Effect of a semi-permeable membrane covered composting on greenhouse gas emissions and bacterial community succession: A comparative study with biomass materials covering

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Aerobic composting has emerged as a sustainable method for the harmless treatment, reduction, and resource utilization of livestock manure (Wang *et al*, 2022). However, it is important to note that massive emissions of NH_3, CH_4, and N_2O are produced during composting, leading to both nutrient loss and air pollution (Bai *et al*, 2016; Zhang *et al*, 2021). Covering is a widely adopted technique to reduce gas emissions in aerobic composting. Numerous studies have suggested that covering biomass materials during manure composting could not achieve a synergistic reduction of polluting gases, and that abating a single pollutant might lead to increases in others (Yang *et al*, 2023). Compared to biomass-covered composting, membrane-covered composting exhibits significant gas synergistic emission reduction effects (Ma *et al*, 2021). Currently, there were few studies on the physical and chemical properties, structural characteristics and microbial community changes of the covering itself. Furthermore, there was a limited number of comparative studies investigating the reduction of pollutant gas emissions in the composting process using biomass covering materials and membrane.

Therefore, this study aimed to achieve the following objectives: (i) Explore the effects of biomass materials (cornstalk and sawdust) and semi-permeable membrane covering on the physicochemical indicators and emissions of greenhouse gases (N_2O, CH_4 and CO_2) and NH_3 during sheep manure composting. (ii) Investigate the succession of bacterial communities in sheep manure and covering materials, and establish their relationships during composting. (iii) Analyze both biological and non-biological factors that influence greenhouse gas emissions. The objectives of this study were to shed light on the impact of different covering materials on gas emissions, microbial community dynamics, and the underlying factors driving greenhouse gas emissions during composting.

This study investigated the effects of cornstalk, sawdust, and semi-permeable membrane covering on gaseous emissions and bacterial communities during composting, and the physicochemical and biodegradable characteristics of covered compost piles. The results showed that cornstalk covering increased NH_3 emissions by 1.5% and reduced N_2O emissions by 47.0%, and the sawdust covering synergistically reduced NH_3 and N_2O emissions by 42.1% and 23.2%, respectively. The biomass materials covering reduced gaseous emissions through physical adsorption and biotransformation. Total nitrogen (TN) emissions increased from 12.50 to 35.90 $g \cdot kg^{-1}$ for cornstalk and from 1.60 to 7.10 $g \cdot kg^{-1}$ for sawdust, while the nitrogen-reducing bacteria substantially increased from 0.21–0.28% to 1.98–2.44% in biomass covering materials. The biomass materials covering increased electrical conductivity and reduced the diversity and network complexity of bacterial communities in compost. Finally, the lignocellulosic structure and functional groups of the biomass materials were destroyed, thus biomass material could not be reused. Correspondingly, the membrane covering simultaneously decreased NH_3 emissions by 53.9% and N_2O emissions by 71.3%. In addition to physical interception, the nitrogen-reducing bacterial communities enriched on the membrane surface (*Georgenia* and *Limnobacter*) further reduced NH_3 and N_2O emissions. The bacterial communities in membrane-covered treatment exhibited concentrated connections and potential cooperation. As a result, the membrane covering achieved higher maturity and better reduction performance of gaseous emissions. Characterization of covering materials revealed that the membrane structure was intact and could be reused. Interestingly, after composting, the membrane surface formed a “microbe-rich biofilm", which exhibited better performance in subsequent covering processes.

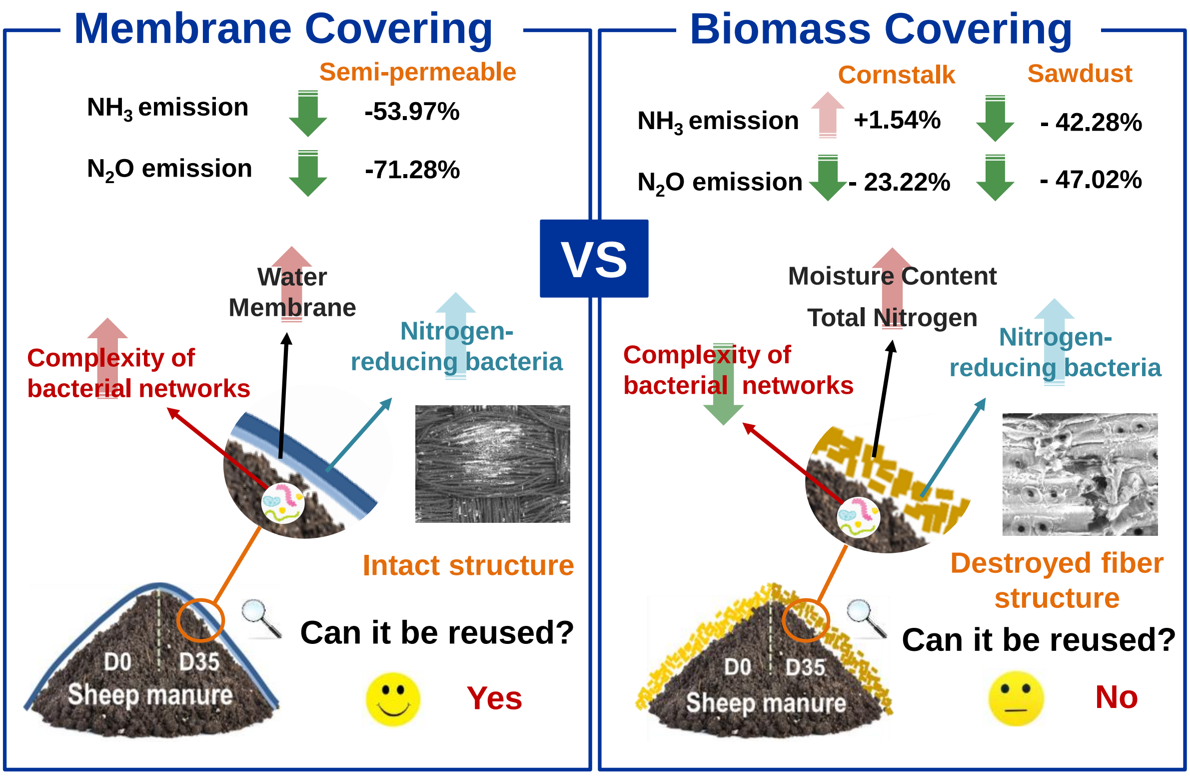

Figure 1. Graphical Abstract

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