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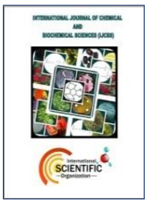

Characterization of oil palm trunk biochar as soil amendment produced by using drum retort kiln

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Abstract

This study was conducted to investigate characteristics of biochar derived oil palm trunk (OPT). Drum retort kiln was used for the pyrolysis process the oil palm trunk. The oil palm trunk biochar were characterized by physical-chemical analysis in order to the use of biochar as a soil amendment. The analytical methods applied for biochar characterization were proximate analysis and elemental analysis. Characterization of surface functional groups of the oil palm trunk biochar was carried out using the fourier transform infrared spectroscopy (FTIR), followed by the scanning electron microscope (SEM) determined the surface morphology of oil palm trunk. The oil palm trunk biochar presents suitable properties for its use as soil amendment for agricultural applications.

Keywords: Biochar, oil palm trunk, pyrolysis, soil amendment, characterization

Full length article

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1. Introduction

Biochar is a carbon-rich the product of thermal degradation of organic materials under an oxygen-depleted environment (i.e., pyrolysis), and is recently recognized as an emerging technology, and is distinguished from charcoal by its use as a soil amendment [1, 2, 3, 4]. However, soil amendment characteristics of biochar are varied with the pyrolysis temperature and feedstock source. Due to the issue of deforestation and the pressure to avoid use of native forest resources for production of char, there is increasing requirement for the use of renewable materials and development of additional sustainable processes. Oil palm trunk, a biomass that presents the property of fast growth, is an alternative to native or reforested wood.

Oil palm is the main commodity in Indonesia, the land area of oil palm plantation is increased from 11.26 million hectares in 2015 to 14.72 million hectares in 2019 [5]. Considering the life cycle of oil palm plant with about 25 years productive period, 4%/year rejuvenating rate, it can be estimated that there will be about 40.0 million tons/year of trunk waste production. In old oil palm plants, the trunk base has a bigger size. The trunk is usually covered with leaf sheath which will fall off when the plant reaches the age of ten years. In 2030, it was estimated that there would be a production of 54 million tons empty fruit bunch (EFB), 31 million tons mesocarp fiber (MF), 15 million tons palm kernel shell (PKS), 130 million tons pal oil mill effluent (POME), 115 million tons oil palm frond, and 59.7 million tons oil palm trunk (OPT) [6]. OPT, is mainly composted of hemicelluloses, cellulose and lignin that has a high potential in Indonesia for biochar applications. However, the application of OPT biomass for the production of biochars using pyrolysis processes is still a challenge as there are only a few studies that have investigated the pyrolysis of OPT [7][8][9]. This paper presents a research in order to verify its main characteristics of physical-chemical properties of oil palm trunk biochar produced by using drum retort kiln.

2. Materials and methods

2.1. Materials

OPT was collected from oil palm plantation PTPN II at Kelambir Lima, Deli Serdang District, Sumatera Utara Province, Indonesia. OPT was harvested at oil palm plantation out using mature stem samples of 20 years age, in cylinder log around 15 m length and 47 cm in diameter. OPT is fibrous, bulky, and has a high moisture content of about 76%. OPT was cutted into 35 x 15 x 10 cm (length x widht x height), the feedstock was dryed under the sun shine to reduce the moisture content about ± 15 % (wet basis) Figure 1(a).

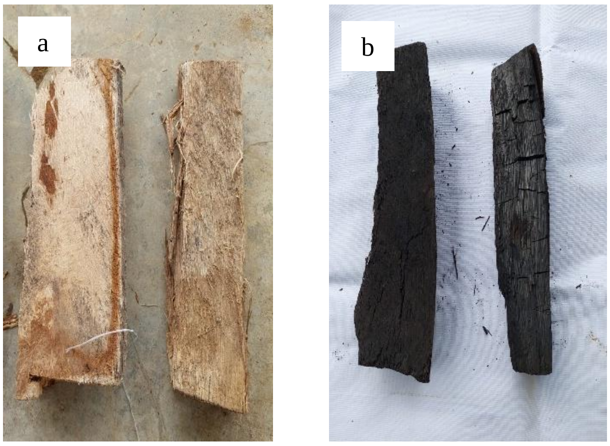

Figure 1: (a) OPT before pyrolysis and (b) OPT after pyrolysis

2.2. Pyrolysis

The pyrolysis was carried out by using a drum retort kiln, 200 litres drum reactor system, heated directly by burning wood in the kiln. In the center of the drum was holed from the top (cap) to the bottom (floor) and placed a pipe as the chimney. The pipe had holes at lower section about 10 cm from bottom of pipe, which would allow smoke to escape and the biomass heated up directly by burning wood in the kiln. The drum formed the necessary gas-tight insulating which carbonization could take place. The drum was sealed by heat isolation fabric (Figure 2). OPT biomass was pyrolysed by using drum retort kiln with ± 15 % moisture. OPT was carbonised under temperature 300 °C to 400 °C. The temperature reading was shown on digital infrared thermometer (BNQ, BN 1000) (Figure 3). The carbonisation was held for 7 hours and cooled down for 12 hours. Figure 3.

