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## Characteristics of biochar methods from bamboo as ameliorant

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**Abstract.** One of the qualities of biochar is determined by the method in biochar production. The development of methods is carried out in traditional (Soil-Pit), conventional (Drum), and modern ways (Kon-Tiki). Thus, it is necessary to study the characteristics of the method in biochar production. The treatment units were allocated based on a Completely Randomized Design with three replication. The results showed that the characteristics of bamboo biochar based on the method of biochar production has a significant on the duration of firing and moisture of biochar and chemical properties of bamboo biochar on pH, EC, liming potential, proximate analysis, CEC, and cation bases (K, Ca and Na-exch), C Inorganic and C Organic. The best method of production of biochar bamboo is modern ways (Kon-Tiki) because it has effective time in the process production, high moisture, yield ratio compared to other methods, and less smoke so it can reduce air pollution.

### 1. Introduction

Biochar is one of the ameliorant materials that help to enhance soil fertility and is also a result of the carbonization process in biomass power plants (PLTBm), where one of its positive features is that it is a resistant or long-lasting substance. Biochar is high in carbon, which is affected by the kind of biomass utilized, such as bamboo, as well as the manufacturing technique. The physicochemical characteristics of biochar are influenced by the biomass feedstock and different process factors, which directly define the application's purpose [1].

From agricultural biomass to forestry, Indonesia is abundant in natural resources, one of which is bamboo. Bamboo is one of the forest product commodities that have the potential to be used as a wood substitute since it is easy to cultivate and has a variety of useful properties. Bamboo has favorable physiological properties for community usage, particularly in agriculture and forestry [2]. As a result, bamboo may be utilized as one of the suggested raw materials for biochar synthesis in a variety of ways. Biochar manufacturing methods have evolved, and they may be divided into three categories: traditional (Soil-Pit), conventional (Drum), and currently employing the Kon-Tiki method. In general, all three techniques use the pyrolysis concept, which is a complicated process in which organic molecules in biomass are transformed by heating at a certain temperature with or without oxygen [3].



The technique used to make biochar has a significant impact on the ratio of biochar produced and the properties of the resultant biochar. The soil-pit method, according to Schmidt *et al.* [4], is a classic biochar production method used by ancient farmers. However, the efficacy 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 uniform temperature and less-than-optimal combustion. While the drum method is often used, it has numerous drawbacks, including the amount of CO<sub>2</sub> emitted and the low yield of charcoal produced. This is because fires in the manufacturing process must be kept to a minimum so that ash or undercooked products do not occur from extinguishing the flames too soon or adding too much biomass during the process [5]. As a result of the development of this approach, the Kon-Tiki method was born.

Kon-Tiki is a cutting-edge method for producing biochar with low CO<sub>2</sub> 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 resultant biochar is properly compacted and produces a constant front surface for transporting oxygen [4]. Combustion takes place in stages in this manner, with the biomass stacked vertically in the furnace and continuous fire. The goal of this study is to determine the yield and properties of biochar made from bamboo, which is effective, efficient, and ecologically friendly and may be utilized as an agricultural ameliorant.

## 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 Soil Research Institute, Bogor 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 the A = Kon-Tiki method; the B = Drum method, and the C = Soil-Pit method with three replications.

### 2.2 Biochar production

The preparation process for biochar production uses bamboo biomass from the type of bamboo betung (*Dendrocalamus asper*) and is cut to a length of approximately 30\*6 cm and dried for one week in the Greenhouse of the Faculty of Agriculture, Andalas University until it reaches moisture of 20.48%. Furthermore, the production process is carried out based on the method that has been carried out with three repetitions.

In the production process of bamboo biomass biochar used as much as 10 kg with the specifications of the method is as follows:

- a. 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.
- 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.
- c. 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.

The results of the production of biochar from each method are watered to stop the combustion process and then dried in a 40°C oven for 2\*24 hours with the aim of homogeneous biochar water content and the next step is to analyze the characteristics of biochar in the laboratory [6,7,8].

### 2.3 Characteristics analysis of biochar and Statistical Analysis

Analysis of biochar characteristics is the book biochar: a guide to analytical methods [9]. The statistical analysis has carried the software SPSS 16, Statistix 8®, and Microsoft Exel 2016 to production and characteristics of biochar. It submitted to an analysis of variance [ANOVA] and If the

F test > F table, then the treatment results show a significant effect at the 5% level [\*] and a very significant effect at the 1% level [\*\*] of Duncan's Test.

