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| RESEARCH ARTICLE

Characterization Biochar Properties from Waste of Cassava, Sugarcane, and Coconut

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| ABSTRACT
Indonesia is an agricultural country in the tropics, so agricultural waste appears and becomes one of the problems in the agricultural sector. These organic materials had good potential used as feedstock for biochar. Biochar is a solid material that is formed by the thermal degradation of organic materials in an oxygen-limited environment. This study aimed to characterize the chemical composition and structure of biochar from Cassava pulp, Sugarcane baggase and coconut husk. Its characterization included Scanning electron microscopy (SEM), Fourier transforminfrared (FTIR) spectroscopy and chemical analysis. Biochar produced cassava pulp has the highest nutrient content, especially C, Ca, Mg, organic matter, ash, pH, but the lowest content of K, Na, Al Sugar care baggase biochar has the highest nutrient content of P, Na, S, Al, EC but lowest content of C, N, Ca, Mg, organic matter. Coconut husk biochar has the highest nutrient content of N, K but the lowest content of P.

| KEYWORDS

Biochar, Cassava pulp, sugarcane baggase, coconut husk, SEM, FTIR

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1. Introduction

Indonesia is an agricultural country in the tropics, which has the potential for a wide variety of cultivated plants. Agriculture is widely used as a livelihood by the people of Indonesia. There are many agricultural lands in Indonesia's territory. Along with this, agricultural waste appears and becomes one of the problems in the agricultural sector. Agricultural waste is part of the results of agricultural management that is left or not needed. Organic materials like cassava pell, sugarcane and coconut husk had a good potential used as raw materials for biochar. In 2017, Indonesian cassava production averaged 19,05 million cassavas, 2.23 million sugar cane, 15.5 billion coconuts per year, equal to 2,17 million tons of Cassava pulp, 892 thousand tons of sugarcane baggase and 31.8 million tons of coconut husk (Indonesian Center for Agricultural Research and Development, 2017). Therefore, these organic materials had good potential used as feedstock for biochar.

Biochar is a carbon product produced by thermal degradation of various organic materials under an oxygen-limited environment (Lehman, 2007). The biochar application potential for sequestering carbon in soil (Lehmann *et al*. 2006). Biochar as soil amandent have benefits for (*i*) enhancing soil fertility and agricultural productivity (Steiner *et al*.2007), (*ii*) improving water-use and nutrient efficiencies (Glaser *et al*. 2002), and (*iii*) mitigating N_2O emissions (Singh *et al*.2010).

Characterization of biochar can vary according to its properties, which are defined as biomass source and the variables related to the pyrolysis process, such as time, temperature and activation treatment (Gaskin *et al*. 2008; Novak *et al*. 2009; Chan and Xu 2009; Nguyen *et al*. 2010). Size and form of feedstock and product of pyrolysis effect to quality and potential uses for biochar product. The surface area of pyrolysis products depends on the temperature of the pyrolysis process. The low temperature of the pyrolysis process caused a hydrophobic biochar surface that can limit the capacity to store water in the soil. (Sohi *et al*., 2009).

This study aimed to characterize the chemical composition and structure of biochar from Cassava pulp, Sugarcane baggase and coconut husk. Its characterization included Scanning electron microscopy (SEM), Fourier transforminfrared (FTIR) spectroscopy and chemical analysis.

2. Material and Methods

2.1. Feedstocks preparation and Biochar Production.

The feedstocks to produced biochar in this study include; cassava pulp, sugarcane bagasse, coconut husk. Cassava pulp and coconut husk were collected at Sei Rampah; Sugarcane baggase was collected from sugarcane juicer seller at Medan, North Sumatra Province. The feedstock was initially cut into 8-10 cm long pieces and put in a pyrolysis drum that had high 89 cm and 56 cm in diameters. The heating was started using wood fuel, and the temperature fluctuated between 300 to 350 ^{o}C. After the pyrolysis process through 6-8 hours, the yield of biochar can be harvested, which is indicated by smoky black color chars. Then biochar was allowed to cool down to room temperature, and the samples were examined for their physical and chemical characteristics.

2.2. Physical and Chemical Properties of Biochar.

Physical analyses of biochar are SEM and FTIR. SEM was performed by using a Hitachi TM 3000 scanning electron microscope, and FTIR were recorded on FTIR Frontier Perkin Elmer Spectrometer at wavenumbers from 400 to 4,000 cm.

