The effect of biochar corn cobs and rice husks on the chemical properties of vertisol from Kupang Regency of East Nusa Tenggara

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Abstract. This study aims to determine the effect of corn cobs and rice husk biochar on Vertisol chemical properties from Kupang Regency, East Nusa Tenggara. This study used a completely randomized design with two factors and three replications. The first factor is the type of biochar which consists of biochar of corn cobs and rice husks. The second factor is the dose of biochar (% soil weight), consisting of 4 levels: 1.5%, 3%, 4.5%, and 6%, and incubated for two months. Chemical properties observed in this study included pH, C-organic, and soil cation exchange capacity (CEC). The results showed that giving biochar of corn cobs and rice husks did not significantly affect changes in soil chemical properties.

1. Introduction
Vertisol soil contains dominant montmorillonite minerals. Montmorillonite is a clay mineral consisting of three hydrated aluminum silicate structures, two sheets of tetrahedral silica, and one sheet of octahedral alumina [1]. Montmorillonite, the tetrahedral sheet, combines tetrahedral silica with Si atoms surrounded by oxygen ions at all four ends [1]. In contrast, for octahedral sheets, it is a combination of alumina octahedron. Octahedron alumina consists of Al atoms surrounded by hydroxy (aluminum, magnesium, iron, and other particles) [2].

One of the essential properties of montmorillonite is its swelling and shrinking properties, the levels of which are related to changes in groundwater content [3]. Expansion occurs for several reasons, partly due to water penetration into the clay crystal layer, which causes expansion in the crystal [4]. However, most of these occur due to water attraction into the colloids and ions adsorbed on the clay crystal [3]. While the shrinking process usually occurs during the dry season. Shrinkage is when the soil becomes cracked due to space or soil pores that are not filled with enough water [5].

Repairing Vertisol's physical properties, an effort can be made to provide a soil repairing agent, namely biochar [6]; biochar is a carbon-rich and porous material produced by heating organic materials under low oxygen conditions [7]. Sources of raw materials for biochar can be obtained from agricultural or forestry residues and agricultural waste. The most potential plant residue used as a raw material source for biochar is rice husks [7].

Biochar has properties that can be used as a soil amendment agent [6]. The important properties of biochar are its high and very porous surface area, low bulk density, good nutrient content, a stable and
resistant material to decomposition processes, a high cation exchange capacity, a neutral pH range, and a high carbon content [6].

Biochar generally contains N, P, and cations such as Ca, Mg, and K. Biochar derived from plant residues is usually deficient in N and P elements but rich in element C compared to biochar from animal waste [8]. The C content in biochar derived from plants increases with increasing pyrolysis temperature. In biochar from animal waste, the P, K, Ca, and Mg content decreases due to evaporation during pyrolysis at high temperatures [9].

In general, biochar is neutral to alkaline so that it can be used to neutralize acidic soils [6]. Biochar pH can range from acid to alkaline [10], where the increase in pH depends on the raw material and pyrolysis conditions [7]. Increasing pH and CaCO$_3$ values align with increasing pyrolysis temperature [9]. The pH value on biochar will run every time in line with oxidation at the soil surface [11].

Based on the description above, it is known that the raw material and the temperature greatly influence the quality of biochar during pyrolysis. Currently, biochar has been widely carried out both on a commercial scale that meets the standards for making biochar and a simple scale produced by farmers. Industrial-scale biochar production generates about 54% carbon from raw materials while using simple equipment. Only 30-40% carbon is found in biochar [12].

Biochar is an ameliorant because it improves soil's physical, chemical, and biological properties [13]. Biochar has been shown to reduce soil acidity, bulk density, nutrient leaching, greenhouse gas emissions, increase cation exchange capacity, efficient nutrient, and water use, and soil ability to habitat for microbes and fungi [7]. Biochar also directly adds several macronutrients (P, K, N, Ca, Mg) and micronutrients (Cu, Zn, Fe, Mn) to the soil, which are needed for sustainable agriculture [14]. Based on this description, research to determine the effect of giving biochar from corn cobs and rice husks on the chemical properties of vertisol soil from the Kupang Regency is deemed necessary.

2. Methods

2.1. Soil sampling location
Soil sampling was carried out in Oesao Village, East Kupang District, Kupang Regency at latitude S: 10.12566 and E: 123.81556 with an altitude of 51 m above sea level and is 36 km from Kupang City. Land in a flat to an undulating location with a 0-3% slope. Soil samples were taken from a depth of 0-20 cm and were distorted (disturbed sample).