### 3. Results and discussion

Table 1 shows that the results of bamboo biochar production in various types of methods used have a very significant effect on moisture, dry weight, and yield ratios and have a significant effect on the duration of the firing of bamboo biochar, but have a non-significant effect on the average temperature of bamboo biochar.

The Kon-Tiki, Drum, and Soil-Pit techniques had the greatest biochar moisture, with 83.74 %, 75.30 %, and 52.63 %, respectively. The moisture content of the biomass and the watering procedure throughout the manufacturing process impacts the high humidity of biochar, which serves to stop the continuous combustion process and prevent the charcoal from converting to ash. The chemical composition of the feedstock determines the physical characteristics of biochar. The amount of cellulose, hemicellulose and lignin in the feedstock will have a big impact on the thermal breakdown processes, and hence on the morphology. The chemical composition of the feedstock influences the physical characteristics of biochar. The amount of cellulose, hemicellulose and lignin in the feedstock will have a big impact on the thermal breakdown processes, which will change the morphology. The thermal stability of these components is arranged in the following order: hemicellulose, cellulose, and lignin. In comparison to crop or grass-derived biochar, biochar with a greater lignin concentration has a more organized structure [10].

**Table 1.** Production of bamboo biochar

Methods	Moisture	Dry Weight	Duration of Firing	Temperature	Moisture	Dry Weight	Yield Ratio
	Feedstock				Biochar		
	%	Kg			Minute	°C	
Kon-Tiki	20.4 8	10	23.00 b	669.33	83.74 a	2.26 a	22.63 a
Drum			31.67 b	652.63	75.30 b	1.69 b	16.94 b
Soil-Pit			42.33 a	645.60	52.63 c	1.36 c	13.63 c
CV (%)	-	20.25	8.91	8.36		8.36	
Duncan's Test	-	*	ns	**		**	

Note : CV = Coefficient of variation

\*\* = Significant at the 0.01 level

\* = Significant at the 0.05 level, and

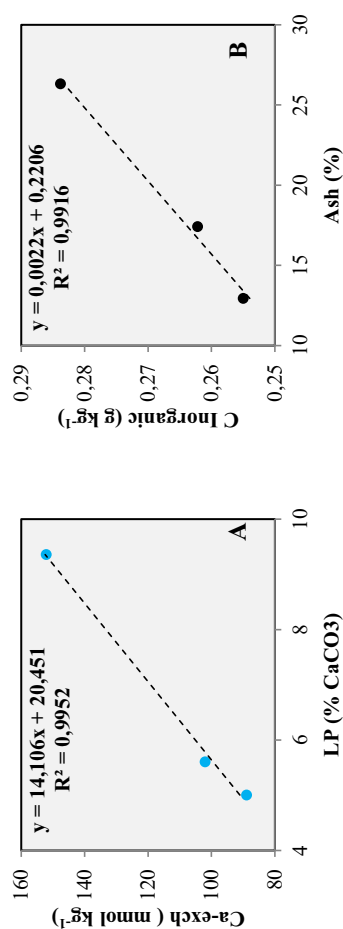
ns = Non-significant

The Kon-Tiki technique (2.26 kg; 22.63 %), the drum method (1.69 kg; 16.94 %), and the soil pit method (1.69 kg; 16.94 %) had the greatest dry weight and bamboo biochar yield ratio (1.36 kg; 13.63 %). This is controlled by the lignin, hemicellulose, and cellulose content of bamboo biomass, which has an impact on the output of bamboo biochar synthesis. Bamboo biomass contains lignin 26.25 percent, cellulose 47.50 percent, and hemicellulose 15.35 percent, making it difficult to convert to ash in the combustion process.

**Table 2.** Characteristics of biochar methods from bamboo

Methods	pH H <sub>2</sub> O	EC dS m <sup>-1</sup>	LP % CaCO <sub>3</sub>	Proximate Analysis			Cation Bases				C	
				Moisture	Volatile Matter	Ash	CEC	K	Ca	Mg	Na	Inorganic
				Unit	%	%	mmol kg <sup>-1</sup>	mmol kg <sup>-1</sup>	mmol kg <sup>-1</sup>	mmol kg <sup>-1</sup>	mmol kg <sup>-1</sup>	g kg <sup>-1</sup>
Kon-Tiki	9.98 b	1.97 b	5.00 c	17.33 b	35.60 c	12.94 c	430.33 b	356.81 <sup>a</sup>	88.93 c	13.16	138.20 a	0.25 c
Drum	10.16 a	2.00 a	9.36 a	37.93 a	44.18 b	17.41 b	342.02 c	321.61 <sup>b</sup>	152.12 a	16.17	5.62 c	0.26 b
Soil-Pit	9.82 c	1.22 c	5.61 b	7.57 c	57.99 a	26.32 a	600.42 a	244.02 <sup>c</sup>	101.97 b	17.77	113.04 b	0.28 a
CV (%)	0.26	0.07	1.99	3.04	1.56	7.86	5.05	3.90	4.50	16.18	2.84	1.32
Duncan's Test	**	**	**	**	**	**	**	**	**	ns	**	**

