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PREPARATION AND CHARACTERIZATION OF BAMBOO PEEL BIOCHAR BY USING SLOW PYROLYSIS FOR THE REMOVAL OF Cd AND Pb IN SOIL (BRASSICA CAMPESTRIS)

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Original research

A B S T R A C T

The experiment was conducted at the University of Haripur, nursery. There are two groups in the research heavy metals and biochar. Cadmium(Cd) and Lead (Pb) spiked with soil different concentrations of 0.5 ppm and 300 ppm in plastic pots after fifteen-day amendment with various application rates of biochar (2.5 mg/kg, 3.5 mg/kg, 5 mg/kg). Brassica campestris are harvested after 45 days for two days air dry and heated in an oven to remove the moisture for powdered form is obtained and weighs 0.5-gram roots and shoots separately and the sample is ready for digestion. The 5mg/kg application rate of biochar has enhanced nitrogen (N), potassium (K), and phosphorus (P). The bioaccumulation factor is higher than the bioaccumulation coefficient because biochar adsorbed the cadmium and lead on their surface and transfer to the shoot was reduced. Cadmium and Lead reduced the Brassica campestris roots and shoots and damaged the overall structure of the plant. The pH and EC play an important role in overall research of biochar-enhanced physical parameters compared to those without bamboo peel biochar. Brassica campestris is grown in the winter season in the presence of sunlight and a lot of water is needed it also can absorb in root and shoot parts of plants. The biochar is higher than cadmium and lead because it is rich in micro-nutrients and growth parameters. The FTIR result showed that the bamboo peel biochar decreased by 45% as compared to raw bamboo peel because it has a large surface area to immobilize Cd and Pb in the soils.

1. INTRODUCTION

Before *Brassica campestris* plants, Cd and Pb may accumulate in the soil and cause phytotoxic effects such asslow growth, chlorosis, and prevented root development (Mourato et al., 2015). These heavy metals cause oxidative damage in plants, which interferes with the functioning of cells and lowers the overall health of the plant (Mourato et al., 2015). Human health can be seriously endangered by consuming Brassica campestris polluted with Cd and Pb. Kidney disease, damage to the lungs, high blood pressure, reproduction issues, and cancer are all linked to consuming Cd (Iqbal et al., 2021; Rahman et al., 2023). Human cancer risk may be increased by exposure to Brassica campestris plants growing in Cd and Pb-contaminated soil, especially when contaminated vegetables are consumed (Ali et al., 2019). When contaminated vegetables are consumed,

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there is a danger to human health from chronic exposure to heavy metals like Pb and Cd found in Brassica campestris (Mahmood & Malik, 2014).

Pb and Cd availability and corrosion are significantly impacted by the amount of biochar in soil. Increased levels of Cd and Pb in pots without biochar in the soil commonly indicate greater toxicity and possible environmental pollution. By immobilizing Cd and Pb into less unstable forms, the use of biochar helps lower their bioavailability, lowering their toxicity and enhancing the quality of the soil (Zheng et al., 2023). Furthermore, it has been noted that biochar reduces the absorption of Cd in roots, indicating its importance in reducing the effects of heavy metals pollution (Zheng et al., 2023).

It has been found that carbon from bamboo enhances *Brassica campestris* development. Research indicates that adding bamboo biochar to soil enhances its characteristics, including its bulk density and porosity, which results in a better soil environment for root growth (Li et al., 2022). Furthermore, adding biochar to the soil increases the availability of nutrients and retains more water, which helps plants grow (Zheng et al., 2023).In contaminated soil, bamboo biochar is effective in immobilizing heavy metals, lowering their bioavailability, and reducing their negative effects on plant development and human health (Lathwal et al., 2023).

Brassica campestris has grown and accumulated more biomass as a result of the bamboo biochar dosages. The use of bamboo biochar increased soil fertility, which in turn promoted the growth of plants and biomass production. By enhancing the availability of nutrients, retained water, and root development in the soil, bamboo biochar created an environment that was favorable for *Brassica campestris* growth (Lestiyani et al., 2023). Bamboo is an eco-friendly method for producing biochar since it is a renewable resource that grows quickly. Because of its quick growth, natural resources may be frequently harvested without being destroyed. Bamboo has an abundance of carbon, which is necessary for producing biochar efficiently. Because of its high carbon concentration, biochar is stable and can hold carbon from the soil (Tsolis & Barouchas, 2023).

