Effect of Feedstock and Production Method on Pyrolysis Char Properties for Use as an Agricultural Soil Amendment

Keith Harris, Julia Gaskin, Brian Bibens, Roger Hilten, and K.C. Das

Dept. of Biol. & Ag. Eng., University of Georgia, Athens, GA

Introduction:

Several studies from the tropics indicate charcoal can benefit soil fertility by increasing soil nutrient status and cation exchange capacity (CEC) (Lehmann et al 2003, Liang, et al 2006). Char, the byproduct of the pyrolysis of biomass for energy production, may have a similar effect. In addition, the recalcitrant nature of char-C may sequester C in the soil, possibly reducing net green house gas emissions (Lehman 2007).

Several studies have shown char has a beneficial impact on soil fertility; however, few have addressed the effect of feedstock and production method on char properties for use as an agricultural soil amendment. Pyrolysis temperature, pyrolysis with steam as a carrier gas, and steam activation after pyrolysis can effect char's porosity, surface chemistry, and reactivity (Abdel-Nasser 2003). The objective of this study was to test the effect of feedstock, pyrolysis temperature, carrier gas, and activation on char properties that could effect soil fertility.

Material and Methods:

Char: Two feedstocks, broiler litter (BL) and pine chips (PC) were selected due to regional availability and contrasting properties. Chars were produced in a batch pyrolysis unit at two temperatures – 400 and 500° C , and three carrier gas/activation regimes – steam carrier gas (S), nitrogen carrier gas (P), nitrogen as the carrier gas/steam activation (A). Each of the six production combinations was replicated three times. Char was ground using a ball mill grinder.

Nutrient analysis: Total C and N - LECO CNS-2000. Nutrients were extracted with Mehlich I solution and measured on a Thermo Jarrell-Ash model 61E ICP.

pH: Char was mixed 5 to 1 vol/vol with DI water, equilibrated for one hour, and measured with Fisher Scientific AR15 digital pH meter.

CEC: Prior to analysis samples were leached with deionized water to remove soluble salts. Na-acetate/ethanol/ NH4-acetate replacement method was used to determine CEC. Na was analyzed by atomic absorption on a Perkin Elmer PE 4100ZL

Soluble Carbon, NO_3-N, and NH_4-N: Prior to CEC extraction, 20mls of DI H_2O was added to a 1 g sample of char. The char was placed on an orbital shaker and shaken for 5 minutes. After shaking the sample was filtered through a 0.45 µm cellulose nitrile filter. The leachate was split with on sample being acidified to pH of 2 and the other unaltered. Both were frozen until analysis. NO3-N and NH4-N were analyzed on a Perstorp EnviroFlow 3000.

Results and Discussion:

Nutrients: Feedstock had a significant effect on Mehlich I nutrient concentrations (Table 1). BL char contained a considerable amount of N,P,K, and Ca. Data from other studies indicates nutrients from char release slowly with wetting and drying. BL char may prove beneficial as a slow release fertilizer; however N leachate data as well as mineralization studies from other char / soil mixtures indicates the N present is not readily available. Neither char exceeded EPA part 503 regulated metal levels.

Table 1. Analysis of C, N and Mehlich I nutrients in char . Number is temperature in ºC, P = pyrolysis w N_2 gas, S= pyrolysis w steam, A= P = pyrolysis w N_2 gas + steam activation.

