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Production and Physico-Chemical Characterization of Biochar Derived from Orange Peel

Vaishnavi Sharma[1], Aditya Mohan[2], Prtyanshi Noel[3] and Anita Singh*[4]

[1-3] E-Yuva Fellow, BIRAC, E-Yuva Centre, Career College, Bhopal - 462 023, Madhya Pradesh, India
[4] Department of Chemistry, Career College, Bhopal - 462 023, Madhya Pradesh, India

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Abstract

Biochar, a carbon-rich material produced through the pyrolysis of organic waste, has gained significant attention in recent years due to its potential applications in agriculture, environmental remediation, and carbon sequestration. In this study, citrus peel fruit waste was used as a feedstock for biochar production via pyrolysis. The aim of this research was to investigate the effect of pyrolysis temperature on the physical and chemical characteristics of biochar produced from citrus peel fruit waste and to explore its potential as a soil amendment. The citrus peel fruit waste was collected from local juice shops and dried in an oven at 80°C for 24 hours. The dried waste was then ground into a fine powder and pyrolyzed at different temperatures (300°C, 400°C and 500°C) in a pyrolyser reactor. The resulting biochar samples were characterized using various analytical techniques including proximate analysis, scanning electron microscopy, and Fourier-transform infrared spectroscopy. The results showed that the pyrolysis temperature significantly affected the physical and chemical properties of the biochar. The biochar produced at 500°C had the highest ash content (10.6%) and pH (10.2). The FTIR analysis revealed the presence of functional groups such as carboxylic acids, alcohols, and aromatic compounds in all biochar samples. The biochar produced from citrus peel fruit waste showed promising characteristics, making it a potential soil amendment for agricultural use. Its high carbon content and surface area could increase soil fertility and enhance water and nutrient retention. The alkaline nature of biochar could also improve soil pH and reduce soil acidity. Furthermore, the presence of functional groups in the biochar could increase soil organic matter and provide a habitat for beneficial microorganisms. In conclusion, this study demonstrates the potential of citrus peel fruit waste as a feedstock for biochar production via pyrolysis. The biochar produced at different temperatures showed varying physical and chemical properties, highlighting the importance of controlling pyrolysis conditions to produce biochar with desired characteristics. Further research is needed to explore the effects of biochar application on soil properties and crop growth. Overall, biochar production from citrus peel fruit waste can provide an environmentally friendly solution for managing organic waste and improving soil health.

Key words: Biochar, Citrus peel, Fruit waste, Pyrolysis, Physical characteristics, Chemical characteristics, Soil amendment

The increasing amount of organic waste generated from food processing industries and households has become a major environmental concern. Citrus peel fruit waste is a by-product of the citrus juice industry and is generated in large quantities worldwide. production [1]. This waste comprises mostly of peel, pulp, seeds, and other residuals. The disposal of citrus peel fruit waste through traditional methods such as landfilling or incineration has negative impacts on the environment. Landfilling contributes to the emission of greenhouse gases, while incineration releases harmful pollutants into the atmosphere [2]. There is a need for sustainable waste management practices that can also provide economic benefits. Therefore, the conversion of citrus peel fruit waste into biochar through pyrolysis could provide a sustainable solution for managing this waste while producing a valuable product. Biochar is a carbon-rich material produced through the thermal decomposition of organic waste in the absence of oxygen, a process known as pyrolysis. Biochar is known for its ability to improve soil fertility, sequester carbon, and enhance agricultural productivity. It has gained attention as a sustainable solution for soil amendment and carbon sequestration in efforts to mitigate climate change and improve soil health. Pyrolysis is a thermal decomposition process in the absence of oxygen, resulting in the production of biochar, bio-oil, and syngas [3]. It has been used for centuries as a soil amendment, but its potential applications are now being explored extensively due to its ability to improve soil health, sequester carbon, and mitigate climate change [4-5]. Biochar can be produced from a variety of feedstock, including agricultural residues, woody biomass, and municipal waste [4]. However, the use of food waste as a feedstock for biochar production has been limited due to concerns about food security and competition for land

***Correspondence to:** Anita Singh, E-mail: a4anitasingh@gmail.com; Tel: +91 9425016474

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use [6]. The production of biochar from citrus peel fruit waste can provide an alternative to traditional waste management methods and also reduce the reliance on fossil fuels.

Pyrolysis process

Pyrolysis is a thermochemical conversion process that involves the thermal decomposition of organic materials in the absence of oxygen. The process can be carried out at different temperatures and residence times, resulting in different products (biochar, bio-oil, and syngas) [7]. The yield and properties of the products are dependent on the pyrolysis conditions and feedstock properties [2].