Fig. 2. Drum retort kiln

Fig. 3. The temperature reading

2.3. Physicochemical characterization

The OPT biochar (Figure 1(b)) were ground to particle size < 20 mess and representative samples were taken for analysis. The analytical methods applied for biochar characterization were proximate analysis and elemental analysis. The proximate analysis for moisture (Carbolite minimum free space oven), ash (Carbolite Horizontal Muffle Furnace), volatile contents (Ishizuka Denki Muffle Furnace) were determined according to ASTM D1762-84 standard method and fixed carbon was determined according to ASTM D3172-17. The elemental analysis (CHN) was performed in duplicate using an Elemental Analyser (Leco CHN 628 USA), and element S by using Leco S144-DR. The organic functional chemical groups of biochar were identified by using The Fourier Transform Infrared Spectroscopy (FTIR) Nicolet IS 10 ATR USA (38/IKA/MT). The chemical functional groups in biochar are vital to understanding the chemical characteristic of the biochar produced. The spectra were recorded with a 4 cm^{-1} resolution between wave numbers of 4000 and 500 cm^{-1}. The surface morphology of biochar was observed by the scanning electron microscope (SEM) (ZEISS EVO MA 10 Germany). The SEM was performed under high vacuum condition with accelerating voltage of 15 kV, and a secondary electron (SE2) detector with magnification of 500X.

3. Results and discussion

3.1. The proximate and elemental analysis

For the proximate and elemental analysis results of OPT biochar, it is shown Table 1. This table shows the proximate and elemental analysis results of the biochar obtained from OPT that produced by drum retort kiln.

Table 1: Properties of oil palm trunk biochar produced by drum retort kiln

Property	
Proximate Analysis (% dry basis)	
Moisture	3.17
Fixed Carbon	65.31
Volatile Matter	26.14
Ash	8.55
Elemental Analysis (% dry basis)	
C	71.83
H	4.14
N	0.04
S	0.03
O*	23,96
H/C	0.52

* Oxygen by difference [Oxygen=100-carbon(C)-hydrogen(H)-itrogen(N)-sulphur(S)]

As can be seen the moisture content, fixed carbon content, volatile matter, and ash content of the biochar were 3.17, 65.31, 26.14 and 8.55 wt.%, respectively. Based on the obtained results, it is observed that the moisture content of biochar samples was not zero after pyrolyzing, which was similar to previous studies [10,11]. The high fixed carbon content of biochar is favorable for soil amendment [10,12].

The high fixed carbon content of biochar also helps improve soil carbon sequestration that describes an increase in soil organic carbon content resulting from a change in land management practices [13]. However, the volatile matter of the biochar remained between 26.14 wt.%, indicating incomplete pyrolysis of the biomass under the investigated pyrolysis temperatures and time. This is because the biomass samples contained some lignin, which decomposes at high temperatures. The lower volatile matter led to higher fixed carbon content of biochar. The ash content of OPT was 8.55 wt.%. The ash in biochar is a non-volatile matter and non-combustible components. The increase in ash content of biochar resulted from the destructive volatilization of lignocellulose components at higher temperature [14].

The elemental composition of the biochar is seen that the C, H, N, S and O content of the biochar was 71.83, 4.14, 0.41, 0.33 and 14.74 wt.%, respectively. The results of ultimate analysis were consistent with the proximate analysis results as indicated by the relation between fixed carbon content and volatile matter, and carbon and hydrogen content. The carbon content of OPT was class 1 according to IBI biochar standard [15]. These results clearly showed that the pyrolysis of biomass produced biochar with a high carbon content and a low oxygen content, which is similar to the results from previous studies [10]. The nitrogen and sulfur content of biochar was relatively low. However, as compared to the raw biomass the biochar had higher nitrogen content. This is due to the combination effect of nitrogen into complex structures and nitrogen bond is also resistant to heat and not easily volatilized [14].

3.2. FTIR analysis result

The FTIR analysis was conducted to determine the chemical functional group in OPT biochar. The FTIR analysis result of the biochar obtained from pyrolysis of OPT is shown in Figure 4. This figure showed that there were many components present in the obtained results.

