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Chemical Characterization of Pineapple Leaf Residue Chars generated by Controlled Combustion and by open burning

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Abstract. This study was undertaken to compare the chemical characteristics of pineapple leave residues (PLRs) char generated by controlled combustion and by open burning. The properties of char generated by control combustion (CC) and open burning (OB) varied, due to differences in the production process. The total N, K and surface area of the char generated by CC were significantly higher than the OB. The results indicate that the CC process was better to be applied as a soil amendment than was the OB process.

1 Introduction

In Malaysia, nearly 70% of the pineapple crop is planted on peat [1]. Though relatively small compared to oil palm and rubber, the pineapple industry plays an important role in the country's socio-economic development of Malaysia.

Abundant of leave residues are produced in the field and open burning is commonly practiced to manage the plant residues in pineapple plantation. As a result, large amount of carbon (C), nitrogen (N) and greenhouse gaseous are emitted to the atmosphere from burning. Alternative way to manage the residues is converting the residues to char and applied as a soil amendment. The char is composed of large amount of stable aromatic carbon and sequester C if used as a soil amendment.

Furthermore, previous studies found out biochar is a good soil amendment as it can increase soil water holding capacity of sandy soil [2] and increase crop yields [3]. Field burning not only convert the biomass into volatile organic compounds, inorganic gas oxides but also chars. Approximate 4 to 6% of chars is produced during the open burning [4,5]. The application of biochar to the soil has been proposed to increase the stable nutrient pool. Control combustion is suggested a better way to retain the nutrient in the char rather than

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open burning. However, there is lack of information of the comparisons of chemical properties of pineapple leaf residue (PLR) chars from control combustion and open burning processes. This study was carried out to determine the chemical characteristics of PLR, chars generated from control combustion and field burning, to compare the characteristics of chars generated by control combustion and open burning.

2 Materials and methods

There were two types of chars being generated under different combustion conditions. The chemical characteristics of the chars varied under different processing and thus were analysed for pH, electrical conductivity (EC), macronutrient contents, cation exchange capacity (CEC) and BET surface area.

2.1 Open burning-generated char

The study site was the Peninsula Pineapple Plantation, Johor, Malaysia. Pineapple leaf samples were collected and air-dried for three months prior to char production under control combustion (CC). The chars were collected after the open burning (OB) conducted in a 6 ha area of the plantation [4]. The char samples from the open burning process were oven-dried, ground, sieved to pass a 2 mm sieve and kept in air-tight plastic containers prior to chemical analysis.

2.2 Control combustion-generated char

The pineapple leave residues (PLRs) were converted into chars in the laboratory by taking 90 g of air-dried leaf samples and combusted them for 3 hours at 340°C [6] in a Carbolite ELF 11/23 type furnace. The char samples from CC were processed similarly to the char samples from OB prior to chemical analysis.

2.3 pH and electrical conductivity (EC) of chars

The pH and EC content of leave and char samples were analyzed using a pH meter and a conductivity meter (Radiometer Analytical, ION check 30) by mixing a 1:10 (v/v) ratio of sample to water.

2.4 Total C and N analysis

Total nitrogen (N) was determined using a micro-Kjeldahl method [7] while Total C (%) was determined by a dry combustion method using a CT analyzer (LECO CR-412, Michigan, USA).

2.5 Total macronutrient analysis

Dry ashing was adopted for the determination of phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg).

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2.6 Available P of Char analysis

Available P in the char samples was determined by Olsen method [8]. One g of char generated by CC and OB processes was weighed into the plastic vial. Then, 20 mL of the extracting solution was added and shaked for 30 minutes. Lastly, the extract was filtered using Whatman no.2 filter paper and the P in solution was determined using Auto Analyzer (AA).

2.7 Available K, Ca, Mg and cation exchange capacity (CEC) of char determination

Prior to analysis, char samples were washed 3 times with deionized water to remove soluble salts. Ammonium acetate shaking methods at pH 7 [9] was used to determine CEC of char samples. About 10 g of samples was weighed into centrifuge bottle, and added with 1 M ammonium acetate solution. Afterwards, it was shaken for 30 minutes at 180 rpm by using reciprocal shaker. After shaking, the bottle was centrifuged at 2500 rpm for 10 minutes. The supernatant was later filtered using Whatman no.2 filter paper, K, Ca and Mg in the supernatant was determined using AA and atomic absorption spectrophotometer (AAS). To remove free ammonium ion from the char, 100 mL of ethanol was added into the centrifuge bottle. Afterwards, it was shaken for 30 minutes, centrifuged, and the supernatant was discarded. This step was repeated for 2 more times. A 100 mL of 0.1 N potassium sulfate was added in the centrifuge bottle and shake for 30 minutes, centrifuged, then supernatant was filtered and send to AA for CEC determination.