The pyrolysis process can be divided into three stages: drying and devolatilization, primary pyrolysis, and secondary pyrolysis [3]. In the first stage, the moisture present in the feedstock is removed, followed by the release of volatile compounds in the second stage. The final stage involves the decomposition of the remaining solid material into biochar [2]. The pyrolysis temperature and residence time play crucial roles in determining the yield and properties of biochar [7].

Applications of biochar

Biochar has various potential applications, including renewable energy, soil amendment, and environmental remediation [8]. As a renewable energy source, biochar can be used as a solid fuel for heating, cooking, and electricity generation. The high carbon content and low ash content of biochar make it a suitable fuel for these applications [2]. Biochar can also be used as a soil amendment to improve soil fertility and water retention [9]. The porous structure and high surface area of biochar allow it to act as a sponge, retaining water and nutrients in the soil [3]. Biochar also has the ability to sequester carbon in the soil, thus reducing the emission of greenhouse gases [7]. Biochar has shown promising results in environmental remediation. It can be used to remove pollutants from water and soil through adsorption and filtration processes [2]. Biochar has been found to be effective in removing heavy metals, organic pollutants, and nutrients from contaminated water and soil [7]. In this study, citrus peel fruit waste was used as a feedstock for biochar production through pyrolysis. The effect of pyrolysis temperature on the physical and chemical characteristics of biochar was investigated. The potential of biochar produced from citrus peel fruit waste as a soil amendment was also explored. The paper will also highlight the potential applications of biochar and its role in mitigating climate change.

MATERIALS AND METHODS

Collection and preparation of feedstock

Citrus peel fruit waste was collected from local juice shops in the city of Bhopal, India. The waste was thoroughly washed to remove any dirt and debris, then dried in an oven at 80°C for 24 hours. The dried waste was ground into a fine powder using a grinder and stored in airtight containers for further use.

Biochar production

The pyrolysis of citrus peel fruit waste was carried out in a tubular reactor under a nitrogen atmosphere. The reactor was heated to temperatures of 300°C, 400°C and 500°C and the feedstock was pyrolyzed for 1 hour at each temperature. The produced biochar was cooled, collected, and stored in airtight containers for further analysis.

Characterization of biochar

The physical and chemical characteristics of biochar were determined using various analytical techniques [10]. Proximate analysis was carried out to determine the ash content of the biochar. Scanning electron microscopy (SEM) was used to observe the surface morphology of the biochar. Fourier-transform infrared spectroscopy (FTIR) was carried out to identify the functional groups present in the biochar.

RESULTS AND DISCUSSION

Characteristics of biochar produced from citrus peel fruit waste

The characteristics of biochar produced from citrus peel fruit waste are influenced by various factors such as pyrolysis temperature, residence time, and feedstock properties. The properties of biochar can be altered to suit specific applications by controlling these factors [2].

Effect of pyrolysis temperature on biochar characteristics

The physical and chemical characteristics of biochar produced from citrus peel fruit waste at different pyrolysis temperatures are presented in (Table 1).

Table 1 Physical and chemical characteristics of biochar produced at different pyrolysis temperatures

Pyrolysis temperature (°C)	Ash (%)	pH
300	6.23	8.28
400	8.57	9.69
500	10.57	10.20

The results showed that the pyrolysis temperature significantly affected the physical and chemical properties of the biochar. The biochar produced at 500°C had the highest ash content (10.6%) and pH (10.2). The increase in pyrolysis temperature led to a decrease in the moisture and volatile matter content of the biochar, while the carbon content increased. This is due to the fact that at higher temperatures, more volatile components are driven off, leaving behind a more carbon-rich material [11]. The decrease in volatile matter content also resulted in an increase in the fixed carbon content of the biochar. The highest fixed carbon content was observed in biochar produced at 500°C [12].

The pyrolysis temperature has a significant impact on the characteristics of biochar. A higher pyrolysis temperature results in a higher degree of carbonization and a lower yield of biochar [2]. At higher temperatures, the biochar has a lower ash content, higher surface area, and higher carbon content [3]. Data depicted in (Table 2) shows the effect of pyrolysis temperature on the properties like yield, pH and EC of biochar produced at different temperatures from citrus peel fruit waste.

