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Response from Day and Hawkins

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Limitations of Char from Biomass

Day and Hawkins (*BioScience* 57: 814–815 [doi:10.1641/B571002]) claim that they have a technology to convert biomass to a fertilizer that is part char and part ammonium carbonate. Various claims for the product are not credible. Foremost, the purported nitrogen (N) content is too high. One hundred kilograms (kg) of (assumed dry) biomass, as plant material, should contain about 2% N or 2 kg N, even less if it is high-cellulose material such as grain stover. The product is said to be 56.4% (56.4 kg) ammonium bicarbonate, which in turn is 17.7% N. (I note also that the quotation to 3 significant figures is inappropriate, given the variability in feedstocks.) Thus, the total N would be 0.177 • 56.4 = 10.0 kg N, far too high. The authors also claim that additional N is sequestered in the char as ammonium nitrate, making the N content even less believable. In a digital publication (*Energy* [doi:10.1016/j.energy.2004.07.016]), Day and colleagues disclose that the ammonia could have been (but was not) made with a hydrogen byproduct of pyrolysis.

The ability of biochar to increase the availability of several nutrients is also conditional, not absolute or necessarily positive. Nutrient retention by strong adsorption is useful in soils with very low ion-exchange capacity (sands, e.g.) but can be competitive with plant uptake in richer soils. One of the academic research groups (see *www.css.cornell.edu/faculty/lehmann/biochar/Biochar_home.htm*) shows biomass gains only at low applications, in soil initial conditions that are not well specified. The value of biochar for sequestering carbon (about half of the original input to the pyrolyzer) is perhaps more credible for the moderate term (century scale). The sequestration should be debited for the fuel use in pyrolysis, which is not specified.

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For brevity we did not include an important detail in one use of our biochar, to create a nitrogen-enriched char by capturing carbon dioxide (CO_2). The Energy *citation referenced by Gutschick (doi:10.1016/j.energy.2004.07.016) provides fuller details. The values for nitrogen content used were measured for pelletized peanut hulls, and were quantified using standardized analytical techniques. In our process, hydrogen from biomass pyrolysis, as demonstrated in our recent 1000-hour process demonstration, can be used to produce ammonia. We did not claim that the ammonia was manufactured on site, but stated that hydrogen generated from our process could be used to produce ammonia. To generate ECOSS [enriched carbon, organic slow-release sequestering], ammonia is hydrated and adsorbed on the porous biochar surfaces, aided by binding to the surface acid functional groups. This treated biochar powder is then injected into a cyclone slipstream of gases high in CO_2, such as recovered exhaust from coal combustion or the exhaust of the biomass conversion system. (For more information on the ammonia carbonation process and its use in CO_2 scrubbing, see research and patents by James W. Lee, our coauthor on the* Energy *article.) The fuel for the pyrolysis comes from the biomass, and therefore the carbon emissions of the process do not need to be debited. The efficiency of manufacturing of ammonia is low, but single-pass production using microscale technology can generate enough ammonia for our purposes.*

The amendment of soil through the use of biochar has not been researched for all soil types, and further research is needed. Johannes Lehmann and others have shown positive effects of biochar on soil properties and crop yields. The examples we gave are known instances where the increase in soil carbon was beneficial; we did not speculate about other possible cases.

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