Because of its high adsorption capacity, bamboo biochar helps stabilize and retain heavy metals in contaminated soil, including Pb and Cd. It is well-known that using biochar, especially bamboo biochar, is an inexpensive and environmentally friendly method to treat heavy metal-contaminated soil, such as lead and mercury. Research shows that significant adsorption capabilities for Cu (II) and Cd(II) can be achieved by bamboo charcoal, especially bamboo biochar, which makes it useful for removing heavy metals from polluted environments(Abbas et al., 2019).

2. MATERIALS AND METHODS

2. 1. Materials

Bamboo peel carbonaceous material, samples of soil contaminated with Pb and Cd, calibration of the highest quality lead and cadmium procedures, De-ionized water, apparatus for analysis (e.g., atomic absorption spectrophotometer)(Alia et al., 2015).

2.2. Preparation of bamboo peel biochar

Collect bamboo peel and wash them thoroughly to remove dirt and impurities. Dry the bamboo peelsin an oven at a temperature of around 100°C.Carbonize the dried peels in a furnace at temperatures of 300°C in an oxygen-limited environment to produce biochar. Cool the biochar and crush it into fine particles for use in the experiment. The duration can vary depending on the desired quality of biochar peel. Once the pyrolysis process is complete, allow the biochar to cool down. Collect the resulting bamboo peel biochar. Slow pyrolysis is a time-consuming process, but it helps to produce high-quality biochar with enhanced carbon content.

2.3. Preparation of soil sample

Collect soil samples from established contaminated with Pb and Cd at known amounts. Particles should be removed from samples of soil and allowed to air dry. To maintain stability and remove large particles, sieve the soil. The soil samples should be contaminated with Cd and Pb levels at determined concentrations to achieve the required levels of contamination (Meier et al., 2017).

2.4. Experimental Setup

Determine the toxic soil sample into groups to be treated with varying amounts of biochar made from bamboo peels. Design up control groups such that they don't have any biochar added for comparison. To achieve a homogeneous dispersion, completely combine the biochar with the soil samples (Li et al., 2022).

2.5. Cd and Pb analysis

The soil samples for a specific period to allow for interaction between the biochar and contaminants.Extract the soil samples using analyze the atomic absorption spectrophotometer to measure the concentrations of Cd and Pb.Compare the concentrations of Cd and Pb in the soil samples before and after treatment with bamboo peel biochar to evaluate its efficacy for removal(Lu et al., 2017).

2.6. Measurement of bioaccumulation and biocofficients factor

Bioaccumulation Factor of the study plants was calculated by using the equation used by (Sharme et al., 1994).

A Bioaccumulation Factor (BAF)

$$= \frac{\text{Conc. of metal in Roots}}{\text{Conc. of metals in soil}}$$

Bioaccumulation coefficients were evaluated through the method adopted by (Schäfer et al. 2015).

$$\text{Bioaccumulation Coefficient (BAC)} = \frac{\text{Conc. of metal in shoots}}{\text{Conc. of metals in soil}}$$

2.7. Statistical analysis

To determine the significance of the outcomes and evaluate the effectiveness of bamboo peel biochar in removing Pb and Cd, use statistical analysis (ANOVA).

3. RESULTS AND DISCUSSION

3.1. FTIR comparison of raw bamboo and Bamboo biochar at 300^{0}C

Raw bamboo's FTIR spectra usually show distinctive peaks that correspond to the various functional groups that are found in the bamboo substance. The range in which these peaks are seen is 1800–1200 cm^{-1}(Afrin et al. 2014). To better understand the raw material for various uses, several investigations examine raw bamboo origins and their FTIR spectra (Ismail et al. 2022). Using FTIR spectroscopy, the solubility of bamboo particles in ionic solutions is also investigated (Cai et al., 2018) as shown in Figure 1.

Figure 1. FTIR of raw bamboo peel

Figure 2. FTIR of bamboo peel biochar

Bamboo biochar produced at 300°C demonstrates high yield, reaching up to 80%(Hernandez-Mena et al., 2014). Because of its characteristics, such as its pore structure and carbon content, this slow-pyrolysis-produced biochar has potential uses. Additionally, studies show that when properly changed, 300°C biochar might promote plant development (Suthar et al., 2018) as shown in Figure 2.