Temp-Method	C %	N %	P %	K %	Ca %
			Broiler Litter		
400-P	39.2 ± 0.66	3.47 ± 0.14	3.01 ± 0.03	5.11 ± 0.22	4.27 ± 0.05
400-S	38.8 ± 2.26	3.19 ± 0.15	3.44 ± 0.29	4.96 ± 1.05	4.89 ± 0.36
400-A	39.9 ± 1.29	3.47 ± 0.13	3.22 ± 0.40	5.26 ± 0.85	4.57 ± 0.52
500-P	39.2 ± 1.50	3.09 ± 0.15	3.59 ± 0.29	5.86 ± 0.51	5.04 ± 0.38
500-S	46.5 ± 2.33	3.38 ± 0.49	4.03 ± 0.15	4.90 ± 2.10	5.66 ± 0.25
500-A	42.1 ± 4.03	3.23 ± 0.28	3.49 ± 0.44	5.47 ± 0.27	4.91 ± 0.64
			Pine Chip		
400-P	73.9 ± 2.99	0.25 ± 0.07	0.015 ± 0.007	0.145 ± 0.01	0.171 ± 0.019
400-S	72.4 ± 8.68	0.20 ± 0.04	0.018 ± 0.013	0.174 ± 0.02	0.206 ± 0.035
400-A	76.1 ± 0.62	0.20 ± 0.01	0.014 ± 0.007	0.151 ± 0.01	0.170 ± 0.040
500-P	81.7 ± 0.34	0.22 ± 0.02	0.014 ± 0.031	0.145 ± 0.03	0.185 ± 0.025
500-S	80.0 ± 2.32	0.23 ± 0.01	0.016 ± 0.030	0.181 ± 0.04	0.193 ± 0.030
500-A	82.0 ± 2.88	0.22 ± 0.02	0.020 ± 0.026	0.225 ± 0.04	0.217 ± 0.075

pH: The pH of char differed solely by feedstock (Figure 1). The high alkalinity of the PL char could have been due to a higher ash content with PL consisting of 42% ash while the PC consisting of only 1% ash. BL char may have potential as a liming agent but further testing is necessary.

CEC: Feedstock also had a significant affect on CEC (Figure 2). BL was also significantly effected by temperature. Lignin and cellulose content of the raw feedstock may have influenced the formation of surface functional groups during carbonization. PC feedstock consisted of 28% acid detergent lignin and 52% cellulose while BL feedstock contained 4% and 20% respectively.

Soluble Carbon: Soluble carbon was also affected by feedstock. BL was affected by temperature as well as treatment with higher soluble carbon concentrations seen in extractions from steam pyrolysis.

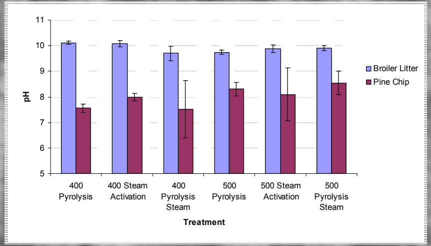

Figure 1. pH of broiler litter and pine chip chars pyrolyzed with different temperatures, carrier gas, and activation.

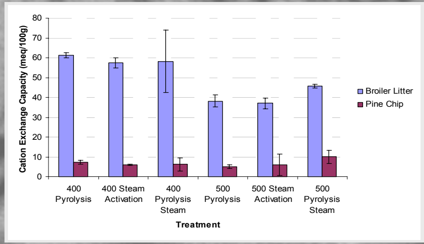

Figure 2. Cation exchange capacity of broiler litter and pine chip chars pyrolyzed with different temperatures, carrier gas, and activation.

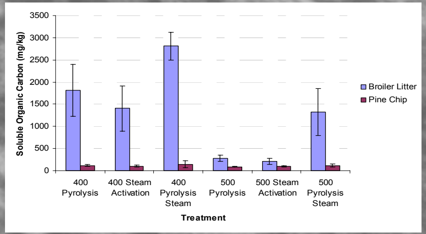

Figure 3. Water soluble organic carbon from broiler litter and pine chip chars pyrolyzed with different temperatures, carrier gas, and activation.

Conclusion:

Feedstock was the most important factor when creating chars at low pyrolysis temperatures for use as agricultural soil amendments. Temperature apparently affected the surface chemistry of the char from boiler litter resulting in changes cation exchange capacity. Final pyrolysis temperatures used for this study are considered low to middle of a typical pyrolysis temperature range, generally 400 to 600° C. The temperatures used had little effect on most of the parameters measured for this study; however a wider temperature range may have a greater effect on these properties. The carrier gas and the post pyrolysis steam activation method used in this study had little effect on most of the parameters measured.

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