Physical and Chemical Characterization of Biochars from Fast Pyrolysis of Three Biomass Feedstocks

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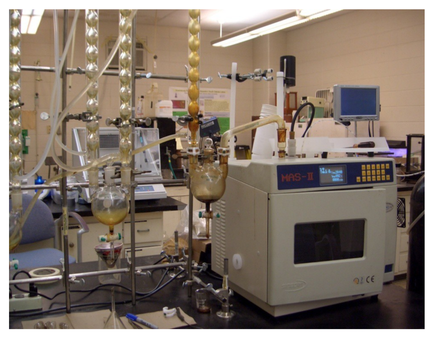
Rationale

- Biomass densification – pyrolysis optimized for bio-oil production
- Processing to increase local economic return – small to medium scale processing plants
- Utilization of processing byproducts – biochar and syngas
- Rehabilitation of eroded landscapes – biochar as a soil amendment

Approach

- Optimization of microwave pyrolytic conditions for bio-oil production from three biomass feedstocs
- Physical and chemical characterization of biochar as a co-product of microwave pyrolysis
- Greenhouse study – studying the effect of biochar on plant nutrient uptake and water holding capacity
- Incubation studies – biochar mineralization and effects on GHG emissions
- Herbicide sorption by biochars
- Field trial – effects of biochar on soil quality and fertility, crop yield, C-sequestration, and GHG emissions

Pyrolysis– Bio-oil Production



Laboratory scale

Pilot plant Scale

➢Pyrolytic temperature - 650 ^{0}C, Residence time – 18 min, and Power – 700 w

Presentation Objective

Characterization of biochars produced from microwave pyrolysis (lab scale) from three sources, corn stover (*Zea mays L.*) switchgrass (*Panicum virgatum L.*) ponderosa pine wood residue (*Pinus ponderosa Lason and C. Lawson)*

Biochars

Corn stover biochar

Switchgrass biochar

Biochars are variable in their properties due to different feedstocks and processing conditions

Ponderosa pine wood residue biochar

Characterization of Biochars

Table 1. Physical and Chemical Properties of Biochars

Properties	Corn stover biochar	Ponderosa pine wood residue biochar	Switchgrass biochar
Physical property			
BET surface area (m^2g^{-1})	38.1	48.1	42.4
Chemical properties			
pH	11.4 ± 0.10	5.82 ± 0.05	10.4 ± 0.12
EC(μS cm^{-1})	3000 ± 60.6	200 ± 22.1	890 ± 0.08
Liming property			
$CaCO_3$ (g kg^{-1})	2.5 ± 0.05	0.30 ± 0.02	2.00 ± 0.05
Surface charge			
CEC (mmol kg^{-1})	60.1 ± 4.66	34.2 ± 2.35	50.6 ± 2.11
AEC (mmol kg^{-1})	29.9 ± 2.12	14.6 ± 1.89	13.9 ± 1.55

Table 2. Elemental Analysis of Biochars

Elemental analysis	Corn stover biochar	Ponderosa pine wood residue biochar	Switchgrass biochar
Nutrients			
Ca (g kg^{-1})	7.51 ± 0.31	2.57 ± 0.03	7.12 ± 0.22
Mg (g kg^{-1})	5.34 ± 0.72	0.62 ± 0.31	5.25 ± 0.11
K (g kg^{-1})	21.4 ± 1.35	1.96 ± 0.04	2.70 ± 0.10
Na (g kg^{-1})	0.69 ± 0.01	0.62 ± 0.03	0.67 ± 0.01
Total P (g kg^{-1})	1.99 ± 0.06	0.36 ± 0.08	1.89 ± 0.08
Total N (g kg^{-1})	12.3 ± 1.03	3.53 ± 0.63	16.4 ± 1.72
Total C (g kg^{-1})	740 ± 23.4	833 ± 29.7	780 ± 19.5
Trace metals			
Fe (mg kg^{-1})	241 ± 18.8	133 ± 21.3	249 ± 28.1
Cu (mg kg^{-1})	14.5 ± 2.43	6.89 ± 0.96	12.0 ± 1.22
Mn (mg kg^{-1})	125 ± 12.1	73.5 ± 6.46	155 ± 10.2
Zn (mg kg^{-1})	44.0 ± 8.15	57.9 ± 6.63	32.7 ± 9.44
Mo (mg kg^{-1})	13.7 ± 1.76	6.71 ± 1.04	7.32 ± 0.96

