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Biochar and covering as optimisation strategies for cattle manure composting: Trade-offs in gaseous emissions and safety

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Abstract

Composting of livestock manure improves nutrient circularity and reduces health risks in smallholder farming systems of sub-Saharan Africa. Since composting requires regular turning and mixing of the manure for better aeration, this can lead to nutrient losses through greenhouse gas (GHG) and ammonia (NH_3) emissions. Given the importance of manure for farm productivity, developing optimised composting approaches and evaluating emissions, nutrient transformations, and compost safety is needed. A three-month outdoor composting experiment was conducted using cattle manure mixed with straw (4:1 w/w) and simulating conditions during solid manure storage in heaps. We evaluated five treatments: (i) unturned control (UC), (ii) turned (T), (iii) turned plus cover (TCov), (iv) turned plus 10 % biochar (TB), and (v) turned plus 10 % biochar plus cover (TBCoV). Mixtures of 200 kg were stored in 600 L plastic containers (n=3) that were equipped for gas measurements. Turning occurred three times during the thermophilic phase. Bacterial counts for Escherichia coli, coliforms, Enterococci and *Salmonella* were evaluated over the composting period.

Temperatures within the heap increased above the sanitisation threshold (50°C) in all composting treatments, and the biochar treatments had the longest thermophilic phase of 16 days. The UC treatment recorded the highest N_2O emissions, whereas emissions were reduced in TB and TBCoV by 61–77 %. Turning triggered high NH_3 emissions which were not reduced by covering or biochar addition, resulting in higher total NH_3 losses in the turned compost treatments. Changes in mineral N (NH_4^+ and NO_3^-) indicated that nitrification and denitrification dominated at different composting stages, while declining NH_4^+:NO_3^- ratios suggested progressive compost stabilisation during maturation. Composting treatments had CH_4 emissions during the thermophilic phase, indicating that anaerobic conditions developed inside the heap. Compared to the control, composting with biochar addition and covering reduced cumulative CH_4 emissions by 51–77 %. All composting strategies showed significant reductions in the four indicator pathogen species with temperature the main driver for pathogen reduction. We conclude that covering and biochar addition during cattle manure composting are promising low-cost interventions to

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reduce CH_4 and N_2O emissions, but not NH_3 losses, while producing a sanitary and safe organic fertiliser for sustainable crop production.

Keywords: Ammonia, crop-livestock integration, methane, nitrous oxide, nutrient circularity