Surface morphology properties of biochar feedstock for soil amendment

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Abstract. A soil amendment is any material added to a soil to improve soil physical properties, support plant growth, improve soil fertility, organic matter, and water holding capacity, improve soil chemical and biological properties. Biochar is an organic amendment that improve soil fertility, mitigates climate change, and effectively keeps nutrients and available to plants. The chemical and physical properties of the biochar are important to know the suitable applications of biochar. The chemical and physical properties of the biochar are depending on the process and biomass feedstock. The research aimed to find out the kind of biomass feedstock for biochar as a soil amendment. The biochar feedstock was evaluated using scanning electron microscopy (SEM) and electron dispersive X-ray (EDX) analysis and can predicting possible uses for the biochars. The result showed that the biochar surface morphology properties were influenced by the feedstock types and pyrolysis temperature. The pores development and mineral contents in coconut shell biochar are the most suitable for soil amendment.

1. Introduction
Soil amendment is any material added in agriculture to improve soil quality, primarily physical properties as water retention, water infiltration, aeration, permeability, drainage and structure [1], support plant growth, organic matter, improving soil fertility, and water holding capacity [2]. Soil amendment can improve chemical, and biological quality of the soil. Soil amendment has two basic types that can improve soil fertility and stabilize site. The types are organic amendment and inorganic/mineral amendments. Organic amendments were derived from biomass and living beings as compost, animal manure, wood chips, biochar, husk, straw, geotextile, and sewage manure. Inorganic/mineral amendments are generally contained minerals associated with soil fertility [3].

Biochar as organic amendment is a carbon-rich solid product obtained by biomass pyrolysis [4]. Biochar can improve soil fertility and mitigate climate change [5], used in agriculture carbon sequestration and wastewater treatment [6], keep nutrients and available to plants [7]. To know the suitable biochar applications, it is very important to understanding the chemical and physical properties of the biochar. The biochar chemical and physical properties are depending on the process and biomass feedstock. The research aimed to find out the kind of biomass feedstock for biochar as a soil amendment. The biochar feedstock was evaluated using scanning electron microscopy (SEM) and electron dispersive
X-ray (EDX) analysis. Scanning electron microscopy (SEM) and electron dispersive X-ray (EDX) analysis can be predicting possible uses for the biochars.

2. Materials and methods

2.1. Research activity
The research was conducted from February to September 2021. The field experiment was carried out in Pineung Village, Banda Aceh, Indonesia. The biochar analysis was done at the Materials laboratory, Department of Physics, Universitas Syiah Kuala.

2.2. Biochar production
The raw materials or biomass feedstock of biochar were coconut shells, rice husks, and wood shavings waste (Figure 1). The raw materials to be used were dried before being burned in the biochar making equipment (Kon-Tiki). Each biomass feedstock was put into a Kon-Tiki (Figure 2). The raw material was then burned by giving a fire as a heat source to burn the raw material. After burned, the raw material/biomass feedstock will be added step by step until the Kon-Tiki full with the feedstock. The process of making biochar was around 1 hour and depend on the type of raw material/biomass feedstock. Before the biochar was removed, the temperature was measured using an infrared thermometer to determine the biochar temperature. After the time of process ends, the biochar was watered with water as soon as possible so that it does not burn to ashes. Furthermore, biochar that was still wet needs to be dried by sun until the water content of the biochar really drops.

2.3. Biochar characterization
The surface observation of biochars were analysed using scanning electron microscopy (SEM) and electron dispersive X-ray (EDX) analysis (Figure 3). For the biochar samples observation, we used the same SEM magnifications (100, 1000, and 5000). One of each spot sample was selected and observed to show microstructure variation. The observation of biochar morphology and surface are commonly used Scanning Electron Microscopy (SEM) and Energy Dispersive EDX (X-ray spectrometry) [8-10].
3. Results and discussion

3.1. Morphological analysis of biochar

The SEM analysis showed that the rice husk biochar had the best pores development and better-defined pores. Coconut shell biochar had larger developed pores and good defined pores. The wood shavings waste biochar had bigger pores than coconut shell biochar and rice husk biochar, less defined and less uniform compared with the pores developed by coconut shell biochar and rice husk biochar (Figure 4).

![Figure 4. SEM micrographs of biochar.](image)

The pores development in biochar is significant with increasing temperature and improvement in the biochar pore properties. The increasing pyrolysis temperature can increase the crystallinity of mineral components and highly ordered aromatic structures form in biochar [11-12].
3.2. Minerals content analysis by SEM and EDX

The minerals content in biochar as carbon, oxygen, and silicate were considered an important characteristic for biochar application as a soil amendment (Figure 5 and Table 1). Other nutrient elements for plant growth such as Na, K, and Ca in biochar are considered as important characteristic of biochar as soil amendment [13-15].

The highest mineral carbon composition was found in coconut shell biochar. The result is consistent with the carbon and oxygen composition (Table 1). Carbon and oxygen contents correlate with gasification temperature. The higher temperature increases carbon content and reduce oxygen in biochar (Table 1 and Table 2). The increasing gasification temperature will increase the volatilization of raw material light compounds. Reaction with the carbon during gasification will reduce the oxygen content of char and increase the mineral contents [14]. This result showed that coconut shell biochar is the most suitable for soil amendment.

![Figure 5. Electron dispersive X-ray (EDX) images of biochar.](image)

| Biochar                  | Carbon (C)    | Oxygen (O)  | Silicate (Si) |
|--------------------------|---------------|-------------|---------------|
|                          | Weight %      | Atomic %    | Weight %      | Atomic %    | Weight % | Atomic % |
| Coconut shell            | 95.3          | 96.4        | 4.7           | 3.6         | -        | -        |
| Rice husk                | 56.5          | 68.5        | 34.1          | 22.8        | 9.4      | 8.7      |
| Wood shavings waste      | 84.2          | 87.6        | 15.8          | 12.4        | -        | -        |

![Table 1. Percentage of minerals content in biochar by SEM and EDX analysis.](table)

| Biochar                  | Temperature (°C) | Duration (minute) | Production (kg) |
|--------------------------|------------------|-------------------|-----------------|
| Coconut shell            | 325.1 – 673.1    | 61                | 4.693           |
| Rice husk                | 114.7 – 393.2    | 321               | 1.968           |
| Wood shavings waste      | 167.4 – 371.5    | 133               | 0.377           |

![Table 2. Temperature and duration of biochar production.](table)
4. Conclusions
The biochar surface morphology properties were influenced by the feedstock types and pyrolysis temperature. The pores development and mineral contents in coconut shell biochar are the most suitable for soil amendment.

Acknowledgement
The Research and Community Service Institutions of Universitas Syiah Kuala funded this research under Lector Research fund with contract No. 172/UN11/SPK/PNBP/2021 on February 22, 2021.

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