Lead(II) adsorption by biochar prepared from tanduk banana peels (Musa X Paradisiaca)

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Abstract. Processing organic waste for use in various sectors is one way to maintain zero-waste and preserve the environment. The banana plant is only a tropical fruit that bears fruit only once and leaves behind the stems, leaves, and banana peels. The use of banana peel as a lead adsorbent was conducted by processing banana peels into biochar. Biochar making a pyrolysis process where the temperature starts from 400°C, 450°C, and 500°C, produces 33.00%, 31.73%, and 29.07% biochar. The biochar moisture content was 12.26%, 11.13%, and 9.32%, while the ash content was 9.62%, 6.08%, and 4.64%, respectively. The ability of biochar to adsorb lead was measured by Atomic Adsorption Spectrophotometry (AAS) with various pH and biochar weight. The optimum adsorption of lead (II) obtained at pH 5 with an adsorption amount of 49.96 mg/g, and a biochar weight of 400 mg with an adsorption amount of 12.49 mg/g

1. Introduction
Banana (Musa paradisiaca) is a horticultural commodity included in the development of superior fruit in Indonesia. Indonesia is one of the largest producers because 50% of Asian banana production is produced in Indonesia. Therefore, banana has been designated as one of the national superior fruit commodities because it has high economic and nutritional value [1].

The increase in banana productivity is directly proportional to the rise in the amount of banana peel waste. After harvesting bananas, the peels, stems, and leaves of the banana (80%) become waste that must be processed to have more value [2]. One of them is by processing waste into biochar. Biochar can be made from organic waste containing lignocellulose, namely cellulose, hemicellulose, and lignin [3]. Plantain peels contain 12.06% cellulose, while kepok banana peels contain 18.71% cellulose [4]. Technically, biochar is produced by the thermal decomposition process technology of organic materials under limited oxygen supply conditions at <700°C) [5]. Biochar is a promising adsorbent and has been made from various ingredients, including banana peel of kepok [6], durian bark [7], zalacca seeds [8], cacao peel [9], red fruit [10], siam orange peel [11], and Lettuce plant [12] to adsorb mercury (Hg) [13], cadmium (Cd), lead (Pb), copper (Cu), zinc (Zn), [14].

This ponders measured the adsorption control of lead (Pb) with biochar made from squandering banana peels. The fundamental concept of adsorption with biochar is to utilize the pore structure of carbon to tie metal particles since the adsorption control is decided by the particles’ surface range and the pore measure[15]. The characteristics of carbon incorporate its physical properties, to be specific adsorption control, add up to surface region, molecule thickness, and viable degree. Whereas the chemical properties of the surface (surface and enacted location) much decide the event of the adsorption handle, which tends to tie particles that have comparable properties.
more effectively, the adsorption capacity of carbon depends on the surface zone; in the meantime, the measure of the pore distance across influences the adsorption prepare [16].

The portrayal of the fabricate and characterization of carbon from natural product peels of Kepok banana (Musa x paradisiaca) has been conducted. Moreover, it utilizes as adsorption of Pb (II) metal particles depicted in this consider.

2. Research method

2.1 Biochar preparation

Tanduk banana peel was cut into little pieces and after that washed using clean water and dried within the sun for 7 days. The dried banana peel was carbonated in a heater at 300ºC, 400ºC, and 500ºC for 2 hours. The biochar come about from tanduk banana peel was cooled in a desiccator. After that, the test was squashed with a mortar and pestle, at that point sieved with a 70-mesh strainer. Biochar from ruddy fruit’s peel is put away in a dry and fixed holder.

2.2 Biochar characterization

2.2.1 Estimation of water substance. Each weight of biochar from the horn banana fruit’s skin is 1 gram, dried within the broiler, and the settled esteem decided. The porcelain plate containing the test was dried in a stove at 105ºC for 3 hours, at that point cooled in a desiccator and weighed to choose the moistness substance.

