Effect of Pyrolysis Methods on Characteristics of Biochar from Young Coconut Waste as Ameliorant

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Abstract. Biochar is produced from the pyrolysis of organic matter (waste and biomass of agriculture) e.g young coconut waste (YC\textsubscript{W}). However, there is little information describing methods for producing biochar as an ameliorant for agriculture. Therefore, research is needed to determine the biochar characteristics of the Kon-Tiki, Drum, and Soil-Pit methods. This study was conducted using a Completely Randomized Design with three replications. The results of biochar production with methods significant on temperature (682°C), moisture (81.27 %), dry weight (2.09 kg) and yield ratio (20.87%) of biochar, and characteristics of biochar from YC\textsubscript{W} on pH (10.82 unit), liming potential (5.50% CaCO\textsubscript{3}), proximate analysis (moisture of 38.80%; volatile matter of 62.73%; ash of 19.50% and fixed carbon of 43.22%), CEC (457.13 mmol kg\textsuperscript{-1}), cation base (K of 356.14 and Na-exch of 131.28 mmol kg\textsuperscript{-1}), C\textsubscript{inorganic} (0.35 g kg\textsuperscript{-1}), and C\textsubscript{organic} (14.27 g kg\textsuperscript{-1}), with the recommended method of YC\textsubscript{W} biochar production using the Kon-Tiki method.

1. Introduction
Ameliorant is a soil enhancer that can be used to improve soil fertility using a variety of organic and inorganic components. Soil organic matter (SOM) is vital in determining soil fertility, it is necessary to increase SOM through the use of organic materials such as biochar in the amelioration. Biochar is made by a pyrolysis process that uses various biomass or other organic wastes with a high C/N ratio that is difficult to degrade so that biochar is an organic material that is stable in the soil. Young coconut waste has the potential to be utilized as biochar.

Young coconut waste (YC\textsubscript{W}) is organic waste from the manufacturing of young coconuts that are solely used for drinking or other culinary products that contain coconut water. Because of the high output and waste, efforts to use young coconut waste as an ameliorant in the form of biochar are required. According to Cerqueira et al [1], the cellulose, lignin, and hemicellulose content of young coconuts was 32.0%, 38.0%, and 0.25%, respectively, where the lignin and cellulose content of young plants varied and was only stable during ripening, whereas the lignin and cellulose content of young coconuts were found to vary between 37.2% and 43.9%.

The process of biochar production from biomass and trash has evolved through time using a variety of biochar production methods, which could be divided into three categories: traditional (Soil-Pit), conventional (Drum), and now the Kon-Tiki method. In general, these three approaches use the pyrolysis concept, which is a complex process in which organic components in biomass are transformed by heating at a specific temperature with or without oxygen [2]. The method used to make biochar has a significant impact on the ratio of biochar produced and the features of the resulting biochar. The soil-pit
method, according to Schmidt *et al* [3], is a traditional biochar production method used by ancient farmers. However, the effectiveness of the production process is harmed by fire, which is difficult to control and is harmed by the insulating dirt wall of the production pit, as well as the production pit's less homogenous temperature and less-than-optimal combustion. While the drum method is commonly used, it has some drawbacks, including the amount of CO₂ released and the low yield of charcoal produced. This is because fires in the production process must be kept to a minimum so that ash or undercooked results do not arise from extinguishing the flames too soon or adding too much biomass during the process [4].

As a result of the development of this system, the Kon-Tiki method was born. Kon-Tiki is a cutting-edge method for producing biochar with low CO₂ emissions. The steel Kon-Tiki has a top diameter of 1.50 m, a height of 0.90 m, and a wall slope of 63.5°, with a steep conical furnace form designed to ensure that the produced biochar is properly compacted and creates a consistent front surface for conveying oxygen [3]. Combustion takes place in stages in this process, with the biomass stacked vertically in the furnace and a continual fire. The purpose of this research is to study the differences in the method of the biochar production process and the characteristics of YCW.

2. Material and method
This research was carried out at the Laboratory of the Department of Soil Science, Faculty of Agriculture, Andalas University, and the Chemical Laboratory of Bogor Soil Research Institute from November 2019 to November 2020.

2.1 Experimental design
This study used a completely randomized design (CRD) consisting of three biochar production methods, namely A = Kon-Tiki method; B = Drum method, and C = Soil-Pit method with three replications.

2.2 Biochar production
YCw from green coconut (*Cocos nucifera* L.) is cut to a length of about 10*5 cm and dried for one week in the Greenhouse of the Faculty of Agriculture, Andalas University until it achieves a moisture content of 18.20%. Furthermore, the manufacturing process is carried out using a method that has been tested three times. Figure 1 shows the process of producing YCW biochar with a weight of up to 10 kg and the following technique specifications: (a) The Kon-Tiki method is made of conical steel which has a top diameter of 100 cm, a height of 90 cm, a wall slope of 63.50°, and a capacity of 827 liters; (b) The drum method is made from modified waste oil drums with a diameter of 58 cm, a height of 86 cm, and a capacity of 200 liters and (c) The Soil-Pit method is a conical hole dug in the ground which has a top diameter of 150 cm, a height of 90 cm, a wall slope of 63.50°, and a capacity of 827 liters.