2.2. Soil media preparation
The soil is mashed and filtered using a 2 mm sieve, then put into polybags weighing 1,500 g. The soil was mixed with biochar of rice husk and corn cobs at a dose according to treatment. The soil was incubated for two months, maintaining the moisture content at a level of 70% of field capacity.

2.3. Research design
This research is a factorial study using a completely randomized design and the LSD further test. The first factor is biochar, which consists of A1 = rice husk biochar and A2 = corn cob biochar. The second factor is the dosage factor of biochar, namely D1 = 1.5%, D1 = 3%, D3 = 4.6% and D4 = 6% of the weight of the soil. The research was repeated three times. Thus there were 24 experimental units.

2.4. Soil analysis
The analysis includes pH (H$_2$O) and C-organic matter using the Walkey and Black method and Cation Exchange Capacity.

3. Results

3.1. Soil properties
Based on the criteria for assessing soil chemical properties [15], the results of chemical analysis on biochar show that both types of biochar have a neutral pH. The analysis results showed that the soil textured clay up to 47%, pH 6, 7 or neutral, 3.21% organic C content, or moderate and high status. CEC 32.28 cmol (+) kg⁻¹C organic, which is very high, and CEC is very high. The results of the analysis show the soil properties in the land as follows (table 1).

**Table 1. Soils properties in the field.**

| Parameters                  | Soils properties |
|-----------------------------|------------------|
| Bulk density (g.cm⁻³)       | 1.20             |
| Sands (%)                   | 26               |
| Silt (%)                    | 27               |
| Clay (%)                    | 47               |
| Texture                     | Clay             |
| pH                          | 6.7              |
| C-organik (%)               | 3.21             |
| CEC (cmol (+).kg⁻¹)         | 32.28            |

3.2. Chemical properties of biochar

Making biochar is done using a rotary drum, where the chopped material is put into the drum then the combustion process is carried out for 5 hours. The results of chemical analysis on biochar show that both types of biochar have a neutral pH, very high organic C, and very high CEC. Biochar properties can be seen in table 2.

**Table 2. Biochar properties of corn cobs and rice husks.**

| Soil Properties | Biochar | Corn Cobs | Rice Husks |
|-----------------|---------|-----------|------------|
| pH (H20)        | 7.9     | 7.6       |            |
| C organic       | 32.41   | 36.52     |            |
| CEC(cmol(+).Kg⁻¹)| 47.16  | 45.32     |            |

3.3. Effect of corn cobs and rice husks biochar on changes in soil chemical properties

The statistical analysis results showed no differences between treatments for all the criteria for soil chemical properties during the two months of the incubation period. Analysis of soil chemical properties showed that incubation for two months in each treatment gave the following results: maintaining neutral soil pH, increasing soil organic C, and maintaining high CEC. Soil chemical properties are presented in table 3.

**Table 3. Soil chemical properties due to biochar application.**

| Treatment | pH | C (%) | CEC (cmol(+).Kg⁻¹) |
|-----------|----|-------|--------------------|
| J1        | 6.7| 3.46  | 29.58              |
| J2        | 6.7| 4.03  | 31.74              |
| J3        | 6.9| 3.98  | 28.63              |
| J4        | 6.9| 3.86  | 30.73              |
| S1        | 6.5| 3.26  | 30.52              |
| S2        | 6.8| 3.62  | 32.41              |
| S3        | 6.9| 3.82  | 29.63              |
| S4        | 6.8| 3.66  | 33.25              |
4. Discussion

4.1. Soil properties

4.1.1. Bulk density. The bulk Density value at the location of the soil sampling is 1.20 g.cm$^{-3}$. The bulk density value of mineral soils ranges from 1.0-0.7 gr cm$^{-3}$, while organic soils generally have a bulk density between 0.1-0.9 grams cm$^{-3}$ [16]. In soils with high clay content, bulk density is strongly influenced by soil moisture content and soil organic matter [17].

Bulk density is an indicator of soil density. The denser the soil, the higher the bulk density, the more difficult it is for water to pass through or penetrate the plant roots. More dense soils have a greater bulk density than similar but less dense soils. In general, the topsoil on mineral soils has a lower bulk density than the subsoil. The bulk density value of mineral soils ranges from 1.0-0.7 gr cm$^{-3}$, while organic soils generally have a bulk density between 0.1-0.9 grams cm$^{-3}$ [13].