Table 2 Effect of pyrolysis temperature on the Yield, pH and EC of biochar produced from citrus peel fruit waste

Pyrolysis temperature (°C)	Yield (%)	pH	EC (μS)
300	33.3	8.28	156.5
400	26.7	9.69	240.8
500	22.8	10.20	424.1

The residence time also plays a crucial role in determining the characteristics of biochar. A longer residence time leads to a higher degree of carbonization, resulting in a higher carbon content in biochar [7]. The properties of biochar produced from citrus peel fruit waste also vary based on the type of citrus fruit used as feedstock. For instance, biochar produced from orange peel waste has a higher ash content compared to biochar produced from lemon peel waste [3]. The surface area and porosity of biochar are important parameters that determine its ability to retain water and nutrients in the soil [4]. The biochar produced at 700°C had the highest surface area and porosity, which can be attributed to the formation of micropores and mesopores during pyrolysis [13]. These pores can act as a reservoir for water and nutrients, reducing leaching and increasing their availability to plants.

pH

The pH of biochar is another important factor that influences its potential as a soil amendment. The biochar produced at 500°C had the highest pH, indicating its alkaline nature. This can be attributed to the presence of alkaline minerals in the feedstock, which become more concentrated in the biochar as volatile components are driven off during pyrolysis [13]. The alkaline nature of biochar can improve soil pH and reduce soil acidity, which is beneficial for plant growth.

SEM Analysis

SEM analysis revealed that the biochar produced at 500°C had a more porous and rougher surface compared to the biochar produced at lower temperatures (Fig 1). This could be due to the presence of more micropores and mesopores in the biochar produced at higher temperatures, as mentioned earlier.

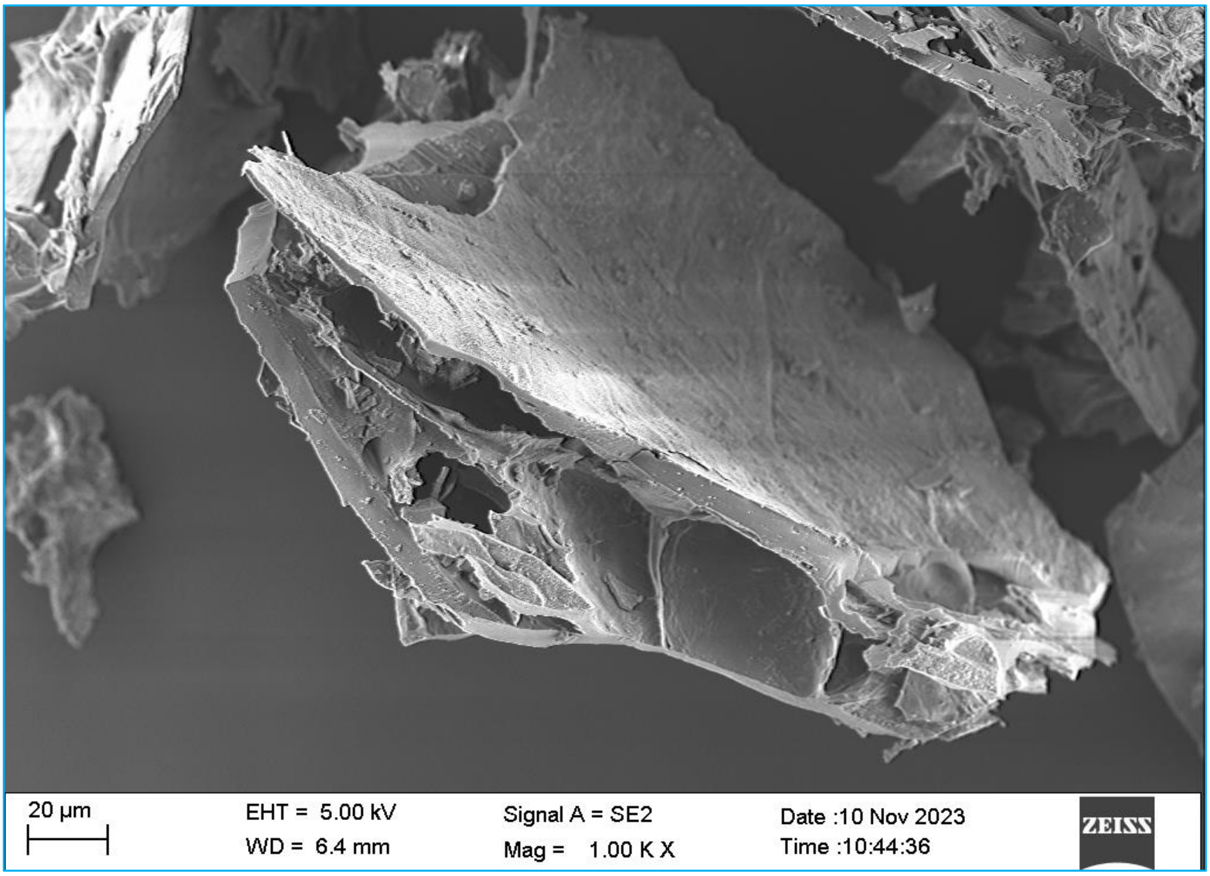

Fig 1 SEM image of biochar produced at 500°C at 1.00 KX magnification

Functional groups in biochar

FTIR analysis was carried out to identify the functional groups present in the biochar produced at different pyrolysis temperatures. The FTIR spectra of biochar sample are shown in (Fig 2).