- ➢ Biochar characteristics were significantly different among these three biomass feedstocks
- ➢ Surface area – Ponderosa pine wood residue biochar > switchgrass biochar > corn stover biochar
- ➢ Surface charge – corn stover biochar > switchgrass biochar > Ponderosa pine wood residue biochar
- ➢Corn stover and switchgrass biochars were more alkaline with higher base cation concentration when compared to Ponderosa pine wood residue biochar

Liming Potential of Biochars

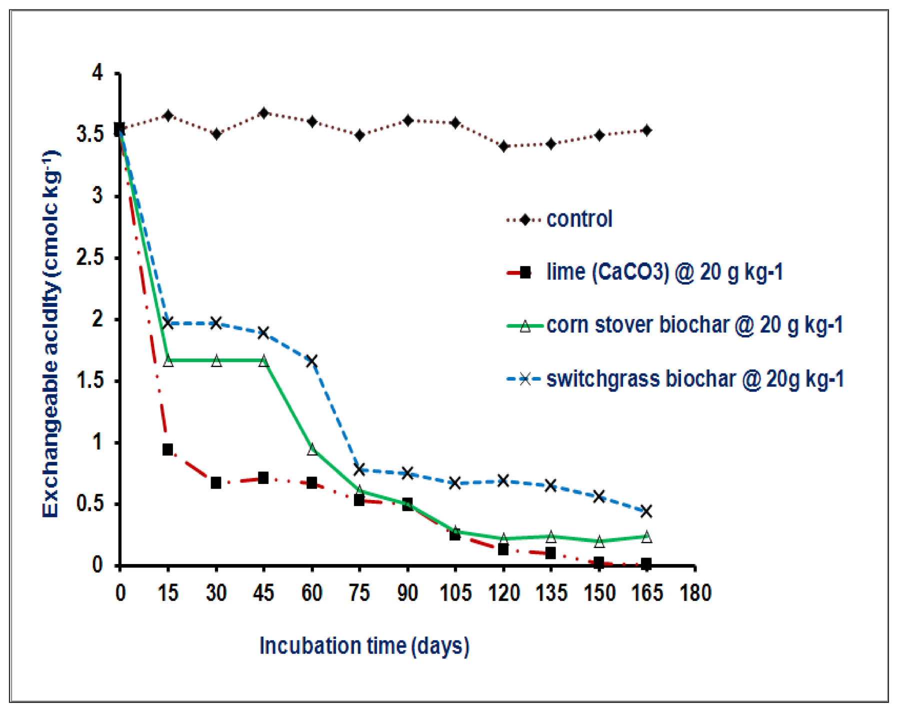


Fig. 1. Effect of incubating biochars and lime with an acidic soil (Grummit soil) on exchangeable acidity. Each data point represents the mean of four replications.

➢Exchangeable acidity (sum of exchangeable H^+ and Al^{3+}) was significantly decreased by biochars and lime during incubation of acidic soil

➢The decrease in exchangeable acidity of the soil can be attributed to the alkalinity, $CaCO_3$ content, proton consumption capacity, and base cation concentration of the biochars

