BIOCHAR CHARACTERISTICS OF AGRICULTURAL CROP RESIDUES

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Abstract- Converting agricultural crop residue such as sugarcane trash and rice straw to biochar being used as soil amendment could potentially improve soil conservation. In this study, selected physical and chemical properties of biochar produced from sugarcane and rice residues and their amendment effects on herbicide adsorption in soils were evaluated. Biochars were produced at 450°C and 750°C, respectively and were characterized for different properties. In general, sugarcane and rice residue biochars exhibited different elemental and molecular compositions. Charring at high temperature decreased N and S contents but increased P, K, Ca, and Mg. Increasing temperature also caused the loss of the surface structures of biochar. Soil treated with either sugarcane leave or bagasse char enhanced the adsorption capacity of atrazine, a common herbicide used in sugarcane production.

Index Terms- Biochar, sugarcane, bagasse, rice, straw, atrazine adsorption.

I. INTRODUCTION

Residue burning associated with harvest residue of agricultural crops is common in many parts of the world. In U.S.A., sugarcane harvest residue in subtropical Louisiana is often burned in the open field before the following season. Approximately 70-90% of the dry matter of harvested sugarcane trash is lost through burning [1].

This practice has caused considerable concerns over water and air quality [2-3].

On the other hand, research has consistently shown decreased sugarcane yields due to cold rainy winter weather if the combine harvest trash is not removed from the field by burning [4].

Recent development using biochar as soil amendment has prompted the interest in converting sugarcane harvest residue as well as processing by-product to biochar and return to field to conserve carbon [5].

Biochar converted from plant biomass contains a unique recalcitrant form of carbon that is resistant to microbial degradation and therefore can be used as a carbon sequester when applied to soil [6].

In addition, biochar has been shown to reduce greenhouse gas (GHG) from agricultural fields and to improve water quality through its strong sorption nature of contaminants [7-8].

Nonetheless, the properties of biochar often vary with biomass sources and pyrolysis conditions [9].

Besides sugarcane harvest trash, approximately 30% of bagasse per metric ton of sugarcane is generated as waste product after extraction of the sugar juice [10], which could be also used to convert to biochar. However, there has been very little work to explore the fundamental properties of biochar produced from these materials. The objectives of this study were to investigate the properties of biochars produced from sugarcane harvest residue, bagasse as well as rice straw and husk as a reference, and to examine environmental benefit of these biochars.

II. EXPERIMENTAL APPROACH

A. Sugarcane and rice resides, and biochar conversion

Sugarcane leave and rice straw residues were collected from LSU AgCenter Iberia Research Station and Crowley Research Station, respectively. Sugarcane bagasse and rice husk were also collected from private processing plants in Louisiana, USA. Biochars of these materials were produced at temperatures of 450 °C and 750 °C respectively using a muffle furnace.

B. Elemental, molecular and surface characterization

Elemental composition of the biochar samples were determined using a Perkin Elmer CHNS Elemental Analyzer for C, N, S and wet digestion (conc. HNO_3 + 30% of H_2O_2) followed by ICP analysis for other elements. Biochar pH was determined using a pH meter at 1:5 solid/water ratio. Molecular composition of biochar samples was characterized using a CDS Varian pyrolysis-gas chromatography with mass spectrometer detector (Py-GC/MS), and surface chemical properties of biochar using a Thermo Nicolet Fourier transformation infrared (FTIR) spectrometer with attenuated total reflectance (ATR) accessory.

C. Herbicide adsorption

Adsorption experiment of herbicide atrazine was conducted with a Commerce silt loam soil amended at different rate of sugarcane biochars and a solution concentration of 10 mg L^{-1} atrazine at a solid:solution ratio of 1:15 for different time periods. The atrazine in the solution after adsorption was analyzed using a Varian GC/MS following concentrating process of atrazine using C18 cartridge.

III. RESULTS AND DISCUSSION

D. Elemental properties

Biochars produced at 750°C generally had lower total N and S contents but higher total P, K, Ca and Mg contents than that at 450°C (Table 1). Sugarcane leave char contained more P, K, Ca and Mg than sugarcane bagasse biochar. On the other hand, rice straw biochar had more of S, K Ca but less P than rice husk. Soil test extraction based on Mehlich III showed that as much as 50% total biochar P and 30-50% total Ca were likely plant-available whereas 8-12% K was plant-available.

Table1. Selected elemental contents in biochars produced from different sugarcane and rice residues.

Biochar	Temp (°C)	C	N	S	P	K	Ca	Mg
		g kg^{-1}						
SLB	450	440	11.0	1.5	1.8	11.1	13.0	4.3
	750	439	2.0	0.5	2.6	33.5	19.9	6.0
SBB	450	395	6.0	0.8	0.8	8.8	1.8	1.8
	750	509	3.0	0.1	1.9	8.7	3.3	2.9
RS	450	447	10.0	0.9	1.9	28.2	10.4	2.8
	750	504	5.0	0.4	3.4	36.0	18.3	5.0
RH	450	539	14.0	0.3	6.0	7.4	1.3	2.8
	750	565	12.0	0.1	11.6	12.8	1.5	5.0

SLB, SBB, RS and RH are sugarcane leaves, sugarcane bagasse, rice and rice husk biochars, respectively.

