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Screening ammonium and ammonia sorption of biochars for N mitigation during biomass processing

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Multiple-use of biochar

1) Biochar use during biomass processing (manure treatment, anaerobic digestion, composting)
2) Use of the biochar-enriched end products as soil improver, slow-release fertilizer or growing media constituent
3) Use of the end products (e.g. spent growing media) as feedstock for biochar production

Due to the heterogeneity in feedstock composition and production method, biochars are very different in quality which effects their application. As such, an understanding of the relationship between biochar properties and the capacity to sorb N is of paramount importance to be able to select biochars for application in biomass processing or to steer biochar production.

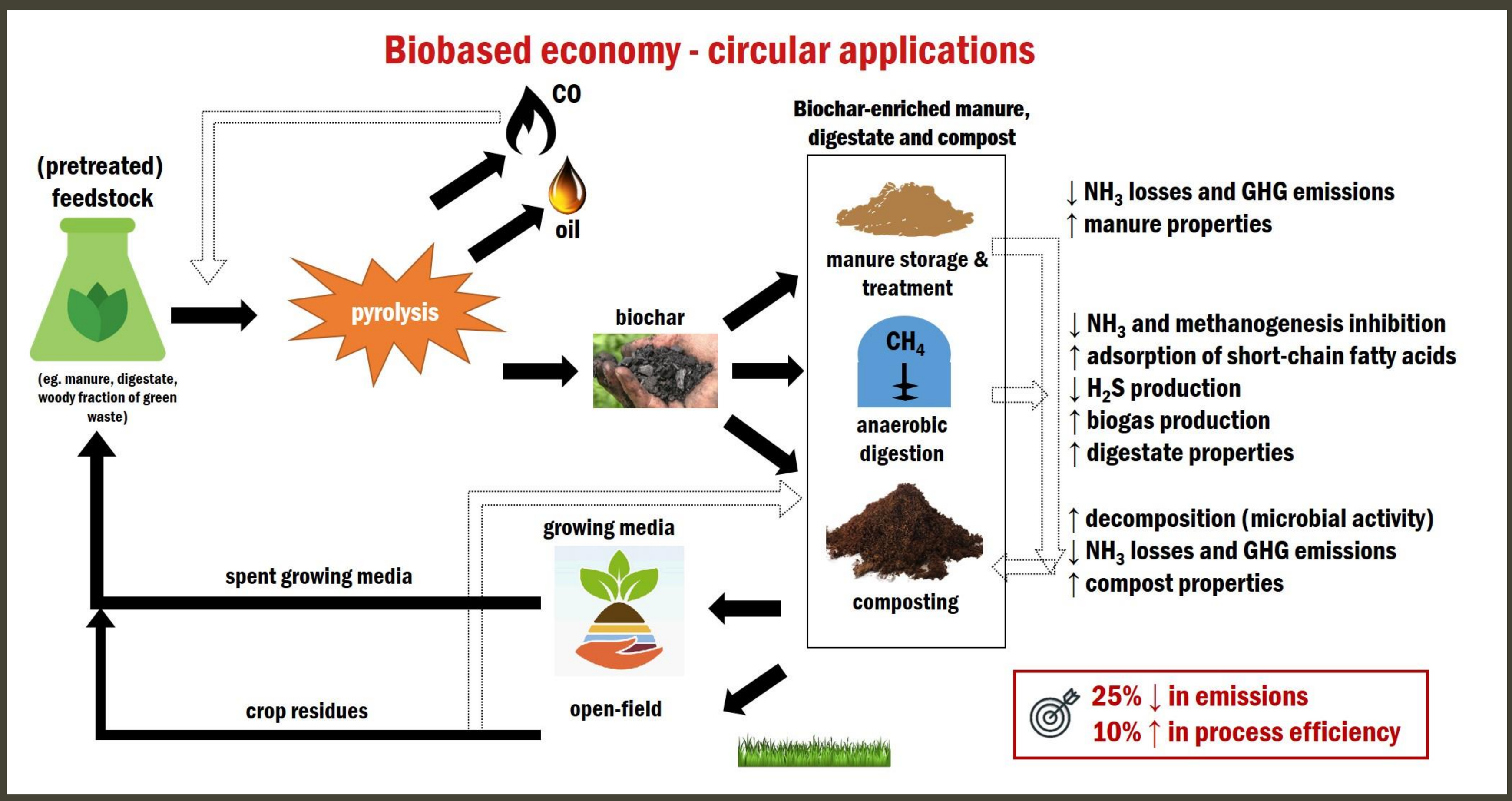

Fig. 1: Overview of all experiments

Two fast screening tests for N sorption

NH_4^+-N sorption test

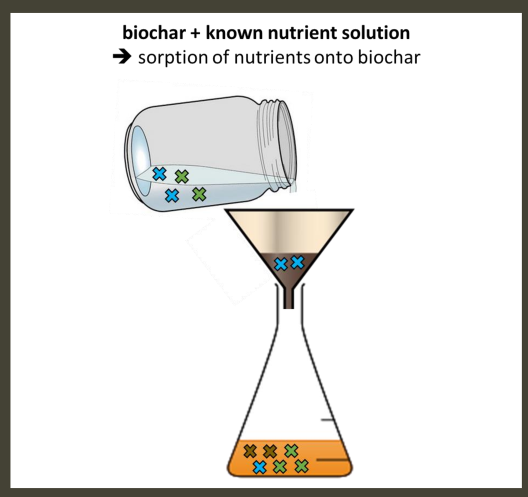

Fig. 2: NH_4^+-N sorption test

$$NH_4^+\text{-N sorption (mg } NH_4^+\text{-N g}^{-1}\text{ fresh biochar)} = \frac{Cb - Ce}{m} * V$$

With: Ce: NH_4^+-N concentration of the filtrate of the biochar treatment (mg L^{-1}), Cb: NH_4^+-N concentration of the filtrate of the blank treatment (mg L^{-1}), m = mass fresh biochar on the filter (g), V = volume of the nutrient solution (L)

NH_3 sorption test

$$\text{Relative } NH_3 \text{ sorption compared to sand (\%)} = 100 - \left(\frac{area\ under\ curve\ of\ biochar}{area\ under\ curve\ of\ sand\ (n=2)} * 100 \right)$$

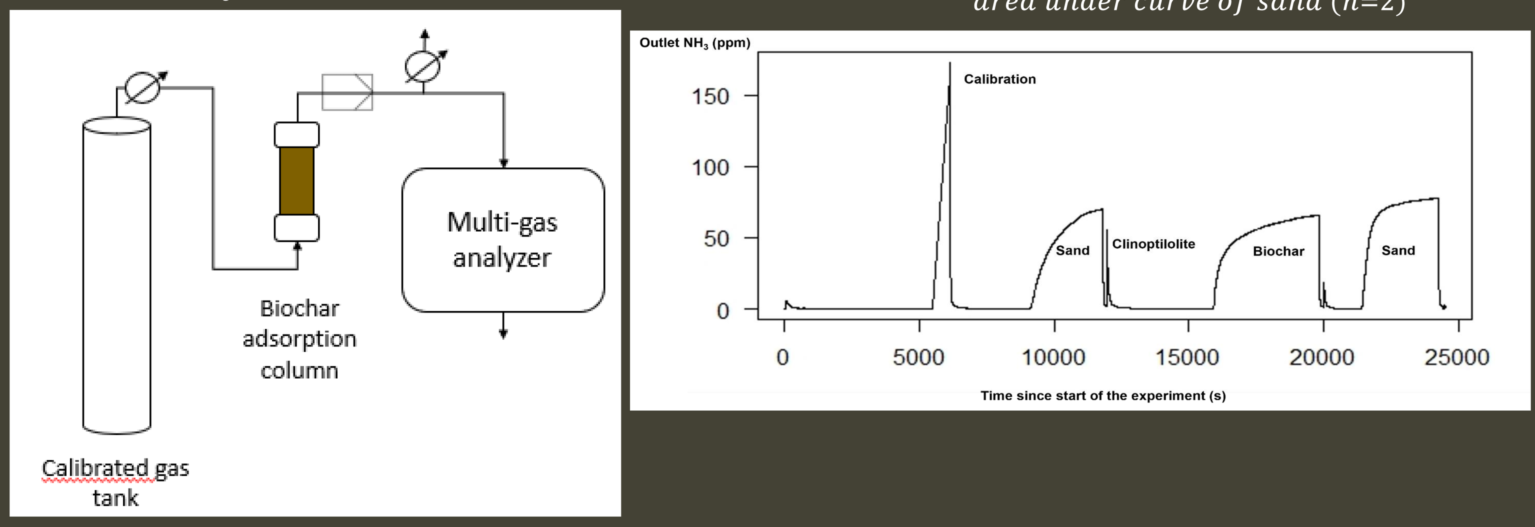

Fig. 3: Left: NH_3 sorption test. Right: Example of the output of the NH_3 sorption test