Anion retention by biochars

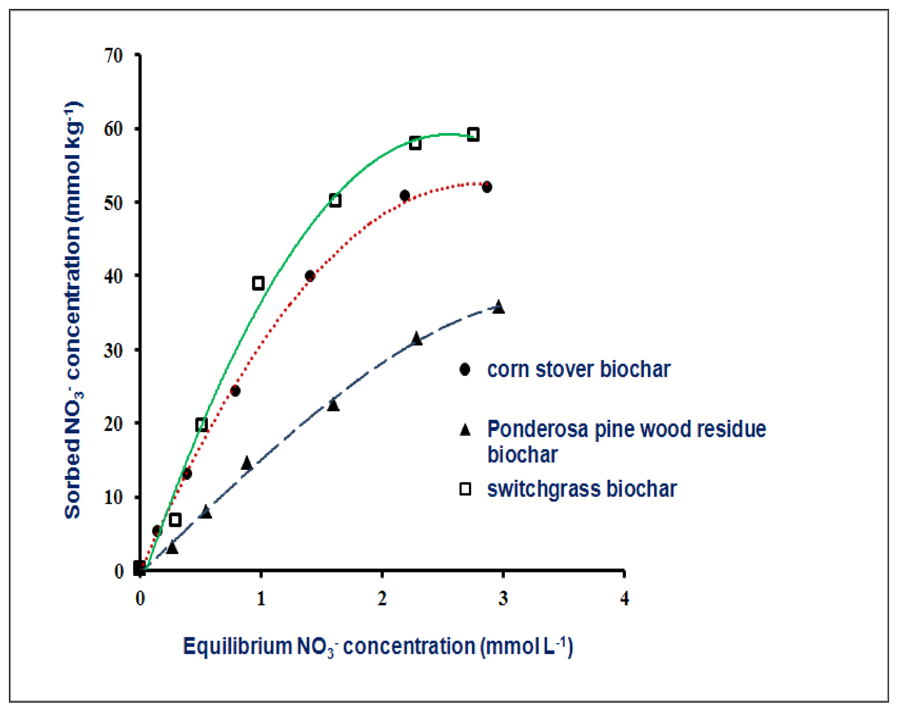


Fig. 2. Nitrate sorption by biochars (Freundlich Isotherms, K_f).

➢ Freundlich isotherm constant (K_f) – switchgrass biochar (111.0 ± 16) > corn stover biochar (97.5 ± 11) > Ponderosa pine wood residue biochar (46.9 ± 6.31)

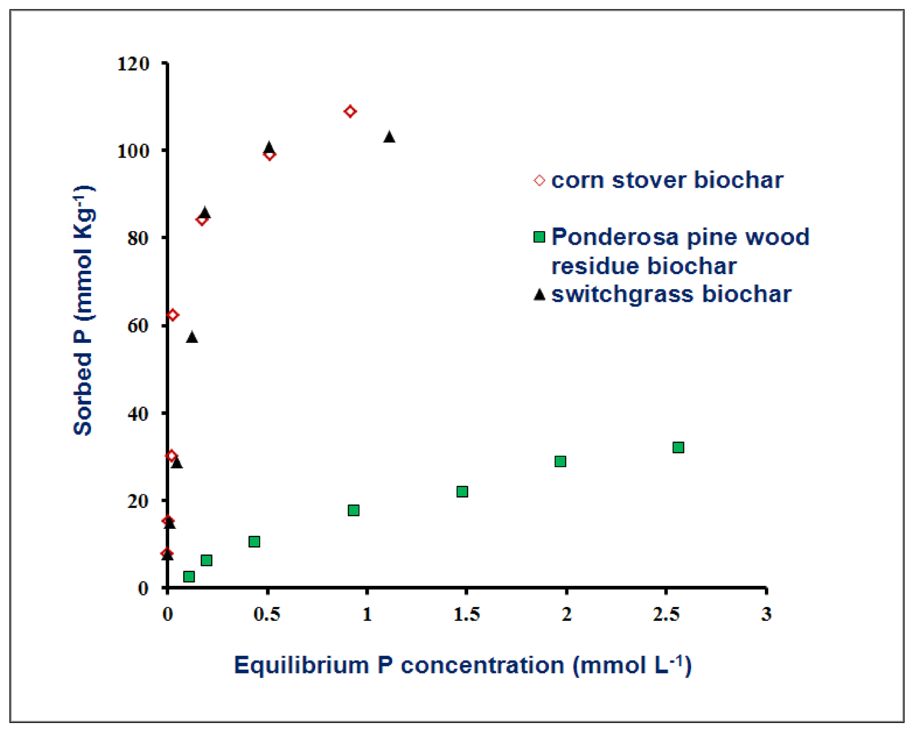


Fig. 3. Phosphorus sorption by biochars

➢Freundlich isotherm constant (K_f) – corn stover biochar (1400 ± 71) > Switchgrass biochar (1161 ± 57) > Ponderosa pine wood residue biochar (55 ± 9)

Summary

- Feedstock source significantly influenced the physical and chemical properties of biochars
- Corn stover and switchgrass biochars are more alkaline with a higher base cation concentration than Ponderosa pine wood residue biochar
- Surface area of Ponderosa pine wood residue biochar is higher than corn stover and switchgrass biochar products
- Corn stover and switchgrass biochars have liming potential and also a relative high affinity for anions

Project update

- Characterization of lab scale biochars have been completed
- Soils have been collected for the greenhouse study
- Biochar amounts suitable for larger scale studies have been secured.
- Biochar mineralization studies have been initiated
- Site has been selected for conducting the field trial

Acknowledgement

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