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SEM-EDX characterization of iron-modified plum stones biochar

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Abstract It has been shown that biochar, an inexpensive and eco-friendly material made by pyrolyzing biomass, has the ability to eliminate pollutants from water and wastewater. The efficacy of raw biochar as adsorbent and catalyst in advanced oxidation processes is limited, but it is significantly increased by modification. Various physical and chemical methods employed before, during, or after biochar production is among the many that have been investigated. By adding iron compounds, biochar's surface area is increased and new contact points are formed, improving its capacity for adsorption. Iron-biochars are valuable due to their exceptional ability to remove pollutants. Iron functionalized biochar prepared by post-pyrolysis surface Fe modification of plum stones. In this study, SEM-EDX analysis was performed to determine the surface morphology and elemental composition of plum stones biochar and $FeCl_3$ impregnated biochar. After coprecipitation with Fe salt, Fe-BPS showed irregular structure with improved porosity. Content of iron significantly increased in Fe-BPS. Iron-based biochar's adsorption ability and catalytic activity work in concert to remove pollutants from wastewater via two mechanisms. Therefore, iron is added to the plum stone biochar to increase its adsorption capacity and reactivity, which makes it possible to remove a variety of organic and inorganic pollutants efficiently

Keywords: SEM-EDX, plum stones biochar, iron-modified plum stones biochar

1. Introduction

Growing fruit and vegetable processing industries (FVPI) produce a lot of organic waste, and disposing of it in landfills is an unsustainable approach with serious risks to the environment. The lignocellulosic waste (LCW) produced by FVPI is a valuable renewable resource with numerous advantageous qualities that can be transformed into materials with substantial advantages (Lopičić et al., 2024). During the 2012–2021 period, the Serbian plum accounted for an average of 42.52% of the nation's total fruit area, significantly more than any other fruit crop. Serbia is the third-largest producer of plums in the world, with an average of 440.9 thousand tonnes produced annually (Gazdić et al., 2024). Approximately 8–10% of the mass of plum fruit is stone (Aurtherson et al., 2023) thus, plum processing generates a significant amount of LCW (stone waste). A possible solution for environmental problems is biochar, a carbonaceous material made by thermochemically converting biomass in an oxygen-limited atmosphere (Rai et al., 2025). Since lignocellulosic biomass is abundant and renewable, it is a desirable feedstock for the creation of biochar. The physical and chemical characteristics of lignocellulosic biochar (L-BC) have been improved by a variety of modified biochars that have been extensively studied for wastewater treatment. Iron abundance and environmental friendliness, together with its exceptional capacity to eliminate a wide range of organic and inorganic pollutants by adsorption, oxidation, reduction, and catalytic processes, have attracted interest in Fe-modified L-BC. When Fe-L-BC is produced, different iron species are created, which can completely affect the biochar's chemical and physical characteristics. It is possible to maximise treatment efficiency by realizing how various types of iron (such as Fe(II), Fe(III), and iron oxides) interact with pollutants and help with pollutant removal processes (Chon et al., 2024). The surface morphology and elemental composition of plum stone biochar BPS and $FeCl_3$ impregnated biochar Fe-BPS were examined in this study using SEM-EDX analysis.

2. Materials and methods

2.1. Preparation of modified biochar, characterization

Pyrolysis process of PS was performed in pyrolytic reactor „APŽ-L-120-N; 03204“ (Elektron, Serbia), in argon flow (Ar flow rate 2 L/min, heating rate 10 oC/min) from room temperature until 500 ◦C. After attaining desired temperature, sample was heated at constant temperature during the next 90 min. The iron-modified plum stone biochar Fe-BPS was produced by the following procedure (Nguyen et al., 2019; Irfan et al., 2023): 10 g of BPS were mixed with (3 g as Fe) $FeCl_3 \cdot 6 H_2O$ in 0.5L DI distilled water and heated at 50 ◦C. After that, 0.05 M NaOH was added dropwise to the suspension to raise the pH to 11 and then stir it for 1 h. Fe-BPS was

washed with DI water to remove the organic residues until the pH reached 7. Fe-BPS is vacuum filtered and then dried overnight at 50°C in a hot air oven. SEM-EDS analysis was performed using a JEOL JSM-7001F field-emission scanning electron microscope coupled with an Oxford Instruments Xplore 15 energy dispersive X-ray spectrometer.

3. Results and Discussion

Fe-BPS has magnetic properties. The elemental composition and surface morphology of BPS and Fe-BPS were determined using SEM-EDX analysis (Fig.1). Smaller and larger cavities are observed on the surface of BPS. After the modification, new cracks are observed on the surface of Fe-BPS. Some particles formed a thin Fe oxide layer that covered the biochar surface. EDX revealed a considerable increase in iron content in Fe-BPS.

4. Conclusion

Since Fe-L-BC are easily modified for improved adsorption, oxidation, reduction, and catalytic activities, they have drawn interest as possible materials for wastewater treatment (Chon et al., 2024). Consequently, for particular wastewater categories, customised Fe-L-BC (Fe species and L-BC type) would be required. An application of Fe-BPS might reduce environmental pollution and support circular economy principles.

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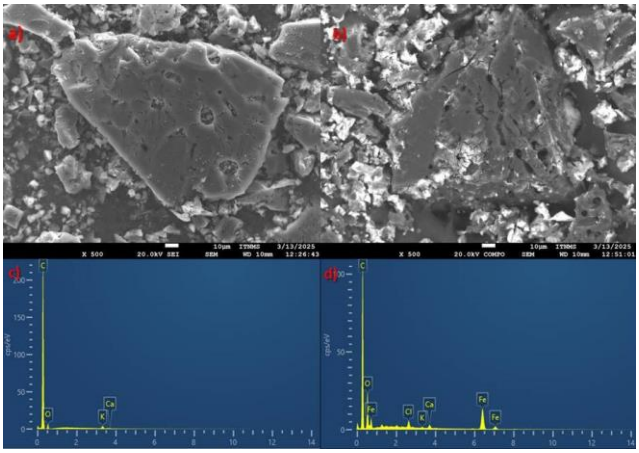

Figure 1. SEM images of BPS a) and Fe-BPS b) EDX spectra of BPS c) and Fe-BPS d)

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