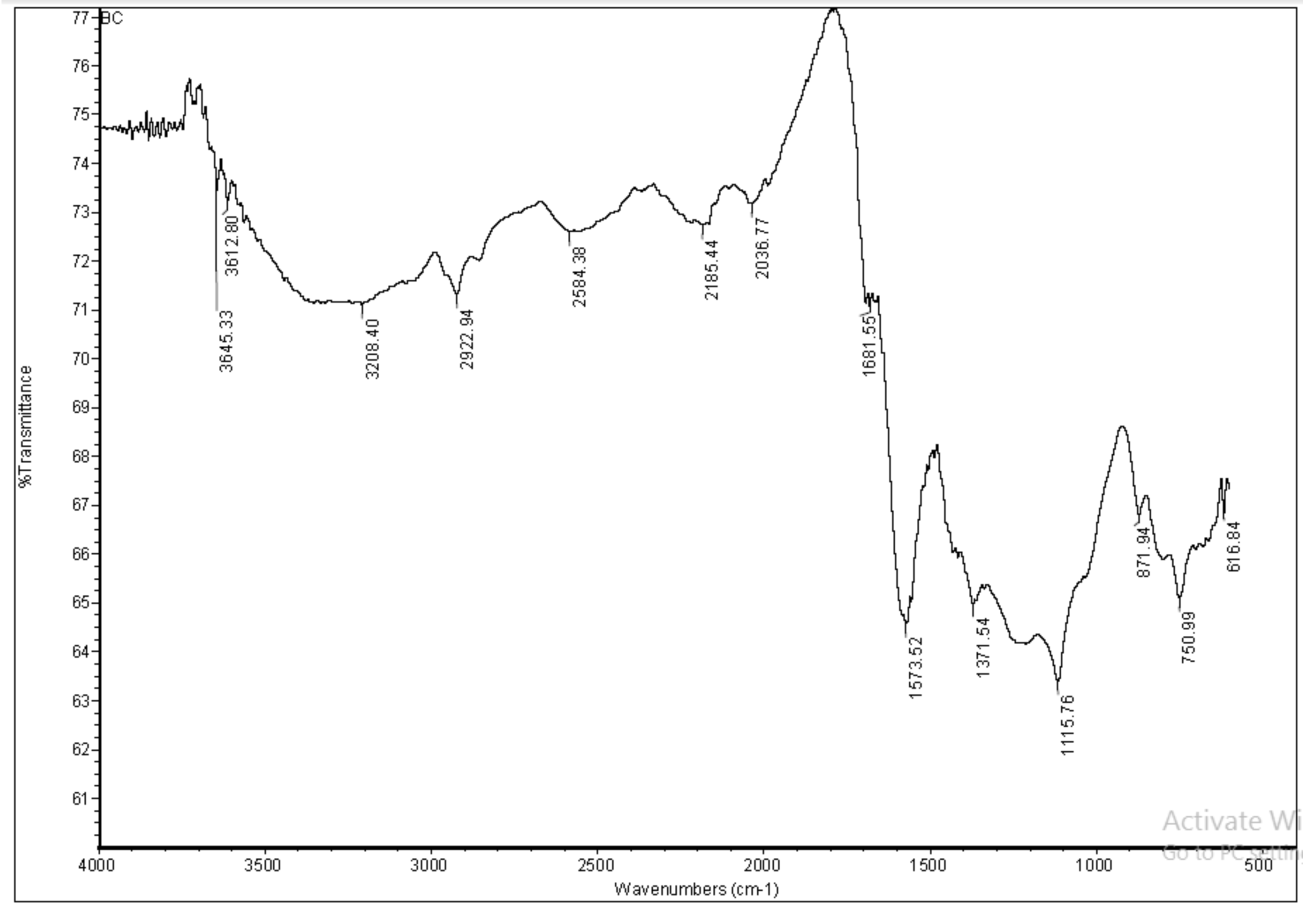

Figure 4. FTIR spectra of OPT biochar

The biochar still contained structures of carbon, hydrogen and oxygen, which mostly remained in the form of lignin. The result of FTIR was consistent with the proximate and ultimate analysis results of biochar discussed previously. The spectra of OPT biochar was not different because of the elemental composition of biochar was relatively similar as indicated by the content of carbon, hydrogen and oxygen. The peaks can be explained as follows. The first peak appeared at 3612-3645 cm^{-1} and was attributed to the stretching of OH group [16]. It is also attributed to acceleration in dehydration reaction of biomass. The small peaks at 3208 cm^{-1} were associated with the C-H stretching vibration of aliphatic and aromatics structures. The carboxylic O-H occurred in the range 2584-2922 cm^{-1} [17]. The observed peak at 1681 cm^{-1} is attributed the presence of carbonyl group in carbohydrate [18]. The aromatic C = C ring stretching vibration occurred at 1573 cm^{-1} [12]. At 1371 cm^{-1}, the peak is assigned mainly to stretching vibrations of aliphatic C–H and CH2 bending in biochar, respectively. The band in the range 1115 cm^{-1} represent the stretching of aromatic C–O and phenolic OH. The weak vibrations of C-H bond in aromatic and heteroaromatic compounds are visible as a band between 616-871 cm^{-1} [18][19].