The chemical analyses of biochar are elemental analyses, organic matter, EC, ash and pH. Total C was determined using Walkey and Black method. Total P was read with a spectrophotometer, and K, Ca, Mg, and Na was measured using AAS. The pH was then measured with a pH-meter (Lutron), and EC was measured with EC-meter (Lutron).

3. Results and Discussion

3.1 FTIR Analysis

The infrared spectrum of the cassava pulp, sugarcane baggase and coconut husk biochar which were analyzed by FTIR, are shown in Fig 1, 2 and 3. Characterization of biochar samples using FTIR to detect functional groups of carbon, impurities, and water that can change the sequestration ability. FTIR data graph of three biochar shows a number of similarities amongst the functional groups present

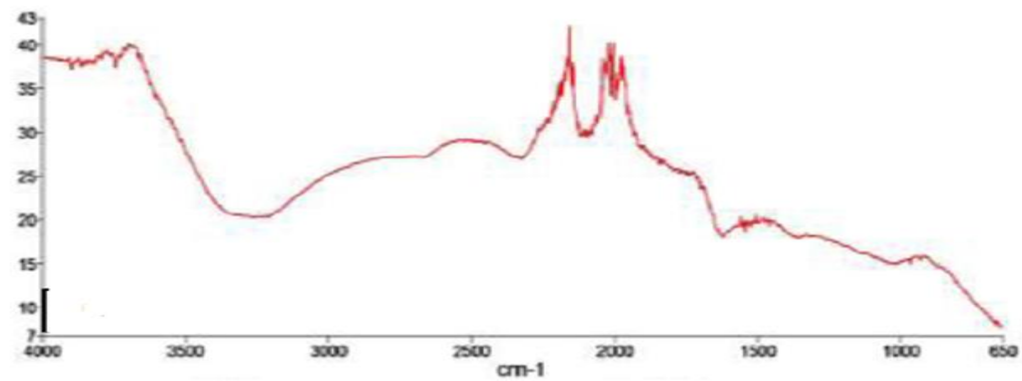

Figure 1. FTIR Spectra of Biochar Produced from Cassava Pulp

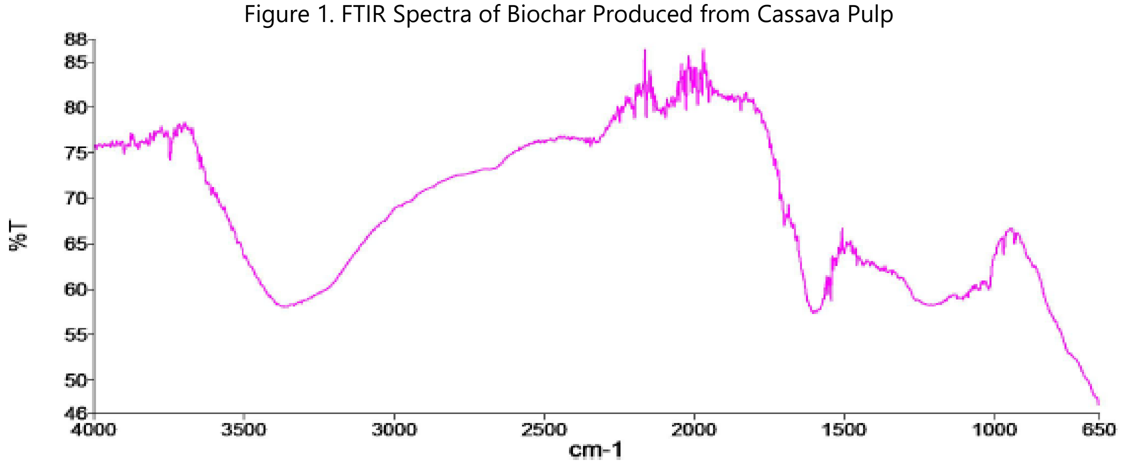

Figure 2. FTIR Spectra of Biochar Produced from Sugarcane Baggasse

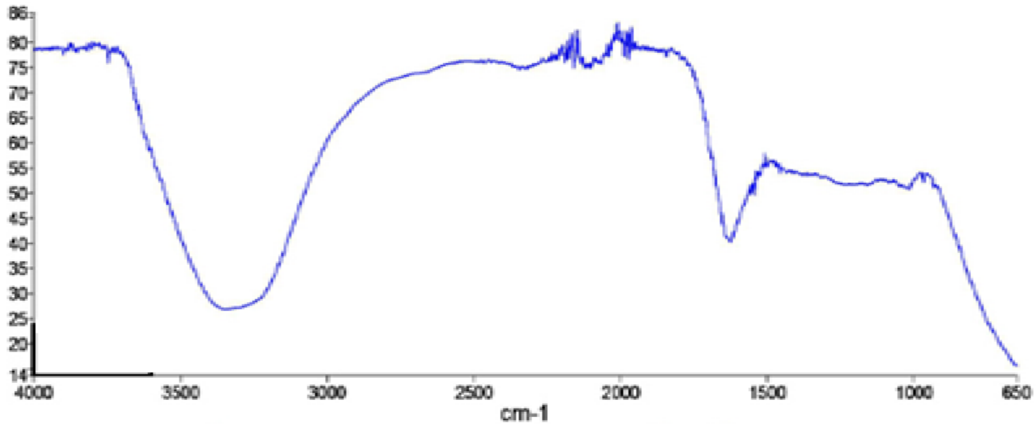

Figure 3. FTIR Spectra of Biochar Produced from Coconut Husk

Band assignments of biochar samples are summarized in Table 1, showing that each biochars contain different functional groups and structures. More information about the contents of the charcoal is discovered through the FTIR analysis. Oxygen and hydrogen are present, important for contaminant interaction in soil.