2.8 BET surface area

The multipoint Brunauer, Emmett and Teller (BET) was used to measure surface area of char samples. Nitrogen adsorption technique at 77K with Automated Gas Sorption Analyzer (Autosorb-1, Quantachrome instruments version 2.01) was used for this purpose. The specific surface area was determined by application of BET analysis software available with the instrument.

2.9 Statistical analysis

An independent t-test was used to detect significant differences between chemical value of the char produced from the CC treatment and from the OB process. Statistical Analysis System (SAS) software version 9.1 was used for the statistical analysis.

3 Results and discussion

The chemical characteristic of the chars generated under CC and OB conditions were analysed and the two different processes will be compared for better quality in term of the nutrient content.

3.1 Macronutrient, pH and EC of char

The properties of char generated by CC and OB varied, due to differences in the production process. The properties of the char are shown in Table 1.0. Both CC and OB combustion processes show high pH (>9) and salinity (>7 mS/cm) in the char, and the high pH and salinity indicate the chars are good soil liming materials. Mineral ash produced during high heating rate in OB process resulted a significant higher pH in the char generated by OB. A significantly higher level of EC found for the CC process suggests that a higher content of metal salts was retained in the laboratory-produced char, probably due to slower heating rates [4].

Total C content under CC conditions (53.30%) was higher than OB conditions (42.19%). A controlled temperature and slow heating rates for the CC production condensed the C of PLR, thereby increasing the total C from the CC process. In contrast, high and uncontrolled temperatures during the OB in the field, would have produced a high level of mineral ash and resulted in more C weight loss [4]. This finding agrees with work of [10], who also found that controlled combustion could further increase the C content of the char that was produced.

The total N under CC conditions (2.60%) was significantly higher than under OB conditions (1.77%) (Table 1). This difference could be attributed to the volatilization of N compounds during open burning at high temperatures. However, N was not volatilized but underwent condensation in the CC process during the controlled combustion.

Table 1. pH, electrical conductivity (EC), total C, total N and C/N ratio of chars produced by controlled combustion (CC) and open burning (OB)

Parameter	CC	OB
pH	9.45^{b}	9.65^{a}
EC (mS/cm)	$12.27^{a} \pm 0.11$	$7.87^{b} \pm 0.87$
Total C (%)	$53.30^{a} \pm 0.70$	$42.19^{b} \pm 0.37$
Total N (%)	$2.6^{a} \pm 0.10$	$1.77^{b} \pm 0.03$

3.2 Total and available P, K, Ca, Mg concentrations and CEC of char

Total P, Ca, Mg and the relevant exchangeable nutrients as well under OB conditions were significantly higher than under CC conditions (Table 2). This difference could be attributed to parts of the PLRs were converted into ash during field burning at high heating rates and temperature and the presence of minerals in the ash residues, thereby increased the concentration of total P, Ca and Mg under CF conditions.

While the K concentration under OB conditions were significantly lower than under CC conditions, suggesting that K ions are highly mobile and vaporized at relatively high temperature during open burning in field [11]. The CEC of the char produced by both CC and OB processes was not significantly different and the values are consistent with the CEC of carbonized rice husk reported in literature [12]. The CEC of the chars tested in this study (15.97– 18.80 cmol(+)/kg) were greater by at least half than the CEC of Ultisols and Oxisols (3–7 cmol(+)/kg) in tropical area [13], except Histosols. The surface area of char made under OB process was found to be lower than under CC process (Table 2.0) suggests that the cell structure of char generated by OB was destroyed by rapid devolatilization rate of the PLRs burned at high heating rates. Higher surface area of char generated by CC enable it to adsorb and retain more nutrients.

Table 2: Available P, exchangeable K, Ca, Mg, CEC and surface area of pineapple leaf char produced by CC and OB processes

Parameter	CC	OB
Total P (%)	0.32^{b}	0.37^{a}
Total K (%)	$8.29^{a} \pm 0.06$	$5.17^{b} \pm 0.21$
Total Ca (%)	0.05^{b}	$0.93^{a} \pm 0.02$
Total Mg (%)	$0.35^{b} \pm 0.01$	$0.75^{a} \pm 0.02$
Exch. K (cmol(+)/kg)	$28.73^{a} \pm 0.84$	$10.84^{b} \pm 0.17$
Exch. Ca (cmol(+)/kg)	$1.71^{b} \pm 0.02$	$11.69^{a} \pm 0.05$
Exch. Mg (cmol(+)/kg)	$7.02^{b} \pm 0.28$	$15.88^{a} \pm 0.39$
CEC (cmol(+)/kg)	$18.8^{a} \pm 0.81$	$15.97^{a} \pm 0.86$
BET surface area (m^2/g)	5.46	2.08

4 Summary

The concentrations of total C, N and macronutrient contents were condensed and increased during conversion of biomass into chars. The chemical properties of PLRs chars varied depending on the combustion conditions. Higher concentrations of total N, K and surface area in the chars generated by CC process suggests the chars under CC process can be applied as a better soil amendment than OB process. However, the effect of PLRs chars on soil nutrient and plant growth should be examined in future research.

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