3.2. Impact of bamboo peel biochar on soil pH and EC

Biochar made from bamboo peel has a considerable effect on the EC and pH of soil. By functioning as a buffer and lowering the soil's acidity or alkalinity, the bamboo peel biochar may help increase the pH of the soil. It can also improve the availability of essential nutrients and soil fertility. Biochar made from bamboo peels has an electrical conductivity that helps control soils EC levels, which improves nutrient and water retention. In general, applying biochar derived from bamboo peels can help increase the manufacturing process and the health of the soil as shown in Figure 3.

The pH of the soil can frequently be altered with bamboo peel biochar. This increase in pH is favorable for increasing nutrient availability, promoting microbial growth, and reducing acidic soil temperatures (Yadav & Bag 2023).

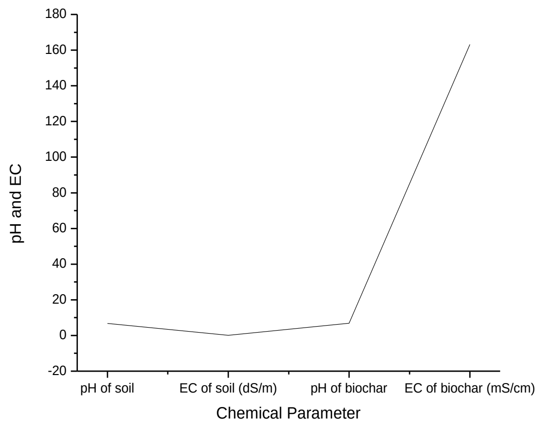

Figure 3. pH and EC chemical parameter

Furthermore, it has been demonstrated that adding biochar increases soil electrical conductivity, potentially as a result of changes to the soil's structure and chemical interactions brought about by the addition of biochar (Semida et al., 2019).

3.3. Impact of bamboo peel biochar on shoot in *Brassica campestris*

It's remarkable to observe that bamboo peel biochar affects Brassica campestris shoot development. By improving the soil's nutrient availability, the bamboo peel biochar may contribute to *Brassica campestris* producing its shoots more successfully. Additionally, it may enhance the soil's water retention and structure, which will help this plant species' healthy shoot growth even more. With all factors considered, *Brassica campestris* shoot growth and development can be favorably impacted by the utilization of bamboo peel biochar as shown in Figure 4 and 5.

Plant length, spike size, root moisture content, spike height, spike breadth, and shoot dry mass are among the indicators of shoot growth that can be enhanced through the use of bamboo biochar (Guo et al., 2022). It has been discovered that bamboo biochar reduces the toxicity of heavy metals in plants such as *Brassica campestris*. It enhances overall plant health by promoting growth and reducing the availability and transfer of contaminants in shoots. Bamboo biochar is a particular kind of biochar that helps reduce the presence of metals in soils and promotes better plant development.

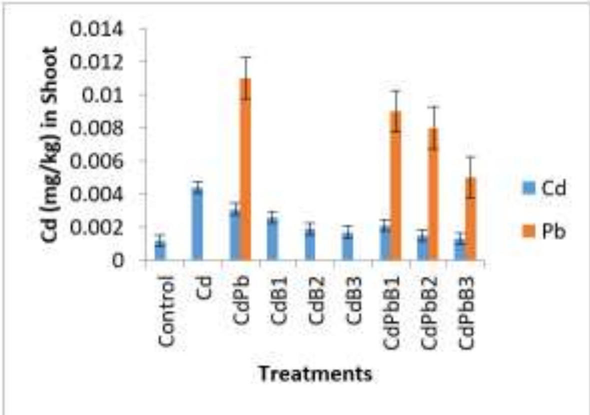

Figure 4. Cd (mg/kg) in Shoot

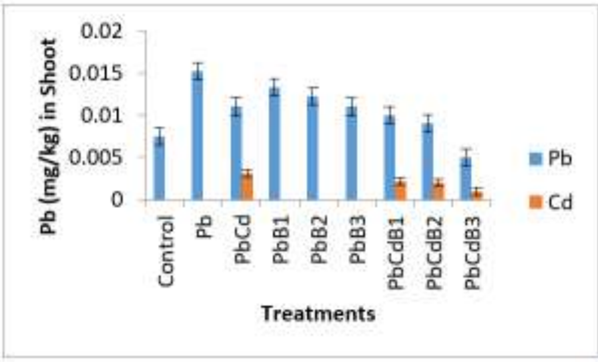

Figure 5. Pb (mg/kg) in Shoot

Because of the less hazardous environment this generates, *Brassica campestris* shoot development is indirectly enhanced (Ali et al., 2019).