3.3. Surface morphology

The morphology of biochar revealed pores created over the surface, with the size and shape of the pores clearly seen in Figure 5. This indicates that the carbonization process had led to the production and release of volatile matter from OPT; the remaining non-volatile components were then transformed into biochar with pores of different shapes and sizes observed on the surface. The surface feature of OPT biochar obtained from this study was similar to the result of [10] and [9]. The creation of large pores is caused by the volatilization of organic compounds or lignocellulosic components. When the pore was larger, the number of pores might be lower, leading to reduced surface area [17]. The large pores are caused by the progressive degradation of the lignocellulosic components including cellulose, hemicelluloses and lignin. At higher temperature, it also facilitates the release of volatile materials and created more pores, resulting in larger pore size of biochar [10]. The high porous structure of biochar may be beneficial for bio-filter applications and soil mixing [20], water holding capacity by increasing the total pore spaces of the soil, in addition to use as soil amendment [21].

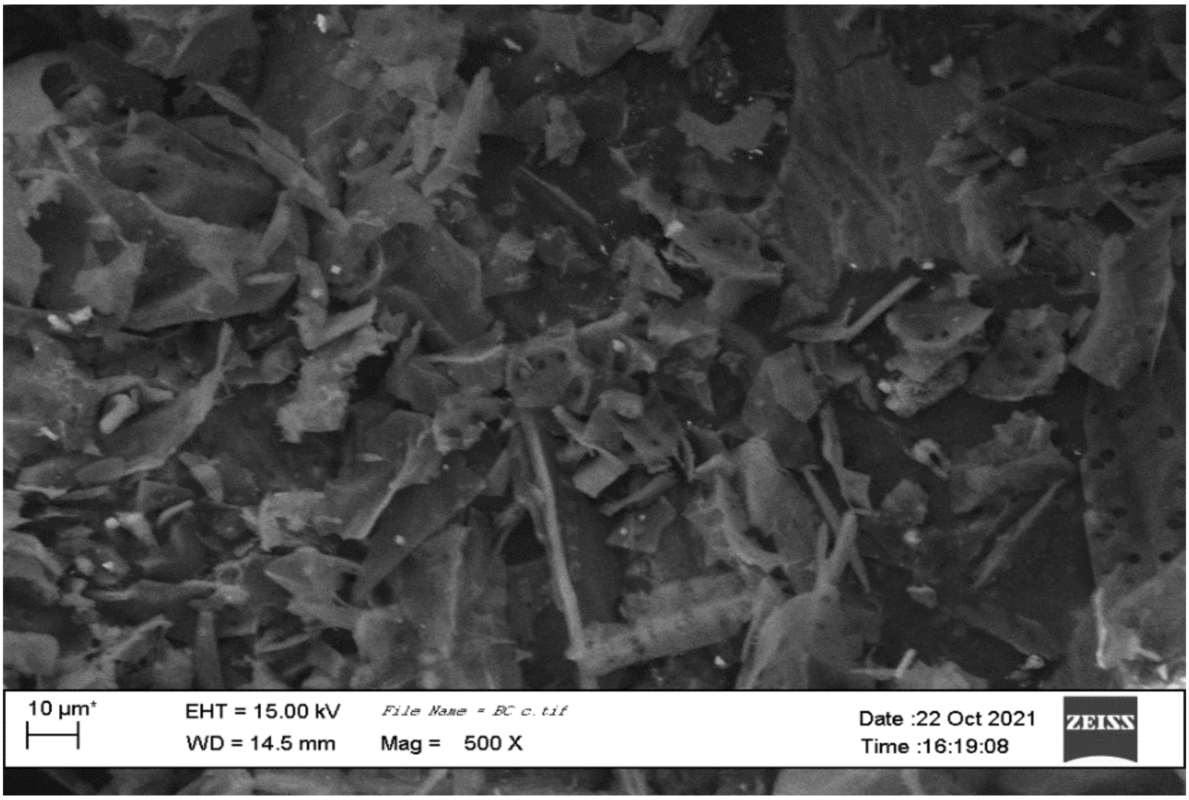

Figure 5. SEM photograph OPT biochar produced by drum retort kiln

4. Conclusions

In general, the results of the study revealed the suitability of oil palm trunk biochar to be used as soil amendment in the agriculture applications. Physicochemical properties of the oil palm trunk biochar provided high fixed carbon and low oxygen contents, matching proximate and ultimate analysis and FTIR. The biochar also had porous structure, which was indicated by SEM. The oil palm trunk as feedstock is renewable and available and the biochar product is environmentally friendly.

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