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Characterization of P and Si solubility in various carbonized organic residues

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Thermochemical treatment through pyrolysis and hydrothermal carbonization (HTC) is an option for stabilizing organic residues and to modify their properties for new products of the circular economy. Agriculture being a major recycling route, nutrient solubility and plant availability in the solid residue of these processes deserves attention.

We conducted experiments on P and Si solubility in various carbonization products. In particular, we used ferrihydrite (the "iron bag" method) as an infinite sink for phosphate and silicic acid - the bioavailable forms of these nutrients. This method was found to better predict P plant availability in chemically diverse recycling and conventional fertilizers. When combined with a classical water extract (1:100 w:v), this approach allows to screen for the behavior of nutrient release from the products.

Phosphorus in carbonized products tended to be less water-souble (according to the water extract) than in their respective feedstocks. This may be due to initial hydrophobicity of the product. Contrastingly, the overall plant availability (according to the iron bag method) was not negatively affected. Nevertheless, increasing Ca:Mg ratio was related to a decrease of P extractability from the product. Silicon in wheat straw biochars exhibited a high solubility, as determined with the iron bag. Neither pyrolysis temperature (450 vs. 750°C) nor combustion influenced the result: with this method, 75-85% of total Si was extracted from wheat straw biochars and ash.

Overall, our results suggest that carbonization does not substantially affect P availability to plant, provided that Ca is not added to the process. Conversely, initial low P solubility is a potential advantage in terms of environmental impact (leaching) and nutrient use efficiency in agriculture. Our preliminaty results also suggest that straw biochar (as well as ash) can be considered a good source of bioavailable Si. Combining infinite sink (iron bag) with equilibrium-based extraction (water extract) methods provides a promising toolbox for product development and assessment in the context of diversifying source materials, fertilizer applications and markets.