Characteristics of three biochar types with different pyrolysis time as ameliorant of peat soil

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ABSTRACT
Biochar is a pyrolysis product resulted from biomass burning in oxygen limited conditions and is expected to serve as soil ameliorant. In this paper a laboratory study was conducted using three types of biochar (palm empty fruit bunches (tankos), rice husk and peat from Bengkalis). The study was aimed at identifying the characteristics of each biochar burned at a temperature of 350°C with different pyrolysis time (3, 4 and 5 hours). The results of Fourier Transform Infrared Spectrometer (FTIR) show lower-layer Bengkalis peat (A2) has more functional group than husk burned for three hours and four hours (8 types and 12 types). The appearance of rice husk biochar surface pores pyrolyzed for 3 hours, with 1000x magnification is sturdy and orderly arranged, smaller macro and micro pore size (3.758 μm) than of husk biochar pyrolyzed for four hours (1.612 μm; 1.800 μm; 2.593 μm). In Bengkalis peat (A2), the macro and micro pores are sturdy and orderly arranged, the size of the pores is partially collapsed so that it is smaller and cannot be measured. Large and orderly arranged structure and form of pores will increase the role of biochar as ameliorant in the soil. The formation of intact pore makes biochar better in terms of bulk density, particle density, and aeration.

Key words: Ameliorant, Bengkalis peat, Biochar, FTIRSpectrophotometer, Pyrolysis, Rice husk.

INTRODUCTION
As an ecosystem, peat soil plays a role as carbon sink, water storage and release, and also can be used as agricultural land for growing crops, energy sources or extractable humic components. Peat fertility is determined by environmental conditions, relatively fertile in basin (topogenous) and coastal areas, and less fertile in peat that has formed dome. For the purpose of crop cultivation, it is necessary to improve peat fertility by adding ameliorant organics such as compost and manure. This activity is still not entirely satisfactory because the positive effect only takes place in a short span of time (only one to two growing seasons). Biochar, a material containing high carbon produced from burning process of organic biomass in an oxygen-limited condition (Lehman, 2007; Steiner, 2008). In addition, the higher the concentration of nutrients (N, P, K, Ca and Mg) in biochar, the more positive contribution of the organic conditioner to the improvement of soil nutrient availability. Biochar can also improve cation exchange capacity (CEC) of the soil, so as to reduce the risk of nutrients leaching, especially potassium and NH₄-N. A good quality of biochar is determined by raw materials and method of preparation. This study focuses on the effects of pyrolysis holding time (3, 4, and 5 hours) on the characteristics of biochar as peat ameliorant prepared from the three raw materials (rice husk, oil palm empty fruit bunches, Bengkalis peat).

MATERIALS AND METHODS
Site: Research conducted at the Laboratory of the Faculty of Agriculture, Universitas Gadjah Mada, from 19 November 2015 until 19 April 2016. This material and research tool used is rice husk, peat Bengkalis, oil palm empty fruit bunches (tankos), Scanning electron microscopy(SEM), Pyrolysis, FTIRSpectroscopy, Pyrolisator (retort), Muffle, exicator, sieve, digital scales, AAS, pH meter, Spectrophotometers, Flame photometer, test tube, percolation, washing waste, etc.

Methods: The implementation of the research consists of 2 activities, namely. 1. Chemical characterization of fresh organic matter and peat soil continued with preparation of materials and biochar manufacture at the Laboratory of

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Energy and Biomass of Faculty of Forestry Universitas Gadjah Mada (UGM). Method pH H₂O by using graphimetric method, Organic carbon with dry destruction, C/N ratio with Walkley-Black method, total N with Kjeldahl method, total P with Spectrophotometer, total K with flamephotometer / 1 N, total Ca and total Mg (ISRI, 2009). Composition of hemicellulose and lignin using graphimetric / H₂O₂ 72% (ISRI, 2009). Peat soil analysis was conducted at Soil Chemistry and Soil Fertility, Faculty of Agriculture, Tanjungpura University, Pontianak.

