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Biochar as phosphorus transporter to support the closure of the phosphorus cycle

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Waste materials rich in phosphorus could partly substitute rock phosphate-based mineral fertilizers. As rock phosphate is listed as critical raw material, measures for increasing the recovery rate of phosphorus and for closing the phosphorus cycle are required. However, direct use of the waste materials as fertilizers are frequently not possible because of legal constraints, adverse side effects because of co-occurring contaminants or hygienic concerns. So this study had the objective to test the appropriateness of carbonizing P-rich residues that can be used as secondary P resources for producing P fertilizers. The resulting biochar or hydrochar products should be tested for the bioavailability of P for plant uptake.

Feedstock materials tested as secondary P resources were chicken manure, animal bone flour, sewage sludge, and digestates. These materials were either pyrolyzed at different temperatures, partly with different chemical modifications, or hydrothermally carbonized. The biochar and hydrochar products were analyzed for their total and available P concentrations, and the plant bioavailability was determined with a standardized plant growth test with rye (Neubauer-test).

The results showed that biochar produced from a mixture of chicken manure and saw dust was equivalent to a standard phosphate fertilizer (superphosphate) with respect to P available for plant uptake. For most materials, a pyrolysis temperature of 400 °C was slightly more beneficial for P availability than 500 °C. Pyrolytic carbonization mostly was more supportive for plant growth than hydrothermal carbonization of the tested feedstocks. For some feedstocks the addition of sodium carbonate improved the P uptake of the plants without affecting the biomass production.

The results show that P-rich waste materials used as secondary resources for carbonization can effectively contribute to increased P recovery, savings in the use of mineral phosphate fertilizers and reduced P loads to non-target ecosystems. Additionally, other benefits of biochar application to agricultural soils like carbon sequestration or improvements of physical soil characteristics may supplement the fertilizer effect of P-enriched biochars or hydrochars.