Data of wavenumbers (FTIR) from all biochar samples showed the most abundant chemical bonds are C ≡ N, C ≡ C, C = O, C – O. The difference between the three biochar samples is that only sugarcane biochar contains C=C. Functional group (C = N) and CH_2 are each not found in sugarcane biochar and Cassava pulp. The functional group (O-H) was heterogenic at the surface of biochar and can make interaction with soil by oxidation and hydrolysis.

Table 1. Main functional groups of the compounds in the Cassava Pulp Biochar, Sugarcane Baggase Biochar, and Coconut Husk Biochar

Cassava Pulp Biochar		Sugarcane Baggase Biochar		Coconut Husk Biochar	
Wave numbers (cm^{-1})	Infrared absorption (chemical bond)	Wave numbers (cm^{-1})	Infrared absorption (chemical bond)	Wave numbers (cm^{-1})	Infrared absorption (chemical bond)
3750 - 3361	O-H	3854 – 3367	O-H	3901 – 3263	O-H
2193 -2016	C ≡ C dan C ≡ N	2249 -2007	C ≡ C dan C ≡ N	2328 -2014	C ≡ C dan C ≡ N
1699	C = O	1844-1699	C = O	1999 - 1845	C = O
1623 - 1542	C = N dan C = O	1603 – 1555	C = C	1739 – 1555	C = N dan C = O
1066	C - O	1542 -966	CH_2 dan C – O	1542 -663	CH_2 dan C - O

Loss of acetyl ester groups due to pyrolysis can be followed by the loss of the bands at 1740 to 1730 cm^{-1} and 1230 cm^{-1}, which is associated with hemicellulose decomposition (Schwanninger *et al*., 2004; Stefke *et al*., 2008). Carbohydrates decomposition during pyrolysis can be followed by the loss of the bands at 1700 cm^{-1}, which indicate the formation of carboxylic and carbonylic groups (Sharma *et al.,* 2004).