Note : EC = Electrical conductivity;  
 LP = Liming potential;  
 CEC = Cation exchange capacity;  
 CV = Coefficient of variation  
 \*\* = Significant at the 0.01 level;  
 \* = Significant at the 0.05 level; and  
 ns = Non-significant

**Figure 1.** Relationship of between on LP with Ca-exch (A) and Ash with C<sub>Inorganic</sub> from bamboo biochar

**Table 3.** Correlations matrix between chemical properties of biochar methods from bamboo

	pH H <sub>2</sub> O	Electrical Conductivity	Liming Potential	Proximate Analysis			Cation Bases					C Inorganic	C Organic	
				Moisture	Volatile Matter	Ash	Fixed Carbon	CEC	K	Ca	Mg			Na
pH H <sub>2</sub> O	1													
Electrical Conductivity	0.869	1												
Liming Potential	0.815	0.421	1											
Moisture	0.986	0.773	0.901	1										
Volatile Matter	-0.584	-0.909	-0.006	-0.439	1									
Ash	-0.628	-0.931	-0.062	-0.488	0.998*	1								
Fixed Carbon	-0.514	-0.872	0.077	-0.362	0.997	0.990	1							
CEC	-0.977	-0.954	-0.673	-0.927	0.743	0.779	0.685	1						
K	0.954	0.680	0.951	0.991	-0.314	-0.366	-0.233	-0.868	1					
Ca	0.774	0.358	<b>0.998*</b>	0.869	0.063	0.008	0.146	-0.621	0.928	1				
Mg	-0.309	-0.740	0.299	-0.144	0.953	0.934	0.975	0.504	-0.010	0.364	1			
Na	-0.784	-0.374	-0.999	-0.878	-0.046	0.010	-0.129	0.634	-0.934	-1.000	-0.348*	1		
C Inorganic	-0.697	-0.961	-0.153	-0.566	0.989	<b>0.996**</b>	0.973	0.833	-0.450	-0.084	0.898	0.101	1	
C Organic	0.958	0.974	0.616	0.897	-0.791	-0.824	-0.737	-0.997*	0.829	0.561	-0.567	-0.575	-0.872	1

Note : \*\* = Correlation is significant at the 0.01 level;

\* = Correlation is significant at the 0.05 level.

The efficacy of biochar production is demonstrated by the amount of time it takes to burn. Table 1 indicates that the Kon-Tiki and Drum techniques burn for 23.00 and 31.67 minutes, respectively, compared to 42.33 minutes for the Soil-Pit method. The design and media tools employed in each technique of biochar generation have an impact on this. According to them Schmidt *et al.* [4], we were close to constructing an improved Kon-Tiki kiln for the manufacture of high-quality biochar in huge numbers and at a very low cost based on these principles, which may represent a U-turn in the contemporary path of pyrolysis for farm-scale biochar production. The basic concept of Kon-Tiki art is to use pyrolysis gases as a cover gas, creating air exclusion for pyrolysis with the fire.

Table 1 demonstrates that the temperature utilized in the manufacture of bamboo biochar is effective at around 700°C. 669.33°C is the highest temperature utilized in the manufacture of biochar bamboo, whereas 645.60°C and 652.63°C are the lowest. The temperature in the pyrolysis process is an essential component in the biochar production process. Biochar is typically made at a low temperature or slow pyrolysis (400–700 °C) with a modest lean rate (less than 10°C minute<sup>-1</sup>) since carbon in biomass quickly decomposes into gas/ liquid products at high temperatures [11]. Biochar is created by a sequence of processes during the pyrolysis of feedstock, including isomerization, dehydration, decarboxylation, depolymerization, and charring [12]. The characteristics of bamboo biochar can be seen in Table 2, where the effect of the method in biochar production is very significant on the characteristics of the bamboo biochar produced such as pH, electrical conductivity (EC), liming potential, proximate analysis, cation exchange capacity (CEC), cation base (K, Ca, and Na), C inorganic and C organic.