2.2.2 Measurement of cinder substance. One gram of biochar from banana fruit peel is considered and put into a weighed porcelain dish, then the porcelain plate, which is filled with the sample, is put into the furnace, which has reached a temperature of 800ºC and left for 3 hours. The biochar, which has become ash, is cooled in a desiccator and weighed until it gets a constant weight.

2.2.3 Preparation of 100 ppm lead(II) standard solution. 0.159 grams of Pb (NO₃)₂ placed into a beaker, and then concentrated HNO₃ was added to the solution, at that point put in a 1000 mL volumetric carafe, and refined water included to check the restrain.

2.3 Estimation of Lead(II) adsorption based on varieties in pH

5 mL of 100 ppm Pb (II) solution was put into Erlenmeyer, then 45 mL of buffer solution pH 3, 4, 5, 6, 7 were added. Then add 0.1 gram of biochar from the banana fruit skin and cover with aluminum foil then shaker for 120 minutes. The blend is sifted utilizing the Whatman channel paper, and after that, the filtrate assimilation is measured using nuclear assimilation spectrophotometry (AAS).

2.4 Estimation of Lead(II) Adsorption based on biochar weight

100 mg, 200 mg, 300mg, 400mg, and 500 mg of biochar weighed. Each of it mixed with 45 mL of Lead(II) solution of 100 ppm, add 5 mL of optimum buffer solution, and then cover it with aluminum foil and shaker it for 120 minutes. At that point, sifted utilizing Whatman channel paper, the assimilation of the filtrate gotten was measured utilizing nuclear assimilation spectrophotometric (AAS).

3. Result and Discussion

3.1 Biochar Production and Characterization

Biochar is made by pyrolysis to produce carbon as the final product. The carbon produced from the incomplete combustion of cellulose from the banana fruit skin follows the general burning reaction:

\[ C_{\text{a}}H_{\text{b}}O_{\text{c}} + O_{\text{d}}(g) \rightarrow C(s) + CO(g) + H_2O(g) \]

Incomplete combustion will produce CO, H₂O, and C. At this stage, the organic material contained in banana peels will be degraded into carbon, and inorganic compounds will be converted into tar.
compounds [17]. The biochar shaped is at that point smashed with a mortar and pestle, then sieved using a 70-mesh sieve to produce a sufficient particle size of the adsorbent and have an optimal surface area. Adsorption productivity could be a work of the adsorbent surface zone where the adsorbent surface region, the more noteworthy the adsorbent’s capacity to adsorb an adsorbate [15].

### Table 1. Biochar Characterization

| Pyrolysis Temperature | Biochar Produced | Water Content | Ash Content |
|-----------------------|-----------------|---------------|-------------|
| 300 °C                | 32.00 %         | 12.26%        | 4.63%       |
| 400 °C                | 31.73 %         | 11.13%        | 6.07%       |
| 500 °C                | 29.07 %         | 9.32%         | 9.61%       |

The determination of yield aims to determine how much carbon can be produced from the banana peel sample. Table 1 shows that the creation of carbon decreases in the presence of an increased carbonation temperature because, at higher temperatures, more and more substances are evaporated besides carbon so that only carbon with higher purity is left [15]. The moisture content proves the high hygroscopic properties of biochar. The information in Table 1 appears that the biochar dampness substance of the horn banana peel has met the Indonesian National Standard, namely 15%. Based on the value of the water content obtained, it can be seen that the biochar from banana peels is hygroscopic and can adsorb other gases or liquids [9]. This water content indicates that the free and bound water content in the banana fruit skin’s biochar evaporates during the carbonation process.

The measurement of ash content aims to decide the metal oxide substance in biochar. Table 1 shows that the ash content obtained increases with increasing pyrolysis temperature and has met the charcoal quality standard set by the Indonesian National Standard (SNI), which could be a most extreme of 10%. The ash content is affected by temperature. The higher the weather, the more hydrocarbons that evaporate, which causes the mass fraction of silicates and minerals in the biochar to be more significant than the mass fraction of carbon so that the percentage of ash content also increases [18]. Ash content is the mineral residue left behind during the carbonation process because the components of the essential ingredients of biochar not only consist of carbon but also contain other minerals, including potassium, sodium, magnesium, and calcium. The elevated level of cinder delivered can diminish adsorption control since the biochar pores filled with metal minerals such as magnesium, calcium, potassium. This increase in ash content indicates a further oxidation process, especially in fine particles [19].