![Figure 1: Production of biochar YCw (A) Kon-Tiki (B) Drum and (C) Soil-Pit Methods](image)

The results of each method's biochar production are watered to halt the combustion process and then dried in a 40°C oven for 2*24 hours to get a uniform water content in biochar. The next stage is to examine the properties of biochar in the laboratory [5,6,7].

2.3 Characteristics analysis of biochar and statistical analysis
The book Biochar: A Guide to Analytical Methods analyzes biochar properties [8,9]. The tools SPSS 16, Statistics 8®, and Microsoft Excel 2016 were used in the statistical study of biochar production and characteristics. It was subjected to an analysis of variance [ANOVA], and if the F test > F table, the treatment results of Duncan’s Test reveal a significant effect at the 5% level [*] and a highly significant effect at the 1% level [**].

3. Results and discussion

The temperature, moisture, dry weight, and yield ratios of YC₆ biochar are all significantly affected by YC₆ production methods, while the methods did not affect the length of YC₆ biochar duration of firing (Table 1). The results of YC₆ production in various types of methods used have a very significant effect on temperature, moisture, dry weight, and yield ratios of YC₆ biochar, but have a non-significant effect on the duration of the firing of YC₆ biochar.

![Table 1. Production of biochar from YC₆](image)

Table 1 shows that the highest temperature in the YC₆ biochar production process is the Drum method (701°C), compared to the Kon-Tiki (682°C) and Soil-Pit (519°C) methods. The structural and physicochemical features of biochar, such as surface area, pore architectures, surface functional groups, and elemental compositions, are affected by the pyrolysis temperature [10]. The release of volatiles at high temperatures can explain the effect of pyrolysis temperature on such properties. As a result, choosing an appropriate pyrolysis temperature involves a compromise between the mentioned surface and chemical qualities. To produce biochars, the pyrolysis temperature should be kept between 500 and 800°C [11].

The Drum, Soil-Pit, and Kon-Tiki techniques had the greatest biochar moisture, with 95.93%, 87.87%, and 81.27%, respectively. The moisture content of the biomass and the watering procedure throughout the manufacturing process impacts the high moisture of biochar, which seeks to end the burning process in a sustainable manner and prevent the charcoal from converting into ash. Biomass sources besides lignocelluloses can be used, such as sewage sludge, chicken litter, feces, bones, dairy manure, and so on [12]. The selection of optimal circumstances for generating a char with the necessary characteristics, therefore, necessitates quantitative and qualitative knowledge of dependencies and affecting variables [13,14].
Table 1 further reveals that the Kon-Tiki technique (2.09 kg; 20.87%), the drum method (1.84 kg; 18.36%), and the soil pit method had the greatest dry weight and yield of YC\textsubscript{W} biochar ratio (1.71 kg; 17.11%). This is impacted by the lignin, hemicellulose, and cellulose content of YC\textsubscript{W}, which has an impact on the yield of YC\textsubscript{W} biochar synthesis. In the manufacture of YC\textsubscript{W} biochar, the effective combustion time is 45 minutes, with the Kon-Tiki and Drum techniques taking 41.0 and 41.7 minutes, respectively. In the Soil-Pit technique, the longest burning period in the formation of YC\textsubscript{W} biochar is 45.3 minutes. Oil (a combination of hydrocarbons), synthetic gas (mixed hydrocarbon gases), and charcoal are the end products of pyrolysis [15]. The proportions of these various products vary according to on temperature, pressure, and residence duration, among other factors [16]. Biochar production with Kon-Tiki methods significantly affects temperature (682°C), moisture (81.27 %), dry weight (2.09 kg), and yield ratio (20.87%) of biochar. The high yield ratio produced and the minimum amount of smoke (CO\textsubscript{2}) formed during the pyrolysis process became the basis for recommendations for biochar production of YC\textsubscript{W} biochar.

Figure 2. Effect of methods on (A) pH; (B) Electrical conductivity and (C) Liming potential of biochar from YC\textsubscript{W}
The effect of the biochar production method has a very significant effect on the pH value and liming potential (LP) of YC<sub>W</sub> biochar but does not have a significant effect on the electrical conductivity (EC) of YC<sub>W</sub> biochar (Figure 2). In Figure 2. A and C, it can be seen that the highest pH and LP values are in the Kon-Tiki and Drum methods of 10.82 units and 7.56% CaCO<sub>3</sub> respectively. While in Figure 2. B it can be seen that the EC values look the same in the three methods of 2.00 and 1.99 dS m<sup>-1</sup>. The pyrolysis temperature and pyrolysis process used to make biochar can change the characteristics [17]. The temperature of pyrolysis and the method used to make biochars with varied chemical and structural characteristics are important considerations. When the temperature of pyrolysis is raised, for example, nutrient availability varies dramatically [18,19].