3.4. Bioaccumulation factor of Cd and Pb

A significant problem to take into account is the the bioaccumulation of the elements Pb and Cd in bamboo biochar. It indicates bamboo biochar capacity to capture these contaminants from the surrounding air. It is essential to understand bamboo biochar bioaccumulation factor for Cd and Pb to evaluate its efficacy in treatment processes and possible environmental effects as shown in Figure 6 and 7.

Several variables affect the BAF of Pb and Cd, including plant species, surrounding factors, and soil conditions. Studies show that the potential for bioaccumulation of Cd and Pb varies. Under certain conditions, Cd indicates to have a larger bioaccumulation potential than Pb (Sahraoui et al., 2021). Other research, however, indicates that as Cadmium get accumulated more in the earth's surface biomass, Pb may be concentrated in root biomass.

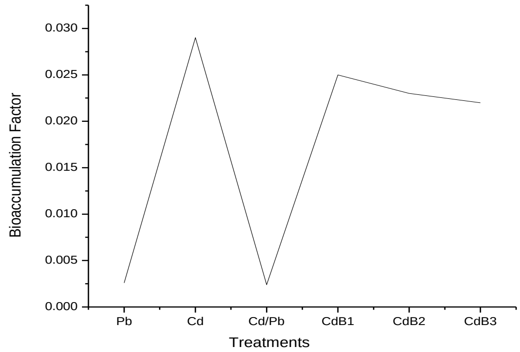

Figure 6. Bioaccumulation factor of Cd

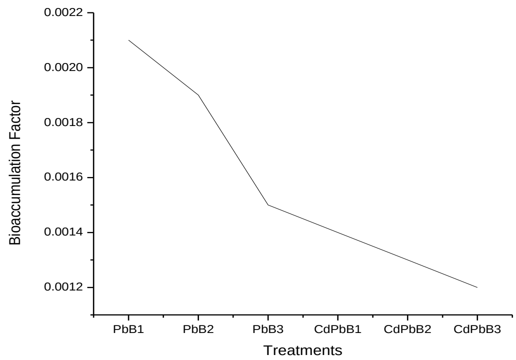

Figure 7. Bioaccumulation factor of Pb

Understanding these variables is essential for evaluating the environmental effects of contamination by heavy metals and preparing effective remediation methods (Messou et al., 2022).

3.5. Bioaccumulation coefficient of Cd and Pb

The capacity of bamboo charcoal to accumulate Pb and cadmium Cd is largely dependent on the metabolism coefficient of these heavy metals. Understanding the capacity with which bamboo biochar is capable of absorbing and holding onto lead and mercury from the environment is helpful for conservation efforts as shown in Figures 8 and 9.

Pb and Cd of the BAC vary based on the living thing and the surrounding environment. The biological concentration-to-environment ratio, or BAC, indicates the amount of a certain metal present in an organism. Research has demonstrated that the BAC levels for Cd and Pb vary among species. The plant Fucus vesiculosus, for example, showed various bio concentration variables such as Pb and Cd. Likewise, the BAC values of green leafy vegetables increased for copper zinc, lead, cadmium, chrome, and Nickel (Henriques et al., 2017). Analyzing these values is crucial in evaluating the potential hazards of heavy metals build-up in living things and environments (Medyńska-Juraszek et al., 2020).