### 3.2 Impact of Biochar pH on Lead(II) Particle Adsorption

Assurance of the ideal pH in inquiring about lead particle adsorption by biochar from tanduk banana peel was carried out at different pH 3, 4, 5, 6, and 7. This pH assurance points to decide the ideal pH of the adsorption of Lead(II) particle arrangement by biochar, as appeared in Table 2.

### Table 2. Lead rate adsorbed based on biochar pH

| pH | C_0 (mg/L) | C_eq (mg/L) | C_e (mg/L) | % Pb(II) Adsorbed |
|----|------------|-------------|------------|-------------------|
| 3  | 100        | 0.2275      | 99.7725    | 99.77             |
| 4  | 100        | 0.1432      | 99.8568    | 99.85             |
| 5  | 100        | 0.0870      | 99.9130    | 99.91             |
| 6  | 100        | 0.6769      | 99.3231    | 99.32             |
| 7  | 100        | 0.6207      | 99.3793    | 99.37             |

Figure 3.1 appears that the lead particle adsorption is impacted by the pH of the arrangement, where at pH 3 to pH 5, there’s an increment in lead metal adsorption. At pH 6, the lead particle adsorption has diminished and once more rises to pH 7. The moo adsorption that happens at pH 3 and 4 is due to three possibilities. To be specific, there’s a competition between H⁺ and Pb²⁺ to connected with the biochar surface. The biochar surface is surrounded by H⁺, which can prevent Pb²⁺ from interacting with the
biochar surface, or the biochar surface becomes positively charged, resulting in rejection. Towards Pb\(^{2+}\), at lower pH, the ion will compete with metal ions, leading to minimal metal ion adsorption and denial between H\(^+\) ions and metal ions [20].

![Figure 1](image.png)

**Figure 1.** The relationship curve between the pH of the solution to the% Lead(II) adsorbed.

At pH 5, the adsorption that occurs is very high at 99.91%. In this condition, the dominant lead species is in the form of cations, and the amount of Pb\(^{2+}\) metal ions in the sample solution is not much. However, at pH 6, the adsorption decreased with the adsorption percentage of 99.32%, and at pH 7, the adsorption increased although not significant, namely 99.37%. At pH 6 and 7, the number of lead ions adsorbed tends to decrease. The reason for this is because Pb\(^{2+}\) ions at high pH can cause reactions between Pb\(^{2+}\) and OH\(^-\) to form Pb(OH)\(_2\) precipitates. These deposits will obstruct the adsorption process that is taking place.

Based on the data obtained, the optimum value for variations in the solution’s pH using biochar adsorbent from the banana peel is at pH 5, which can adsorb as much as 99.91% lead ions. In a pH range of 2 to 5.5, the adsorption increases, and when the pH exceeds 5.5, the adsorption capacity will decrease [21].

### 3.3 The Impact of Biochar Adsorbent Weight Variety on Lead (II) Particle Adsorption

Determination of the optimum adsorbent weight aims to determine the minimum amount of adsorbent that can be used for the adsorption process. The amount of adsorbent use is more efficient and cost-effective. The adsorbent weight determined in this study was carried out using 100 mg, 200 mg, 300 mg, 400 mg, and 500 mg of banana peel biochar adsorbent (Table 3).

| Adsorbent weight (mg) | pH | \(C_i\) (mg/L) | \(C_{eq}\) (mg/L) | \(C_b\) (mg/L) | % adsorbed |
|-----------------------|----|----------------|------------------|----------------|------------|
| 100                   | 5  | 100            | 0.2356           | 99.7644        | 99.76      |
| 200                   | 5  | 100            | 0.1450           | 99.8550        | 99.85      |
| 300                   | 5  | 100            | 0.0845           | 99.9155        | 99.91      |
| 400                   | 5  | 100            | 0.0241           | 99.9759        | 99.97      |
| 500                   | 5  | 100            | 0.0845           | 99.9155        | 99.91      |