E. Pyrolysis-GC/MS and FTIR analysis

Sugarcane leave biochar converted at 450 °C was dominated with various lignin derived phenols (9, 11, 12, 15) as well as non-specific aromatic compounds such as toluene (3) and xylene (6) as evidenced by Py-GC/MC analysis (Fig. 1.) Sugarcane bagasse biochar (450 °C) was more dominated with both lignin derived phenol (9) and poly aromatic hydrocarbon (PAH) such as naphthalene (22). On the other hand, rice straw and husk chars were more dominated with non-specific aromatic BTX compounds with the later had the greatest in the composition. Biochars produced at higher temperatures exhibited generally weak signals and more dominance of PAHs.

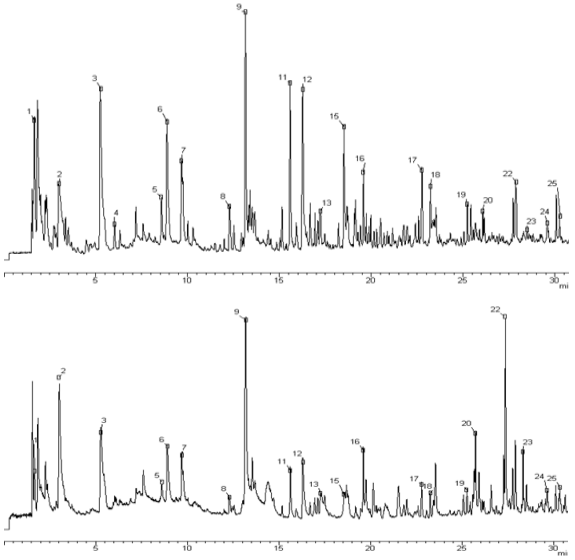


Fig. 1. Pyrograms of sugarcane leave (A) and sugarcane bagasse (B) biochars produced at 450 °C.

From FTIR analysis, it was shown that increasing charring temperature generally caused the loss of several surface structures in rice straw biochar (Fig. 2). Similar results were also observed for sugarcane residue chars. At 450 °C, biochar surface had similar functional groups as the raw materials except for losing OH-stretching band at around 3307 cm^{-1}, as well as aliphatic CH stretching of CH_3 and CH_2 at around 2890 cm^{-1}. At 750 °C, charred material was only dominated with 975 cm^{-1} band, which is assigned to C-O-C of aromatic ethers, and lost 1560 cm^{-1} band of the aromatic C=C stretching.

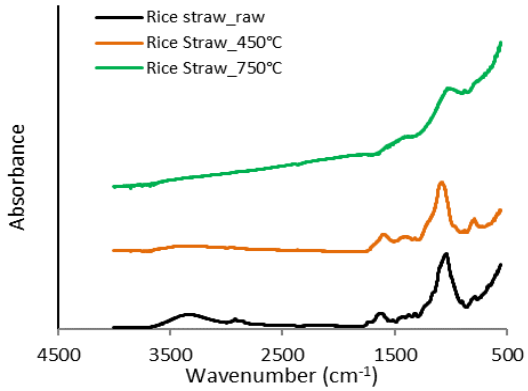


Fig. 2. FTIR spectra of rice straw feedstock and rice straw biochar produced at two different temperatures.

F. Biochar adsorption of atrazine

Both sugarcane leave and bagasse biochar treatment significantly enhanced adsorption capacity of atrazine by Commerce silt loam soil as compared to that without the biochar treatment (Fig. 3). Addition of wheat biochar at a rate of 1 % (w/w) to soils increased the sorption of several pesticides including ametryne, bromoxynil and diuron compared to non-amended soils [11]. Soil amendment of hardwood biochar also significantly reduced mobility of tylosin, a macrolide class antibiotic in animal manure-affected soils [12].

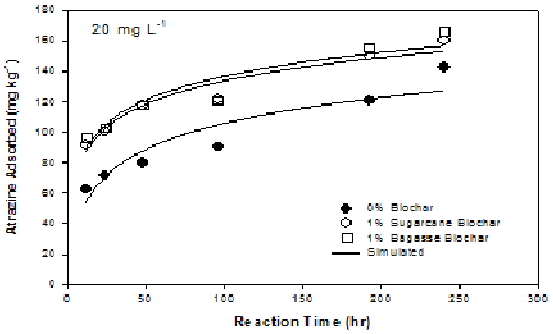


Fig. 3. Atrazine adsorption by Commerce soil treated at 1% sugarcane leave and bagasse biochars.

CONCLUSION

Biochars produced by sugarcane and rice residues showed different elemental and molecular compositions. Increasing charring temperatures decreased N and S contents but increases P, K, and Ca.

It also caused the loss of the surface structures of biochar. Rice husk had the highest hydrophobic composition of BTX and PAH compounds than other biochars. Treating soil with either sugarcane leave or bagasse char enhanced adsorption capacity of atrazine, a common herbicide used in sugarcane production. Overall these biochars show strong ability in improving soil adsorption of pesticides and antibiotics.

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