The biochar production method has a very significant effect on the proximate analysis of YC<sub>W</sub> biochar, where the value of moisture, volatile matter (VM), and fixed carbon (FC) in the Kon-Tiki method is higher, respectively, by 38.80% 62.73% 43.22%, compared to other methods (Figure 3). We discovered that when the pyrolytic temperature increased, volatile matter decreased, which was verified by many experiments on different types of biomass [20]. The required reaction time during the re-polymerization of the biochar structure may be affected by the residence time interval selected. Longer residence times may encourage the development of condensed aromatic structures with many micro-, meso-, and macropores, resulting in a greater yield of fixed carbon and improved porosity [21,22]. The cleaving of volatile portions of the biomass after extended heat treatment results in the formation of more stable aromatic structures [23].

The biochar production method has a very significant effect on CEC and cation base (K and Na-exch) YC<sub>W</sub> biochar (Figure 3. B), where the highest value for the drum method is 731.04; 428.49 and 186.04 mmol kg<sup>-1</sup>, compared with other methods but did not have a significant effect on the cation base (Ca and Mg-exch) YC<sub>W</sub> biochar. Increases in biochar C, P, K, Ca, ash content, pH, and specific surface

**Figure 3.** Effect of methods on proximate analysis (A); CEC and cation bases (B) and C<sub>Inorganic</sub> and C<sub>Organic</sub> (C) of biochar from YC<sub>W</sub>
area (SSA) are generally observed with increasing pyrolysis temperature, while decreases in N, H, and O content are typically observed [13,24]. Because of partial degradation and the survival of acidic functional groups, biochar generated at lower temperatures tends to be more acidic [25]. Biochar made from organic-rich biomass is predicted to have a greater nutritional content, and the preferential breakdown of Ca and K-bonded components of biomass at higher pyrolytic temperatures (700–800°C) would impact final pH [26]. The biochar production method has a very significant effect on C inorganic and C organic biochar \( Y_{C_{w}} \) (Figure 3. C), where the highest value of inorganic C in the Kon-Tiki and Soil-Pit methods is 0.35 g kg\(^{-1} \), while the highest organic C value in the Drum method was 15.21 g kg\(^{-1} \). Greater pyrolysis temperatures resulted in a larger biochar surface area, higher pH, and higher percent C content [27].

Characteristics of biochar from \( Y_{C_{w}} \) on pH (10.82 unit), liming potential (5.50% CaCO\(_{3} \)), proximate analysis (moisture of 38.80%; volatile matter of 62.73%; ash of 19.50%, and fixed carbon of 43.22%). The ash and fixed carbon content in biochar can contribute various additional nutrients in the form of oxide such as P\(_{2}\)O\(_{5} \), K\(_{2}\)O, and others into the soil so that it has the potential to increase soil and plant productivity. CEC (457.13 mmol kg\(^{-1} \)), cation base (K of 356.14 and Na-exch of 131.28 mmol kg\(^{-1} \)), C\(_{\text{inorganic}} \) (0.35 g kg\(^{-1} \)), and C\(_{\text{organic}} \) (14.27 g kg\(^{-1} \)). The high CEC of biochar directly increases the CEC of the soil, especially in the exchange of nutrients such as K\(^{+} \), Ca\(^{2+} \), Mg\(^{2+} \), and Na\(^{+} \). The majority of variable-charge hydroxyl groups at biochar surfaces belong to organic acid functional moieties that can be broadly categorised into carboxylic, lactonic and phenolic groups. Biochar carboxylic groups are expected to be available for cation exchange, but they probably don’t contribute substantially to CEC–pH dependences, except in very acidic soils. In contrast, lactonic groups are expected both to contribute to cation exchange processes and to be predominantly responsible for CEC-pH dependences and phenolic groups to have a lesser contribution overall to the CEC and, at typical soil pH values, only a small contribution to the CEC–pH dependence [33]. Therefore, the increase in soil fertility as a result of increased cation retention by biochar may be advantageous only in sandy soils and low organic matter.

### 4. Conclusions

\( Y_{C_{w}} \) biochar is determined by the effect of the manufacturing technique. Biochar production with methods significantly affects temperature (682°C), moisture (81.27 %), dry weight (2.09 kg) and yield ratio (20.87%) of biochar, and characteristics of biochar from \( Y_{C_{w}} \) on pH (10.82 unit), liming potential (5.50% CaCO\(_{3} \)), proximate analysis (moisture of 38.80%; volatile matter of 62.73%; ash of 19.50% and fixed carbon of 43.22%), CEC (457.13 mmol kg\(^{-1} \)), cation base (K of 356.14 and Na-exch of 131.28 mmol kg\(^{-1} \)), C\(_{\text{inorganic}} \) (0.35 g kg\(^{-1} \)), and C\(_{\text{organic}} \) (14.27 g kg\(^{-1} \)), with the recommended method of \( Y_{C_{w}} \) biochar production using the Kon-Tiki method.

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