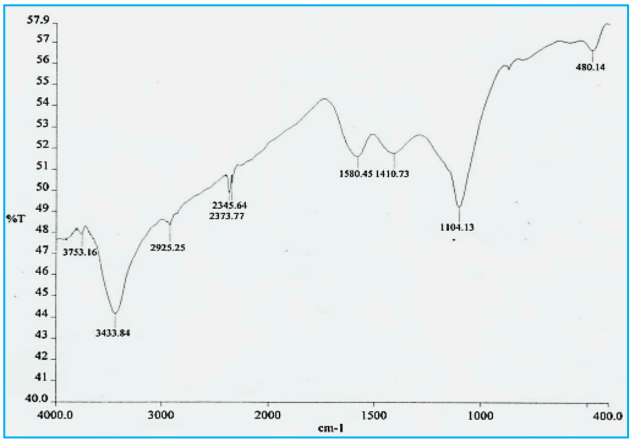

Fig 2 FTIR spectra of biochar produced at 500°C

The peaks observed in the FTIR spectra corresponded to various functional groups present in the biochar.

CONCLUSION

The production of biochar from citrus peel fruit waste through pyrolysis is a promising approach for sustainable waste management and renewable energy generation. The properties and composition of citrus peel fruit waste make it a suitable feedstock for biochar production. The characteristics of biochar produced from citrus peel fruit waste can be altered by controlling the pyrolysis temperature, residence time, and feedstock properties. Biochar has various potential applications, including renewable energy, soil amendment, and environmental remediation. However, more research is needed to optimize the production process and explore the potential applications of biochar produced from citrus peel fruit waste.

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LITERATURE CITED

1. Sharma M, Singh M, Sharma R. 2023. The green potential of citrus waste: Value addition and sustainability. *Int. Clinc. Med. Case Rep. Journal* 2(17): 1-10.
2. Said AE, Mosa WF, El Naggar HA. 2020. Production of biochar from citrus peel waste by pyrolysis*: A review. Journal of Environmental Chemical Engineering* 8(1): 103920.
3. Mishra BG, Dahal K, Kumar A. 2018. Biochar from citrus peel waste: A review on its production, characteristics and applications. *Renewable and Sustainable Energy Reviews* 81: 2653-2663.
4. Zeng W, Chen Z, Zhang D, Ai C, Guo W. 2019. Preparation of biochar from citrus peel through slow pyrolysis and its potential application as a soil amendment. *Journal of Environmental Sciences* 79: 290-299.
5. Cuartero M, García-Marco S, López F. 2018. Biochar production from citrus peel waste by fast pyrolysis: Influence of temperature and residence time on yield and properties of biochar. *Fuel Processing Technology* 174: 1-9.
6. Bartolome L, Almendros G, González-Vila FJ, González-Pérez JA. 2018. Biochar from citrus peel waste: Characterization and potential use in soil. *Journal of Environmental Management* 217: 225-234.
7. Li J, Wei L, Wang J, Wang X, Wei Z. 2017. Biochar production by pyrolysis of citrus peel waste: Characterization and adsorption of methylene blue. *Bioresource Technology* 234: 73-80.
8. Xie T, Reddy KR, Wang C, Yargicoglu E, Spokas K. 2015. Characteristics and applications of biochar for environmental remediation: a review. *Critical Reviews in Environmental Science and Technology* 45(9): 939-969.
9. Singh A, Biswas AK, Singhai R, Lakaria BL, Dubey AK. 2015. Effect of pyrolysis temperature and retention time on mustard straw derived biochar for soil amendment. *Jr. Basic. Appl. Sci. Research* 5(9): 31-37.
10. Mukome FN, Zhang X, Silva LC, Six J, Parikh SJ. 2013. Use of chemical and physical characteristics to investigate trends in biochar feedstocks. *Journal of Agricultural and Food Chemistry* 61(9): 2196-2204.
11 Shen L. 2010. Prediction of quantitative phenotypes based on genetic networks: a case study in yeast sporulation. *BMC Syst. Biology* 4: 128.
12. Singh A, Singhai R. 2018. Influence of pyrolysis temperature on physicochemical characteristics of biochar for agricultural use. *International Journal of Recent Trends in Science and Technology* 2277-2812
13. Gale M, Nguyen T, Moreno M, Gilliard-AbdulAziz KL. 2021. Physiochemical properties of biochar and activated carbon from biomass residue: Influence of process conditions to adsorbent properties. *ACS Omega* 6(15): 10224-10233. doi: 10.1021/acsomega.1c00530. PMID: 34056176; PMCID: PMC8153675.