Results:

- NH_4^+-N sorption varied between 0 and 1.54 mg NH_4^+-N g^{-1} fresh biochar and was higher for manure-based biochars with a high nutrient content and cation exchange capacity, produced at lower temperatures (300-450 °C) (*Fig. 3*).
- For some biochars, the feedstock itself had a higher NH_4^+-N sorption than the biochar.
- Grinding and washing increased the NH_4^+-N sorption.
- A general linear model was proposed to give an indication of the NH_4^+-N sorption based on three chemical characteristics:

$$NH_4^+\text{-N sorption} = 0.02\ (\pm 0.10) + 0.0120\ (\pm 0.0030) * \text{total CEC} + 0.0199\ (\pm 0.0040) * \text{total P} - 0.0006\ (\pm 0.0001) * \text{ABC}$$

With: NH_4^+-N sorption in mg NH_4^+-N g^{-1} fresh biochar, cation exchange capacity (CEC) in cmolc kg^{-1} fresh biochar, total P in g kg^{-1} DM, acid-buffering capacity (ABC) in mmol H^+ L^{-1}, and standard error in between brackets.

- NH_3 sorption varied between 0 and 100 % of the negative control and showed a linear positive relationship with the NH_4^+-N sorption, moisture retention factor and cation exchange capacity (*Table 1*).
- Pyrolysis temperature and feedstock type did not significantly affect NH_3 sorption.
- Next step: validation of the fast screening tests in pilot-scale biomass processing experiments.

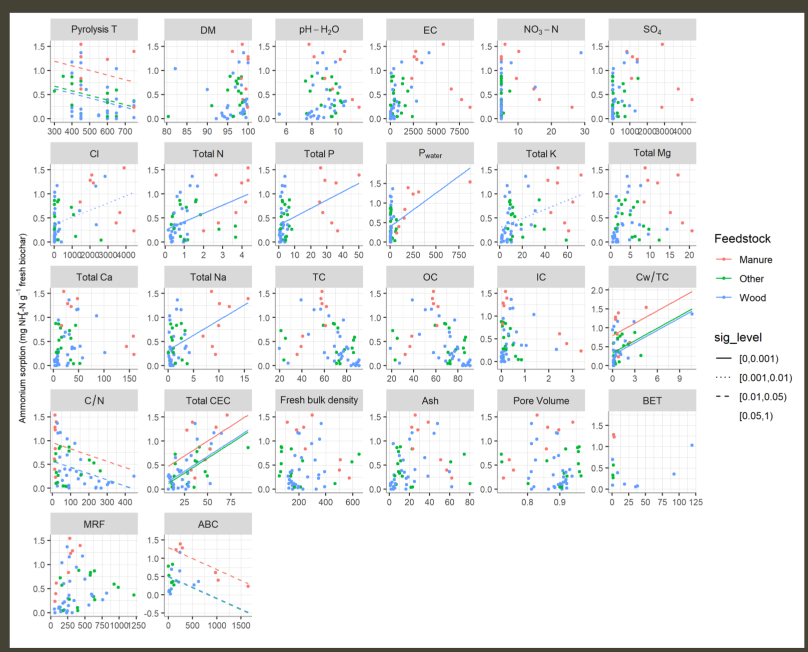

Fig. 3: Relationship between NH_4^+-N sorption and chemical characteristics of the biochars as given by the linear regression models

Biochar	% NH_3 sorption compared to negative control
B1_650_oak	99.7
B33_450_spstrawpeat	99.5
B39_450_frass	80.0
B42_750_frass	87.0
B41_600_frass	69.1
B21_450_pine	45.1
B22_550_pine	40.4
B43_450_gwaste	91.7
B53_450_gwaste	95.5
B44_600_gwaste	67.6
B36_450_coffee	-0.8
B37_600_coffee	61.4
B28_600_chickenmanure	-6.3
B24_450_willow	90.2
B25_550_willow	74.5

Table 1: NH_3 sorption of different biochars

More info: Viaene et al. (2022). *Screening ammonium and ammonia sorption of biochars for N mitigation during biomass processing. Waste Management. Under review.*

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