Manufacture of biochar from 3 types of raw materials and characteristics of biochar: Laboratory-scale research for characterizes the chemical properties of biochar tankos, coconut shells, and bengkalis peat that are in different pyrolysis at 350°C. The experiment is organized with 2 factors. The first factor was biochar type ie tankos, rice husk, bengkalis peat and second factor was pyrolysis duration ie 3 hours, 4 hours and 5 hours, so there were 9 kinds of biochar which analyzed functional group and pore size. The combustion is carried out at 350°C with a pyrolysis device. Functional cluster analysis was performed to determine the presence of functional groups in each biochar. Functional group analysis was conducted at the Organic Chemistry Laboratory, Faculty of Mathematics and Science, Gadjah Mada University using FTIR, IR SHIMADZU PRESTIGE 21. Further analysis of surface area, pore volume and pore size of biochar using Quanta Chrome / Gas Nitrogen: Quantachrome NovaWin2 Instruments Version 2.2. SEM analysis of 1000x enlargement is used for the appearance of pore surface of biochar by using Scanning electron magnetic (SEM) method of Evex mini SEM SX 3000 5-30 kv 30 30000x), conducted in Faculty of Mathematics and Natural Sciences, Scanning Electron Microscope Laboratory, Institut Teknologi Bandung.

RESULTS AND DISCUSSION

a. Chemical properties of organic materials prior to the research can be seen at Table 1.

The analysis was calculated based on Absolute Dry Weight (BKM) which characterized the condition of peat soil results on the ground, and there should be a correction factor in the form of Bulk Density (BD), which ranged between 0.05-0.2 g cm⁻³. Therefore, if expressed in BD, the results of the analysis should be multiplied by an average value of 0.15-0.20. (Maas, 1997)

Based on data from Table 2, peat soil generally has a relatively high level of acidity with a pH scale ranging from 2 to 3. The levels of peat soil acidity are closely correlated with the content of organic acids, namely humic acid and fulvic acid. The content of the low bases along with high value of the cation exchange capacity (CEC) leads to low availability of bases. The low content of bases in inland peat is closely correlated with the process of formation, which is highly influenced by rainwater (Leiwakabessy, 1979).

Biochar from Bengkalis peat and rice husk has high hemi cellulose and lignin content. This is very beneficial because it contains high carbon and low ash content, and not easily broken (Schmidt and Noack, 2000). Such Biochar can be directed as ameliorant for long-term recovery and of improvement of soil quality; while biochar from biomass such as straw, stem pith of sago, corn and cattle residue of high ash content with low carbon, is easily broken physically. The effect of giving them in the soil takes place faster in improving soil fertility and plant growth.

In regard to the high content of lignin Bengkalis peat and rice husk have a better potential as ameliorant than oil palm empty fruit bunched.

Biochar Functional Groups: The identification and interpretation of biochar functional groups (Sastromijojo 2007) used infrared spectroscopy has been presented in Fig 1, 2 and 3).

In Bengkalis peat (A1), there are 8 functional groups dominated by aromatic group (6 groups) and aliphatic group (2 groups). Meanwhile, of lower-layer Bengkalis peat (A2), there are 12 functional groups dominated by aromatic
group (8 groups) and aliphatic group (3 groups) and inorganic group (1 group) (Fig 1).

In rice husk biochar, the longer the pyrolysis, the lower the number of the functional groups. With the duration of 3 hours, the number of functional groups is 10 groups and dominated by aromatic group (7 types) followed by aliphatic group (1 type) and inorganic group (2 types). With 4 hours of pyrolysis, the number of functional groups is 10 consist 3 aliphatic groups, 5 aromatic groups and 2 inorganic groups. With 5 hours of pyrolysis, the number of functional group is 5 consisting of 2 aliphatic groups, 2 aromatic groups and 1 inorganic group. (Fig 2).

In tankos biochar, the longer the pyrolysis, the lower the number of the functional groups. With the duration of 3 hours, the number of functional groups is 10 which are dominated by inorganic group (4 types), aromatic group (3 types) and aliphatic group (3 types). With 4 hours of pyrolysis, the number of functional groups is 10 consisting of 3 aliphatic groups, 4 aromatic groups and 3 inorganic groups. With 5 hours of pyrolysis, the number of functional group is 9 consisting of 2 aliphatic groups, 4 aromatic groups and 3 inorganic groups (Fig 3).

