AERATION EFFECT ON NITROGENOUS EMISSIONS DURING THE COMPOSTING OF TURKEY OR CATTLE MANURE

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ABSTRACT

In the last years, there is increasing interest in controlling the pollutant emissions of farm techniques. Composting belongs to the recycling techniques for agricultural wastes. Aeration is one of the most important factors because composting is basically an aerobic transformation of organic matter. The aim of this study was to determine the effect of aeration on nitrogenous emissions during the composting of turkey and cattle manure as generated by farm-scale management practices: moisture increase, compaction and turning.

Around one ton of cattle manure and three tons of turkey manure were composted in six cells for 46 days. The cattle manure was turned or not turned, the turkey manure was either moistened, compacted or stored. Temperature, mass, moisture, carbon and nitrogen content, porosity, bulk density, heap volume and emission of ammonia and nitrous oxide were monitored.

The results show that for similar manure the aeration increase induced higher ammonia and nitrous oxide emissions. In the case of cattle manure, the overall nitrogenous emissions were lower than that of turkey manure despite the turning. It was due to the higher carbon availability and the lower nitrogen availability reflected by the higher C:N ratio.

Therefore, the management of aeration should take into account the carbon availability in order to control the nitrogenous emissions when composting organic materials with high nitrogen availability.

INTRODUCTION

There is increasing interest in controlling the pollutant emissions of farm techniques. For the windrow composting technique, aeration is generally achieved by turning the windrows periodically. While composting allows simple management of animal manure, excessive aeration can increase emissions of polluting gases such as ammonia or nitrous oxide. It has been suggested that intensive management of compost transformation is not necessary when time and the area available for composting are not constraints (Golueke, 1973). Aeration is one of the most important factors because composting is basically an aerobic transformation of organic matter where O_2 is consumed, and gaseous H_2O and CO_2 are produced (van der Werf and Ormseth, 1997). Losses of nitrogen compounds during decomposition of animal wastes in the first stage of composting occur through emission of gases such as NH_3 and N_xO_y. The emissions are the result of physical and biological reactions. Increased free air space can directly increase air renewal or the area of the gas/liquid interface. In addition, the free air space increases both the oxygen diffusion and the insulation coefficient. This leads to heat production and temperature increase. Although free air space is primarily related to particle size, compacting can reduce it. Any form of compaction that reduces the free air space will reduce air permeability (Singley et al., 1982) and the natural air convection which is increased by the wind. Adding water can reduce free air space and aeration while turning can increase aeration. Compaction and water addition modify the free air space in different ways: compacting reduces the free air space in the macropores whereas adding water reduces the free air space, initially at least, in the micropores. Therefore, compost management practices which modify aeration through turning, compacting or changes in water content are likely to affect the nitrogenous emissions as well as carbon dioxide and water vapor losses. The aim of this study was to determine the effect of aeration on nitrogenous emissions during the composting of turkey and cattle manure as generated by farm-scale management practices: moisture increase, compaction and turning.

MATERIALS AND METHODS

Around one ton of cattle manure (C) was collected in the center of a dairy cow building, homogenized, transported and composted in two heaps for 46 days. We chose a cattle manure with a rather high carbon content in order to evaluate to what extent turning can increase the nitrogenous emissions when they are supposed to be low. Three tons of turkey manure (T) were collected from a commercial facility where the turkeys were bred on wood shavings and straw. It was first homogenized, then transported and composted in four heaps for 51 days. We chose a turkey manure with a rather high nitrogen content in order to evaluate to what extent compaction or addition of water can be used to reduce the nitrogenous emissions when they are supposed to be high. The experimental arrangement consisted of four isolated cells (area: 3.5 m^2; volume: 8 m^3) laid out in an experimental building with controlled temperature. In each of them, a heap having the shape of a half windrow was made. The first heap of cattle manure was not turned (C); the second (Ct) was turned twice after 15 and 30 days as it is recommended by the french "Institut de l'Elevage". For the turkey manure, water was added in two treatments (Tw, Twc), while the two others remained dry (T, Tc). The heap was compacted in two treatments, one wetted (Twc) and one dry (Tc), whereas it was not compacted in the two others (Tw) and (T). The air flow rates were measured continuously with four hot-wire anemometers (Tsi 8450, Fig. 1), controlled manually with a propeller-anemometer (Air flow LCA6000) and by checking the law of air renewal by density differences (Souloumiac and Itier, 1989). Psychrometers equipped with iron-constantan thermocouples measured air temperature and humidity. Compost temperatures were measured by six iron-constantan thermocouples. All measurements were made each minute, averaged every 30 minutes, and stored on two AOIP dataloggers (SA120 and SA70) and one Campbell 21X datalogger. Water, ammonia and nitrous oxide concentrations were measured continuously inside and outside the cells with a spectrophoto-acoustic gas analyzer (Bruel and Kjaer, 3426). Carbon dioxide was measured with an infrared sensor (Edinburgh sensors, gascard II). We checked the absence of NOx (less than 0.1 ppm) with Dräger tubes. Emissions were calculated from the concentration gradient and air flow rates. The air density was deduced from temperature and humidity measurements. The initial manure and the final compost were analysed for water content, carbon and nitrogen. The volume of the heaps was monitored each week. The free air space was deduced from the mass, dry matter and water measurements and assuming a density of the organic matter equal to 1600 kg/m^3.

