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Nitrogen conservation in swine manure composting—land application systems

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Abstract: *The use of bedding in the popular hooped houses for swine production generates large volumes of manure that composts easily. However, composting results in nutrient losses, especially for nitrogen, which then diminish its value as a fertilizer. This study looks at carbon and nitrogen dynamics in the composting process and subsequent soil mineralization.*

Background

Manure management is an important issue in hooped house swine production systems. A large volume of manure is generated, requiring considerable labor to spread on cropland, and the nutrient value of the manure is highly variable. Composting reduces the volume and weight of the manure for ease in spreading, but composting also results in nutrient losses, particularly nitrogen lost through ammonia volatilization and denitrification, with reported losses ranging from 21 to nearly 77 percent. Conservation of nitrogen during composting and subsequent availability of carbon and nitrogen in the soil are particularly important for integrated crop and livestock farms, where manure plays a key role in energy and nutrient cycling.

Project objectives were to evaluate:

- The effectiveness of different nitrogen conservation strategies applicable to the swine manure composting process,
- The rates of nitrogen release to soil from compost of various levels of stability,
- Strategies for enhancing the efficiency of nitrogen utilization, and
- The impacts of compost application on microbial activity and soil structure.

Approach and methods

This study addressed carbon and nitrogen dynamics as influenced by the composting process and land application of the compost product. Typical rates of carbon and nitrogen loss from the hoop manure composting process were measured in twelve 90-liter (L) bioreactors, designed to simulate the typical windrow composting process.

Four trials with bioreactors were completed, one focusing on the effects of moisture during composting, a second evaluating different bedding rates and thus increased C/N ratios, and the third and fourth examining alternative management strategies expected to reduce nitrogen loss during composting. The management strategies considered were:

- The addition of topsoil to the mixture to provide extra exchange sites for nitrogen, and
- The application of a layer of stabilized compost on top of the pile as a “biofilter” to trap ammonia in the exhaust gas stream.

Each of the trials consisted of four treatments, including a control with unaltered hoop manure, and each treatment was replicated in three individual bioreactors. Compost was mixed and sampled weekly to observe N transformations, and on weeks 0, 2, 4, and 6 samples were collected for laboratory incubation to measure soil C and N mineralization. Dried,

ground composts were blended with equal parts of quartz sand and soil and incubated aerobically for 28 days at 30º C.

Results and discussion

The composting process in the 90L bioreactors generally simulated observations in full-scale systems with similar materials, although moisture content tended to increase due to condensation in the exhaust systems in the bioreactors, which contrasts with the drying normally observed in outdoor windrow systems.

There was a trend to reduced ammonia volatilization and total N losses with increasing C/N ratio mixtures. While the biofilter and high C/N ratio treatments did appear to have the desired effect on reducing N losses, the trend was only statistically significant for the high high C/N treatment.

The release of N from manure in the soil is controlled by the balance among immobilization of mineral N (nitrate, nitrite, and ammonium) into microbial biomass, mineralization of organic N (from manure and biomass) to mineral forms, and losses of N via leaching, ammonia volatilization, and volatile losses of N_2O and N_2 through denitrification. These processes are influenced by the availability of substrate (C/N ratio, compost stability, and maturity) and environmental conditions in the soil (moisture, pH, and oxygen status). Mineralization of manure C is usually coupled with these processes in soil.

Conclusions

This study was able to simulate large-scale compost processes effectively at a pilot scale, allowing controlled investigations into parameters that impact biodegradation and N-losses during composting, as well as subsequent C and N mineralization in the soil. The C/N ratio decreased over the course of the experiments, while the concentration of total N increased. On a mass basis, carbon, nitrogen, and moisture decreased by an average of 49, 25, and 19 percent respectively, across three trials.

Replication of environmental conditions within the three reactors in each treatment was generally quite good, although some individual reactors occasionally deviated from the norms. Despite the generally good replication of compsoting process variable within treatments, a large degree of variability in C, N, and water losses was observed. An unexpected outcome of this research was the large gap between measured N losses as NH_3 and total N losses, which could also include N_2O and N_2 as products of nitrification/denitrification.

In this study, the investigators quantified C and N mineralization in composted swine manure mixed with corn stalks at varying ratios composted for varying lengths of time, both of which can effect the C/N ratio of the composted manure. The organic C and N in composted manure are humidified and relatively stable. The addition of composted material to soil therefore resulted in less microbial activity relative to fresh manure, as indicated by CO_2 evolution in the incubation trials.

Three general conclusions can be drawn from the soil incubation component of the study:

1. Organic substrates that did not degrade because of suboptimal conditions during the composting process may readily mineralize after compost incorporation in soil, where moisture and C/N ratio constraints are reduced. Therefore, cumulative carbon mineralization in compost-amended soils following suboptimal compost conditions can be increased relative to similar-aged composts.
2. Compost produced after several weeks of intensive composting under near-optimum conditions may not result in net N miner-

alization after soil incorporation. The dynamics of mineralization, nitrification, denitrification, ammonia volatilization, and N cycling through the microbial biomass are complex in soil systems, and can be affected by compost feedstock, processing conditions, and time.

3. Denitrification may severely limit N availability from compost when the compost is applied to agricultural soils.

These results indicate that bedding management and environmental conditions during livestock production have a substantial impact on C and N dynamics during composting and subsequent soil mineralization. Ultimately, further understanding of these processes can help farmers develop compost products that synchronize nitrogen release and crop-uptake and improve the overall quality of the soil.

Impact of results

By demonstrating the practical values of composting and compost use, as well as identifying potential challenges related to N losses and availability, the study has raised the overall farmer interest in more sustainable manure management systems in Iowa. Several Practical Farmers of Iowa and Farm Bureau cooperating farmers are participating in a follow-up study on the plot and field-scale effects from hoop manure and hoop manure compost use.

Scientific impacts of the study include the recognition that nitrification/denitrification is a central process to N-cycling both during composting and subsequent compost utilization. This has two important implications for sustainable manure management. First, much more attention must be paid to controlling the volatile N losses during composting, as they not only represent a waste of nutrient losses, but also unleash a potent greenhouse gas. Second, these nitrification/denitrification losses appear to play a major role in N availability in soil from composted manures, creating challenges in processing and timing for optimum compost utilization. Some of these issues are being addressed by related projects, but those investigations are occurring at plot and field scales and are not designed to control these processes, but only to document their effects. Better understanding of the fundamental mechanisms that control nitrification/denitrification as well as other N-losses during composting and compost utilization should be a major topic of future work.

Education and outreach

Two scientific publications based on this project's findings are being written. The work of two graduate students was supported by this project. Results from the study have been presented at a wide range of forums, including farmer organization meetings, ISU Extension events, and academic seminars. Producer sessions included the Practical Farmers of Iowa annual meetings and cooperators meetings, and the Swine System Options conference in 1999. Presentations were made at Rhodes Farm field days and at a conference on the microbiology of composting in Innsbruck, Austria.

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