Figure 2 shows that the weight affects the adsorption process where at a mass of 100 mg to 400 mg, there is an increase in adsorption of Lead(II) ions with an uptake percentage of 99.76% to 99.97%. Still, at a mass of 500 mg, the adsorption of Lead(II) ions experiences the decrease in the absorption percentage was 99.91%.

The adsorption increase occurred at 100 mg to 400 mg biochar weight. Based on this, it shows that the increasing number of adsorbents that interact with lead metal causes an increment within the adsorption, where the surface region of the adsorbent to absorb the metal increases so that the amount of metal that is bound will be more. Besides, it is also due to the influence of the density of the adsorbent.
cells in the solution, which results in a reasonably significant interaction between the dynamic center of the adsorbent cell wall and leads metal ions more and more active biochar to react. Whereas at 500 mg biochar weight, the adsorption of Lead(II) ions decreased. The decrease happens because the biochar has fully adsorbed the lead ions in the solution. In other words, the biochar has completely adsorbed the lead particles within the arrangement. The condition can also happen since the biochar’s surface is soaked with lead particles, so the biochar weight increment does not influence the metal particles by the biochar [22].

Based on the description above, it can be seen that the optimum adsorption of lead ions occurred at the weight of 400 mg biochar with an adsorption percentage of 99.97%. At a value of 400 mg, this is the saturation limit so that above this limit, the amount of adsorbent used is not efficient for absorption.

3.4 The maximum ion adsorption capacity of Lead(II) ion

In this study, Langmuir adsorption isotherm equation is used to be applied to the adsorption kinetics of lead ion by biochar. Langmuir adsorption isotherm developed a quantitative model that was applied to explain the adsorption events. Isotherm Model Langmuir defines that the maximum absorption capacity occurs due to the presence of a single layer (monolayer) of adsorbate on the adsorbent surface. The bond between the adsorbent and the adsorbed substance can occur chemically. The bond must be strong to prevent the adsorbed molecules’ movement on the adsorbent surface [23].

Based on the linearity curve in Figure 3 for Lead(II) uptake at pH variations, the correlation coefficient \( R^2 = 0.9999 \), absorption affinity \( k = 128.20 \) and maximum absorption capacity of 98.039 mg / g. The value means that 1 gram of biochar from tanduk banana peel can adsorb 98.039 mg of lead ion.
Figure 4. Langmuir linearity curve of Lead(II) uptake at weight variation.

Adsorption of Lead(II) on the variation of adsorbent weight in Figure 4 obtained a correlation coefficient of $R^2 = 1$, absorption affinity ($k$) = 250, and the maximum absorption capacity 101.01 mg / g. The value means that 1 gram of banana fruit skin biochar can adsorb 101.01 mg of lead ion.

4. Conclusion

The utilization of tanduk banana peels as adsorbent of Lead(II) ion has been done. Based on the study results, it can be concluded that making biochar from banana fruit peel is carried out at temperatures of 300°C, 400°C, 500°C for 2 hours. The results of the characterization of biochar at temperatures of 300°C, 400°C, and 500°C were the yields of 32.00%, 31.73%, and 29.07%, respectively. The water content was 12.26%, 11.13%, and 9.32%. The ash content was 4.63%, 6.07%, and 9.61%. The adsorption capacity of banana peel biochar against Lead(II) ions based on pH variations obtained optimum adsorption at pH 5 with the adsorption percentage of Lead(II) ions, which were absorbed by 99.91%. The adsorption capacity of banana peel biochar against Lead(II) ions based on the variation of biochar weight obtained optimum adsorption at a value of 400 mg, with the percentage of Lead(II) ion adsorption of 99.97%.

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