The technique used in the manufacture of bamboo biochar appears to have a large impact on the pH, EC, and LP values of the biochar. In comparison to the Kon-Tiki technique, the drum method had the highest pH, EC, and LP values of 10.16 units, 2.00 dS m<sup>-1</sup>, and 9.36 % CaCO<sub>3</sub> correspondingly (Table 2). (9.93 units; 1.97 dS m<sup>-1</sup> and 5.00 percent ). Soil-Pit (9.82 units; 1.22 dS m<sup>-1</sup>; 5.61 dS m<sup>-1</sup>). The temperature of pyrolysis has a significant impact on biochar production, pH, CEC, pore architectures, and other physicochemical characteristics. The yield of biochar declines as the pyrolysis temperature rises, and this tendency is particularly noticeable for wood-derived biochars and temperatures between 300 and 500°C. The pH of biochar has increased somewhat. This is because, at higher temperatures, weak biochar bonds (such as the hydroxyl bond) are broken inside the biochar structure [13]. Although most biochars are alkaline, lower pyrolysis temperatures (e.g., 400°C) can generate biochar with a pH of 7.

The production method showed a very significant effect on the CEC value of bamboo biochar with a high value in the soil-pit method of 600.42 mmol kg<sup>-1</sup>, while the highest cation base for K in the Kon-Tiki method was 356.81 mmol kg<sup>-1</sup>; for Ca in the Drum method of 152.12 mmol kg<sup>-1</sup>, and for Na in the Kon-Tiki method of 138.20 mmol kg<sup>-1</sup>. However, it did not give a significant effect on the cation base (Mg-exch). As a result, choosing the right pyrolysis temperature is critical if biochar is to be used for soil pH mediation. The temperature of pyrolysis has an impact on morphological characteristics as well. The specific surface area of biochars grows dramatically as the pyrolysis temperature rises [14]. This rise is thought to be caused by the breakdown of aliphatic carboxyl and alkyl groups, as well as the exposure of lignin aromatic cores. However, at higher pyrolysis temperatures (i.e., > 700°C), the surface area and pore space of the resulting biochar tend to decrease. This is due to the opening of micropores. Various proximate characteristics will arise from different pyrolysis temperatures [14,15]. In general, when the temperature rises, the amount of volatile stuff in the atmosphere decreases. This is due to the emission of more labile forms of C (i.e. volatile matter) at higher temperatures [16].

Table 2 also shows that the effect of production has a significant impact on the proximate composition of bamboo biochar, with the highest moisture (37.93 percent) and the highest volatile matter (VM), ash, and fixed carbon (FC) (57.99%, 26.32%, and 31.67%, respectively) in the Drum method analysis. Biochar contains ash, volatile materials, and fixed carbon, according to a proximate study. Biochars made from methods have a wide range of proximate characteristics. Table 2 demonstrates that the biochar production technique has a substantial impact on the Inorganic C and

Organic C content of bamboo biochar, with the Soil-Pit method having the greatest Inorganic C content of 0.28 g kg<sup>-1</sup>. In the Drum technique, the maximum level of Organic C is 15.70 g kg<sup>-1</sup>. According to Wang *et al.* [10]; Li *et al.* [17] Ash content in biochar is highly dependent on the compositional chemistry of the initial feedstock and follows the order of crop residues > wood. This is because inorganic mineral components are mostly retained during pyrolysis, and higher feedstock ash content results in higher biochar ash content. Biochar's stability in environmental applications is essential because it is largely reliant on feedstock. It is well known that a higher lignin concentration leads to a higher aromatic carbon (C) content, which leads to greater stability [18].

In Table 3 it can be seen that the correlation between the characteristics of bamboo biochar has a very significant effect on the potential liming with a cation base (Ca-exch) of 0.998, if we connect it with a linear trendline, the linear equation is formed  $y = 14.106x + 20.451$ ;  $R^2 = 0.9952$  (Figure 1). The correlation between the characteristics of bamboo biochar is very significant for ash and inorganic C of 0.996 (Table 3), if we connect it with a linear trendline, the linear equation is formed  $y = 0.0022x + 0.2206$ ;  $R^2 = 0.9916$  (Figure 1).

#### 4. Conclusions

The characteristics of bamboo biochar based on the method of biochar production have a significant effect on the duration of firing and moisture of biochar and chemical properties of bamboo biochar on pH, EC, liming potential, proximate analysis, CEC, and cation bases (K, Ca and Na-exch), C Inorganic and C Organic. It is advised that the biochar production process employ the Kon-Tiki technique based on the findings of research that has been done to increase the potential of biochar in agricultural applications.

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