Acid-activation of biochars and ashes to increase plant phosphorus availability

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Background

Pyrolysis or incineration of phosphorus (P)-rich wastes reduces volume, increases nutrient concentrations, removes microbial and organic pollutants and - in case of pyrolysis - leads to the formation of recalcitrant carbon. However, the resulting biochars and ashes contain P compounds with low solubility and consequently poor plant availability, which limits P recycling from these materials. **Acid activation could potentially increase solubility and plant P availability from ashes and biochars.**

Materials & Methods

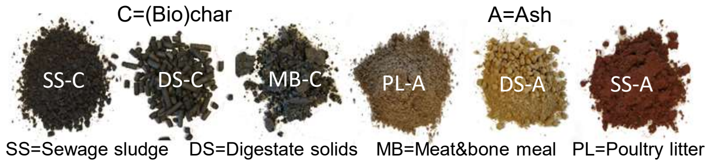

Figure 1: Biochars and ashes derived from P-rich feedstock materials.

Table 1: Total P (TP) content, pH and water extractable P (WEP) content of biochar and ashes, as well as sulfuric acid concentrations used for activation and the resulting pH and WEP.

		DS-A	DS-C	MB-C	PL-A	SS-A	SS-C
P	mg / g	81.3	26.6	106.9	57.5	96.3	69.8
pH		10.8	11.2	11.2	12.4	8.6	7.2
WEP	%TP	0.0	0.2	0.3	0.2	0.0	0.0
				Activation			
H_2SO_4	M	7.5	5	5	10	10	10
pH		5.8	1.8	3.5	3.1	3.3	1.4
WEP	%TP	31	63	71	66	44	43

Activation

Materials were mixed with increasing concentrations of sulfuric acid (2.5-10 M) and subsequently dried at 60 °C. Water extractable P (WEP) and pH of the acidified materials were measured. Based on this, it was decided on an acid treatment to achieve a WEP content larger than 30 % of the initial total P content.

Pot study

The labile soil P pool was labelled with ^{33}P to determine P uptake from soil and fertilizer based on isotopic dilution. Untreated and acidified materials were mixed into soil according to their initial total P content (80 mg g^{-1} soil) and maize was grown for 40 days in a climate chamber. At harvest, shoot biomass, P uptake, specific activity of plant material and soil pH were measured.

Results

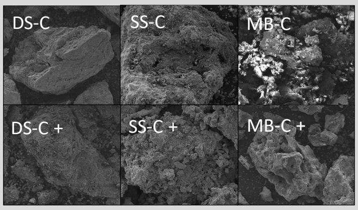

Figure 2: SEM images of the surfaces of the three biochars before and after activation (+)

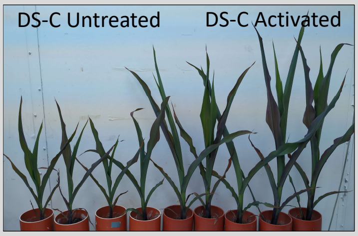

Figure 3: Maize fertilized with untreated (left) and activated (right) digestate solid biochar (DS-C).

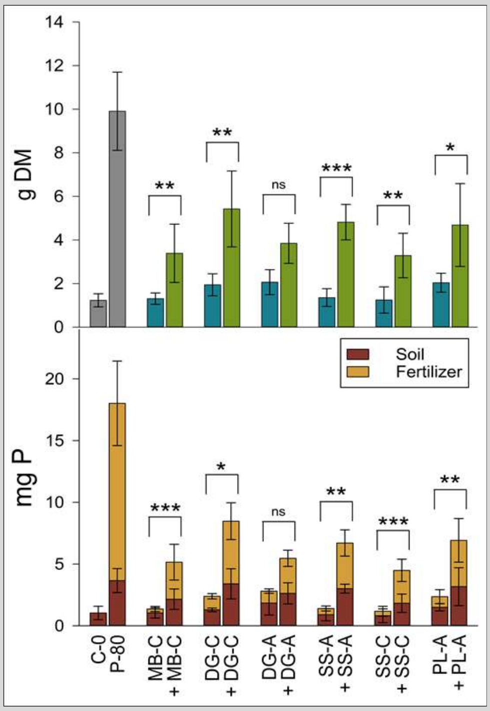

Table 2: Mineral fertilizer equivalent (MFE) (calculated with fertilizer derived P based on isotopic dilution) and soil pH after harvest of the untreated (Untr.) and activated (Activ.) materials. *: Stars indicate significant differences (p<0.05). Soil pH with all materials did not differ significantly from both controls

	MFE			pH		
	Untr.	Activ.	Sign.	Untr.	Activ.	Sign.
Ctrl 0				6.3		
Ctrl P80				6.4		
DS-A	6.8	25.0		6.7	6.3	
SS-A	3.5	33.1	*	6.2	6.2	
SS-C	2.6	28.1	*	6.2	6.1	
DS-C	7.7	39.3	*	6.6	6.2	*
MB-C	2.2	26.3	*	6.3	6.2	
PL-A	6.0	31.5	*	6.5	6.3	

Figure 4: Shoot biomass (g DM) and P uptake (mg P) from fertilizer and soil of untreated and activated materials. Error bars represent Standard Errors. Letters indicate significant differences between untreated and activated materials (p<0.05). For P uptake, letters indicate significant differences in fertilizer derived P.

Key findings

- Materials required different acid concentrations to achieve a minimum proportion of WEP.
- Shoot biomass, P uptake and consequently mineral fertilizer replacement was increased with activation.
- The effect was especially high for SS-A, DG-C and MB-C.
- Soil pH was not affected by application of activated material.

Conclusion

Acid-activation increased maize DM yield and P uptake for all biochars and ashes, while the application of acidified materials did not negatively affect plant growth or decrease soil pH
→Acid-activation appears to be a promising pre-treatment method to increase plant P availability from P-rich ashes and biochars.

Future investigations

- Is carbon stability of biochars altered by activation?
- What is the medium/long-term P release from activated materials?
- Does activation increase heavy metal availability compared to untreated materials?
- Is ash activation more economically viable than acid extraction?

FertiCycle
"This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No.860127"