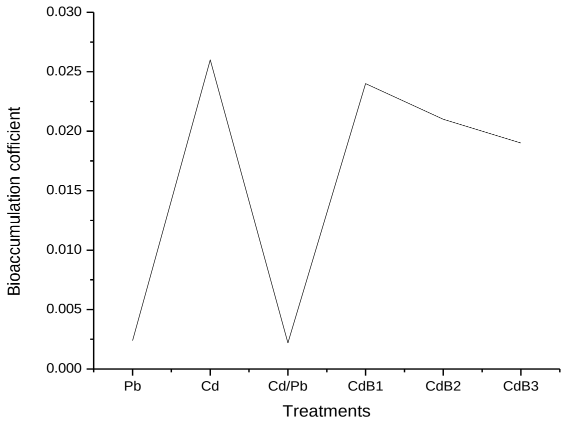

Figure 8. Bioaccumulation coefficient of Cd

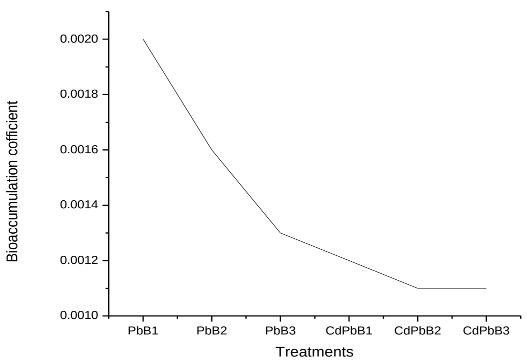

Figure 9. Bioaccumulation coefficient of Pb

3.6.Nutritional value in*Brassica campestris*

Brassica campestris has an extremely high nutritional value. Nutrients such as minerals, antioxidants, and vitamins are abundant in this food. There are several health benefits when consuming *Brassica campestris*, including increased immunity, improved digestion, and support for general well-being. When included in a nutritious diet, it provides nutrition (Table 1).

More commonly referred to as field mustard or field mustard, Brassica campestris is a very nutritious food that includes important elements including K, P, and N. These nutrients are essential to the growth, development, and general well-being of the plant. Nitrogen is a fundamental constituent of protein and chlorophyll, which is necessary for the growth and photosynthesis of plants (Saini et al., 2020). energy use transmission, the synthesis of DNA, and the growth of cell membranes all require phosphorus (Hedges & Lister, 2006).

Table 1. Nutritional parameter of Cd and Pb with bamboo peel biochar (*Brassica campestris*)

Nutritional Parameter (Mean)	N (mg/kg) in shoots	P (mg/kg) in shoots	K (mg/kg) in shoots
Control	0.076333	0.537366667	0.04
Cd	0.057667	0.5887	0.032
Pb	0.07	0.613233333	0.033
Cd Pb	0.0598	0.501	0.030666667
Cd B1	0.188333	1.540333333	0.201
Cd B2	0.107	1.493333333	0.221
Cd B3	0.107667	1.507	0.131333
Pb B1	0.159333	1.501666667	0.113666667
Pb B2	0.144	1.306333333	0.125333333
Pb B3	0.152667	1.529333333	0.114
Cd Pb B1	0.168	1.431333333	0.076333333
Cd Pb B2	0.147333	1.402333333	0.116666667
Cd Pb B3	0.147333	1.438666667	0.066333333

K plays a crucial role in plant development, capacity for stress, and disease resistance through its activation of enzymes, oxygen regulation, and water absorption (Sharma et al., 1994).

4. CONCLUSION

In conclusion, the use of bamboo peel biochar shows promise as an effective means of removing cadmium (Cd) and lead (Pb) from contaminated soil. Our study found that the application of bamboo peel biochar resulted in a significant reduction in the concentrations of Cd and Pb in soil samples. This suggests that bamboo peel biochar has the potential to be used as a sustainable and environmentally friendly solution for soil remediation in areas affected by heavy metal contamination.

The efficacy of bamboo peel biochar was likely due to its high surface area and porous structure, which can adsorb and immobilize heavy metal ions. The results also suggest that the effectiveness of bamboo peel biochar may be influenced by factors such as biochar dosage, particle size, and contact time with soil. Further research is needed to optimize these factors and to assess the long-term stability and environmental impact of bamboo peel biochar in soil remediation applications.

Overall, our findings support the use of bamboo peel biochar as a viable option for the remediation of Cd and Pb-contaminated soils. Further studies are warranted to explore its potential use in field-scale applications and to evaluate its effectiveness under different soil and environmental conditions.

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