学位論文内容の要旨

博士の専攻分野名称：博士（農学）　　氏　名：Yunsik SHIN

学位論文題名

Effect of adding biochar to suppress ammonia emission
during livestock manure composting process
（家畜ふん堆肥化過程におけるアンモニア揮散抑制を目的としたバイオ炭添加の効果）

In modern agriculture, composting is crucial for managing different agricultural wastes, including livestock manure. However, ammonia emissions during manure composting pose significant challenges, such as odors, air pollution, human-health risks, and nitrogen loss. While various mitigation strategies have been developed, including physical, chemical, and biological methods, they often face limitations, particularly under high ammonia concentrations. Biochar, a by-product of biomass pyrolysis, has emerged as a promising solution due to its large surface area, high adsorption capacity, and ability to influence microbial activity, which can help reduce ammonia emissions. However, its full potential in enhancing existing ammonia removal techniques remains underexplored. Hence, this study investigates how biochar can improve the performance of two representative ammonia mitigation methods—additives during composting and biofilters—towards achieving zero ammonia emissions during composting.

1. Low-temperature biochars are more effective in reducing ammonia emissions through various mechanisms during manure composting

Biochar application during composting (co-composting) is valued for biochar's large pore volume, oxygen-containing functional groups (OFGs), and nutrient content, which enhance NH_3 adsorption and nitrification. However, the effectiveness of biochar depends on its production conditions, such as type of feedstock used and pyrolysis temperature. To maximize its performance, we investigated how biochar properties affect ammonia reduction during composting. Biochars were produced from dairy manure and Japanese larch at 300 and 800°C. The composting experiments were conducted by mixing biochar (12 g) with dairy manure (300 g). Biochars produced at 300°C were more effective in reducing ammonia emission during composting than those made at 800°C. This was attributed to their higher content of OFGs, cation exchange capacity, ash content, and lower pH, which enhance ammonia adsorption and nitrification. However, despite the

effectiveness of biochar, some ammonia emissions remain unavoidable during composting, indicating that biochar addition may not be sufficient to achieve zero ammonia emissions during composting.

2. Mixing biochar with compost biofilters to improve removal of ammonia

Compost biofilters offer a promising solution for complete ammonia removal by combining adsorption with biological processes. However, during manure composting, high ammonia concentrations can inhibit microbial activity within biofilters, reducing their efficiency. Maintaining microbial activity is essential for continuous ammonia removal. To address this challenge, we added biochar to the compost biofilters (co-biofiltration). We hypothesized biochar's high adsorption capacity and large surface area can help capture ammonia directly, reducing its toxicity to microbes. We explored the effect of co-biofiltration using dairy manure biochar (produced at 300°C) at different ratios (0 to 50%) under ammonia concentrations of 1000 and 2000 ppm. All biochar-mixed biofilters showed improved ammonia removal at both concentrations, with the 25% biochar-mixed biofilter achieving the highest performance. Ammonia removal in biofilters occurred through NH_3 adsorption, chemical precipitation, nitrification, and denitrification, all enhanced by biochar at 1000 ppm. However, at 2000 ppm, microbial activity was still inhibited even with biochar due to rapid ammonia accumulation. These findings suggest that compost biofilters can achieve continuous and complete ammonia removal at lower ammonia concentrations, which can be further enhanced by mixing biochar. Therefore, to ensure continuous complete removal of ammonia, it is crucial to reduce ammonia concentrations during composting. In this context, the integration of co-composting and co-biofiltration may offer a promising approach in achieving zero ammonia emissions.

3. Combining system of co-composting and co-biofiltration with biochar for continuous zero ammonia emission during composting

The next phase of the study investigated the synergistic effect of co-composting and co-biofiltration on ammonia removal during composting. Both biofilters (with or without biochar) achieved complete ammonia removal by reducing ammonia emissions during composting through co-composting. Co-biofiltration, in particular, enhanced the long-term reuse potential by improving nitrification during co-composting.

Overall, the findings of this study demonstrate that zero ammonia emissions can be achieved during manure composting, with biochar playing a pivotal role through the combined processes of co-composting and co-biofiltration.