From biochar produced, the biochar is selected based on the assumption that the organic materials contain high lignin and has the most functional group, namely husk 3 hours, husk 4 hours and lower-layer Bengkalis peat (A2).

High organic C content in biochar is suitable as ameliorant in order to improve long-term soil fertility. The addition of biochar with high organic C content as ameliorant to the soil indicates that this ameliorant is resistant to decomposition and stable in the soil for a long period of time; although biochar is resistant to decomposition, in the long run it may undergo reduction, oxidation and mineralization on the surface of biochar (Demirbas, 2004; Gaskin et al., 2008). This fact shows that the higher the micropores are formed, the higher the surface area of biochar will be. The higher surface area is considered as the cause of the increased negative charge on the surface of biochar. Such ameliorant characteristics when applied to the soil is expected to increase the adsorption complex, water retention, release of cations and anions of P in peat, which in turn increases the availability of P for plants.

The analysis of functional groups using FTIR (Fig 1-3) is aimed at identifying the content of biochar’s functional groups, which shows that biochar is mostly composed of aromatic groups. This is indicated by the high percentage of the area of the aromatic group in biochar. This composition is affected by the making process and raw materials. The raw materials of rice husk and Bengkalis peat with hemicelluloses content of 11.80% and 38.68% and lignin content of 18.4% and 50.23% are stronger to be converted into charcoal compared to ash content which is heated to a
pyrolysis temperature of 350°C (Demirbas, 2004; Gaskin et al., 2008). According to Lehmann and Joseph (2009), biomass with low cellulose and lignin content is mostly in the form of ash during the process of pyrolysis (oil palm empty fruit bunches and rice husk). The correlation between raw materials and pyrolysis temperature is the formation of micropore structure. Micropores are formed as the pyrolysis temperature increases.

**Biochar’s pore size:** The appearance of pore surface of three hours rice husk, four hours rice husk biochars using SEM analysis at a 1000 times magnification regarding the pore shape and pore size are presented in Fig 4 and 5.

The appearance of pore surface of the pyrolysis of husk biochar pyrolysis at 350°C for 3 hours is sturdy and orderly, larger macro and micro pores size (3.758 µm) compared to pyrolysis biochar for husk 4 hours (1.612 µm; 1.800 µm; 2.953 µm) the pores will enhance the role of biochar as ameliorant in the soil. According to Lehmann and Joseph (2009) during the formation of pores of biochar surface at a pyrolysis temperature of 250-500°C, the structure of the pores is not orderly arranged, the structure of the biochar pores start to be orderly arranged at a pyrolysis temperature of 800-2500 °C, but such pores are easily collapsed (Brown, 2009) so that the structure of pores is in total disorder. This will reduce the role of biochar as a soil ameliorant. Biochar of Bengkalis peat (A2) still has the potential to be used as ameliorant on peat soil because the pore is still intact and the structure is neat and orderly (Fig 6).

The appearance of pore surface of Bengkalis peat (A2) biochar; it can be seen that macro and micro pores with 1000x magnification are sturdy and orderly arranged, the pore size is partially collapsed so that the size is smaller and cannot be measured.

**CONCLUSION**

It can be concluded that of the three types of organic materials used, namely rice husk, oil palm empty fruit bunches (tankos) and Bengkalis peat, and pyrolyzed for 3 hours, 4 hours and 5 hours, at a temperature of 350°C, three types of biochar have better characteristics than the others if used as ameliorant in peat soil, namely husk 3 hours, husk 4 hours and lower-layer Bengkalis peat (A2). The results of FTIR Spectrometer show lower-layer Bengkalis peat (A2)
has more functional group than husk pyrolyzed for 3 hours and 4 hours (8 types and 12 types). The appearance of rice husk biochar surface pores pyrolyzed for 3 hours, with 1000x magnification is sturdy and orderly arranged, smaller macro and micro pore size (3.758 µm) than that of husk biochar pyrolyzed for 4 hours (1.612 µm; 1.800 µm, 2.593 µm). In Bengkalis peat A2, the macro and micro pores are sturdy and orderly arranged, the size of the pores is partially collapsed so that it is smaller and cannot be measured. Large and orderly arranged structure and form of pores will increase the role of biochar as ameliorant in the soil.

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REFERENCES