4.1.2. Soil texture. The soil texture in the research location belongs to the clay texture class. The distribution of sand particles is around 26%, dust 27%, and clay 47%; this is consistent with the characteristic of Vertisol, which has 35-95% clay content [18]. Vertisols are characterized by high clay content, the high clay content of Vertisols can reach 73.23% in Jeneponto, South Sulawesi [19], 37-73% in Queensland Australia [20], and 49% in North Mexico [21].

4.1.3. Soil pH. Table 1 shows that the soil pH is around 6.7 or close to neutral (pH = 7). According toDebele [22], 61% of total distribution Vertisols in the world have a pH of 5.5 - 6.7, 21% have a pH ranging from 6.7 to 7.3, and the remaining 9% have a pH > 8 [22]. The factors contributing to the pH value of Vertisols are the presence of CaCO3 and the high content of calcium and magnesium elements in the soil profile [23].

4.1.4. Soil organic carbon. Soil organic carbon in the study area ranged from 3.21%. Previous studies have shown that most Vertisols in Jeneponto have a C-organic content exceeding 2.60% [18]. This study indicates that the organic C content in Vertisol is relatively high; this is because the expansion and shrinkage process in Vertisol can affect the mineralization of organic matter and microbial development [24]. The clay minerals in Vertisols increase the protection against organic matter due to the complex bonding between the organic matter and the clay [25] and the trapping of organic matter and microbes in the aggregate [26].

4.1.5. Cation exchange capacity. The CEC value at the location ranged from 32.28 cmol (+)/kg or moderate to high. The high and low CEC values depend on soil texture and organic matter content. Soils with high clay minerals will have a high CEC as well. Variations in CEC value and cation exchange are usually directly related to changes in water content that directly affect expanding shrinkage [27] and shrinkage of soil structure [28].

The research location is a land that is developed from limestone (CaCO3). The results of previous studies indicate that calcium is a contributor of 52 to 85%, magnesium ranges from 10 to 30%, and sodium ranges from 20% of the total cation exchange [24].

4.2. Chemical properties of biochar

The chemical properties analysis of biochar in table 2 shows that the highest C-organic content is found in biochar from rice husks. In contrast, the highest cation exchange capacity is found in biochar from corn cobs.

Biochar derived from plants is rich in organic C elements [29] and will increase the C-organic content when immersed in the soil [30, 31]. Apart from being rich in organic C, biochar is also able to increase the CEC value of soil [9, 32, 33]. The cation exchange capacity of biochar can reach 40 cmol g$^{-1}$ and increase after immersion in the soil due to oxidation effects [34]. Based on the chemical properties
criteria of the two types of biochar, the two types of biochar can be used as ameliorants to improve soil chemical properties because they have a neutral pH, organic C, and high CEC.

4.3. Effect of corn cobs and rice husks biochar on changes in soil chemical properties

4.3.1. Soil pH. The analysis showed that biochar maintained the soil pH value at around 6.7. The original soil condition has a pH of 6.7. In general, biochar has a pH ranging from neutral to alkaline [8] and will continue to increase with time due to the soil's oxidation process surface [11].

4.3.2. C-Organic. The biochar application increased the C value of soil organic from the initial soil properties 3.21% to 3.26%. Biochar derived from plants is rich in element C [8, 10]. Biochar application to soil increased soil organic C compared to control [30, 31]. The process of expanding and shrinking clay provides protection against organic matter from microorganism attacks [24]. This is what causes a decrease in the amount of C-organic at low water content. The clay minerals in Vertisol increase protection against organic matter due to the presence of complex bonds between organic matter and clay [25] and the trapping of organic matter and microbes in the aggregate [26].

4.3.3. Cation exchange capacity (CEC). Provision of rice husk and corn cobs biochar maintains the CEC value of the soil. The highest treatment was found in treatment S4 or at a dose of 6% by weight of the soil. Biochar has a high CEC so that if it is added to the soil, it will increase the number of CEC in the soil [9, 33, 34]. The biochar cation exchange capacity can reach 40 cmol g\(^{-1}\) and increase after immersion in the soil due to oxidation [34]. Previous research has shown that biochar can improve soil fertility, improve water-holding capacity, and increase CEC and soil pH [35]. Giving biochar also enhances the number of roots and the penetration power of the roots in the soil. Bruun et al. [36] reported that giving biochar 2% of soil weight significantly increased the total root density by 54% compared to controls who had root densities of around 33% and root penetration reaching a depth of 80 cm compared to controls which only reached 40 cm [36]. The ability of biochar to improve root development can increase a plant's ability to absorb nutrients and water.

5. Conclusion
The administration of corn cobs and rice husk biochar with 4 treatment levels did not significantly affect changes in soil chemical properties during the two months of the incubation period.

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