH, and OH on its surface, can be employed as an adsorbent of pollutants in the environment [3, 6, 7].

The traditional methods of producing biochar is via hypoxia pyrolysis, which needs to be performed in an inert environment at high temperatures assorting from 400 to 800 °C [8]. The physicochemical characteristics and yield of biochar are influenced by pyrolysis parameters including temperature and time, as well as biomass species [2, 3]. Depending on the desired product, different pyrolysis methods are used; for example, long-term and low-temperature pyrolysis can achieve the highest yield of solid product [9]. However, the higher temperature process consumes more energy, resulting in lower yields due to the degradation of biomass constituents after pyrolysis [8]. To address the issues, microwave pyrolysis has emerged as a major emphasis in carbonization technologies. Microwave pyrolysis is preferred because it saves time, energy, and money for producing biochar [2].

Microwave pyrolysis is a low-power, long-duration, and economical method of producing biochar from agricultural waste [10]. Microwave-induced biochar exhibit higher porosity and surface area than biochar prepared by the conventional pyrolysis methods [11]. The temperature required for microwave pyrolysis is 245–390 °C, which is significantly lower than the 500–1000 °C required for conventional carbonization [12].

Different types of analyses have been reported to characterize the biochar including specific surface area, pore volume, and elemental analysis [13]. The mentioned analyses are among the common characterization analyses conducted to investigate biochar unique properties, for instance broader surface area, high alkalinity, superior hydrophilicity, and availability of diverse functional groups. These are advantageous features for atmospheric carbon fixation and emissions reduction, which will aid in climate change mitigation [14]. Different equipment are employed to characterize the biochar including scanning electron microscope (SEM), energy dispersive X-ray analysis (EDX), X-ray diffraction (XRD), transmission electron microscope (TEM), X-ray photoelectron spectroscopy (XPS),and Fourier transform infrared spectrometry (FTIR) [15].

involves the activation of biochar surface morphologies and properties to enhance its porosity, surface area, pore volume, and other physical properties. Chemical modification utilizes solvents, acid/base, or others to modify and enhance the functionality, pore structure, and also surface area of the biochar, which could involve both one-step and two-step modification procedure. In general, the choice of physical and chemical modifications depends on the intended application of the modified biochar itself.

References

1. Sajjadi B, Broome JW, Chen WY, Mattern DL, Egiebor NO, Hammer N et al (2019) Urea functionalization of ultrasound-treated biochar: a feasible strategy for enhancing heavy metal adsorption capacity. Ultrasonics Sonochem 51:20–30
2. Wahi R, Zuhaidi NFQ, Yusof Y, Jamel J, Kanakaraju D (2019) Chemically treated microwave biochar from sago bark waste. In: Proceedings ISER 119th international conference, Malaysia, pp 52–54
3. Choudhary M, Kumar R, Neogi S (2020) Activated biochar derived from Opuntia ficus-indica for the efficient adsorption of malachite green dye, Cu^{+2} and Ni^{+2} from water. J Hazard Mater 392:122441
4. Mohamad Fathi NK, Mohamad Bukhori MF, Abd Aziz Abdullah SM, Wahi R, Zailani MA, Raja Gopal MM (2022) Effect of sago bark biochar application on Capsicum annuum L. var. Kulai growth and fruit yield. Malaysian Appl Biol 51(3):127–135
5. Marsin FM, Ibrahim WAW, Nodeh HR, Sutirman ZA, Ting NN, Sanagi MM (2018) Recent advances in the preparation of oil palm waste-based adsorbents for removal of environmental pollutants—a review. Malaysian J Anal Sci 22(2):175–184
6. El-Nemr MA, Abdelmonem NM, Ismail IMA, El Nemr SRA (2020) Ozone and ammonium hydroxide modification of biochar prepared from Pisum sativum peels improves the adsorption of copper (II) from an aqueous medium. Environ Process 7:973–007
7. Imran-Shaukat M, Wahi R, Rosli NR, Aziz SMA, Ngaini Z (2021) Chemically modified palm kernel shell biochar for the removal of heavy metals from aqueous solution. IOP Conf Ser Earth Environ Sci 765(1):79–91
8. Weibin Y, Jiwen H, Yichang Y, Ma D, Gong W, Qiu H et al (2021) Facile preparation of sulfonated biochar for highly efficient removal of toxic Pb(II) and Cd(II) from wastewater. Sci Total Environ 750:141545
9. Kaya N, Arslan F, Uzun ZY (2020) Production and characterization of carbon-based adsorbents from waste lignocellulosic biomass: their effectiveness in heavy metal removal. Fullerenes, Nanotubes Carbon Nanostruct 28(10):769–780
10. Mohamed BA, Kim CS, Ellis N, Bi X (2016) Microwave-assisted catalytic pyrolysis of switchgrass for improving bio-oil and biochar properties. Bioresource Technol 201:121–132
11. Wahi R, Zuhaidi NFQ, Yahaya SA, Lam SS, Imran-Shaukat M, Aziz SMA et al (2022) Engineered microwave biochar from sago bark waste for heavy metals adsorption. Mater Today: Proc 57(3):1403–1414
12. Wahi R, Aziz SMA, Hamdan S, Ngaini Z (2016) Biochar production from agricultural wastes via low-temperature microwave carbonization. In: IEEE international RF and microwave conference, 04, pp 244–247
13. Wang J, Guo X (2020) Adsorption isotherm models: classification, physical meaning, application and solving method. Chemosphere 258:127279
14. Shi J, Fan X, Tsang DCW, Wang F, Shen Z, Hou D et al (2019) Alessi. Removal of lead by rice husk biochars produced at different temperatures and implications for their environmental utilizations. Chemosphere 235:825–831