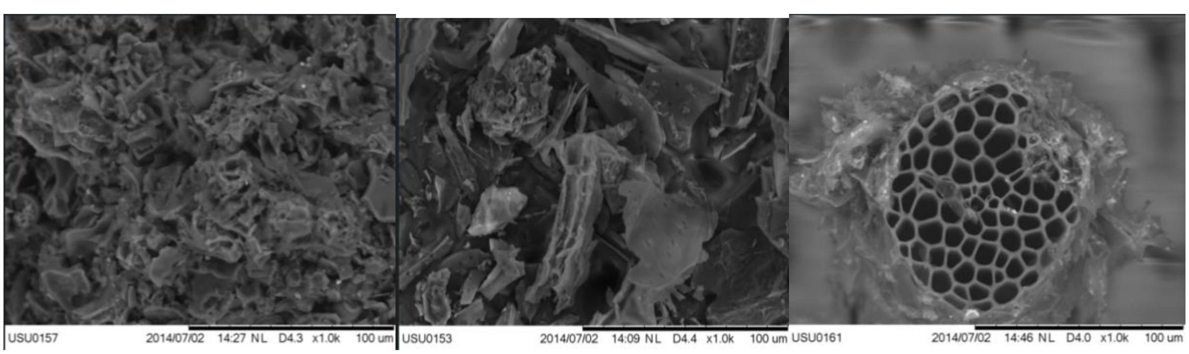

Figure 4. SEM of Biochar Produced from Cassava, Sugarcane and Coconut Husk

Scanning electron microscopy (SEM) is often used to describe the physical structure of biochar and the architecture of cellulosic plant material (Figure 4). Soil water-holding and adsorption capacity can be assumed to be influenced by the pore structure of biochar (Day *et al*., 2005; Ogawa *et al*., 2006; Yu *et al*., 2006).

3.2 Biochar characteristics

The properties of biochars produced from cassava pulp, sugarcane baggase and coconut husk are shown in Table 2. As shown in Table 2, each biochar has its own advantages regarding the nutrient content of the resulting product. Biochar made from cassava pulp has the highest nutrient content, especially C, Ca, Mg, organic matter, ash, pH, while sugarcare baggase biochar has the highest nutrient content of P, Na, S, Al, EC and coconut husk biochar has the highest nutrient content, namely N, K of the other two biochar. Biochar made from cassava pulp has the lowest nutrient content, especially K, Na, Al, while sugarcare baggase biochar has the lowest nutrient content of C, N, Ca, Mg, organic matter, and coconut husk biochar has the lowest nutrient content, namely P of the other two biochar.

The different properties of biochars seem to be associated with the nature of the chemical constituents in the feedstock biomass, like types of materials and charring conditions (Brown *et al*., 2006; Chan and Xu, 2009; Hammes et al. 2007). These are consistent with earlier studies (Gaskin *et al*. 2008; Novak *et al*. 2009), which found that biochar properties are strongly influenced by chemical composition and nutrient concentrations of feedstocks and pyrolysis temperature. Sing *et al.* (2010) research found that (*a*) plant-based biochars, made from eucalyptus wood and leaf materials, possessing high C, low contents of total N, P, K, S, Ca, Mg, Al, Na, and Cu, and low CEC and exchangeable cations values; and (*b*) manure-based biochars, made from poultry litter and cow manure, showing an opposite trend to the plant-based biochars for these properties.

Table 2. Biochar Properties From Cassava, Sugarcane and Coconut Waste Biochar

No	Component of Analysis	Biochar		
		Cassava Pulp	Sugarcane Baggase	Coconut Husk
1	Total C (%)	20.33	16,63	19.05
2	Total N (%)	1.09	1,04	1.74
3	Total P (%)	1.10	1,42	0.72
4	Total K (%)	0.93	1,48	2.37
5	Total Ca (%)	5.29	4,87	5.24
6	Total Na (%)	0.05	0,08	0.06
7	Total Mg (%)	0.58	0,41	0.55
9	Total S (%)	0.72	0,92	0.91
10	Total Al (%)	0.59	0,71	0.69
11	Organic Matter (%)	24.75	7,55	23.90
12	EC (μS/cm)	1.00	1,21	0.98
13	Ash (%)	15.24	14,95	9.85
14	pH	6.99	6,85	6.96

Tested by: UISU Laboratory, 2014

4. Conclusion

This paper identified a set of Characterization Biochar Properties From Waste of Cassava, Sugarcane, and Coconut of the case study. By integrating iochar produced cassava pulp has the highest nutrient content, especially C, Ca, Mg, organic matter, ash, pH but lowest content of K, Na, Al Sugarcare baggase biochar has the highest nutrient content of P, Na, S, Al, EC but lowest content of C, N, Ca, Mg, organic matter. Coconut husk biochar has the highest nutrient content of N, K but lowest content of P. Overall, our experiments indicate that Characterization Biochar Properties From Waste of Cassava, Sugarcane had greater effects on biochar performance than the production of those biochars.

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Conflicts of Interest: The authors declare no conflict of interest.

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