RESULTS AND DISCUSSION

The temperature, gaseous emissions, and mass measurements show that turning, which theoretically increases natural aeration, induced higher compost temperatures and losses. Conversely, adding water and compacting, which theoretically should reduce the free air space, reduced them. However, we observed that free air space did not increase with turning whereas it decreased with compaction and water addition. The ammonia and nitrous oxide emissions of turkey and cattle manure observed in our experiments are illustrated in Figures 1 and 2. The emissions from the turned cattle manure were higher than when it was undisturbed.

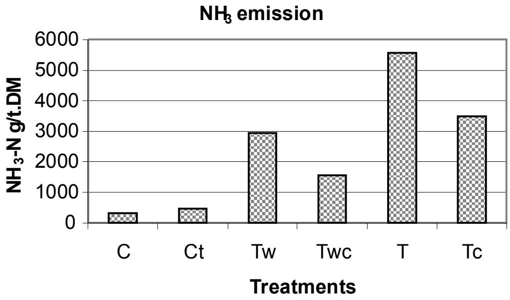

Figure 1. *Ammonia emissions.*

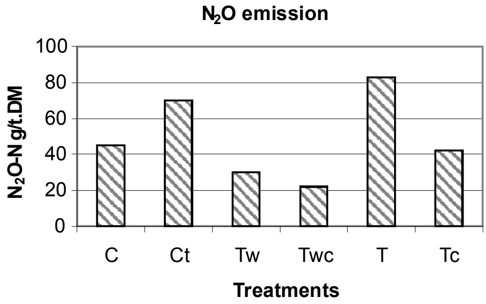

Figure 2. *Nitrous oxide emissions.*

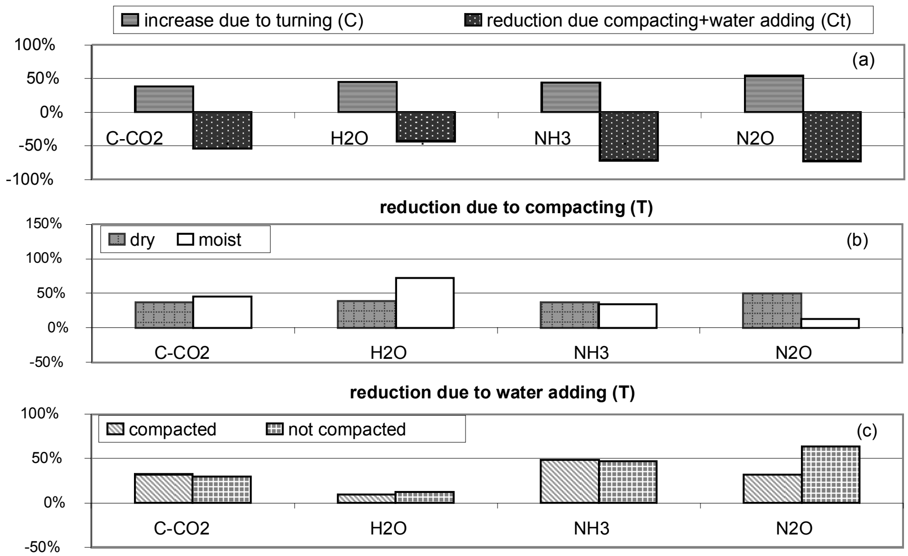

Figure 3. *Effect of turning, compaction and addition of water on the emissions.*

We suggest that the free air space distribution in the turned cattle manure was more efficient for gas diffusion than in the un-turned manure. For similar free air space between 55 and 70% (C, Ct, T, Tc), the nitrogenous emissions of turkey manure were much higher than those of cattle manure: this can be explained by the higher C:N ratio of the cattle manure (Kirchmann and Witter, 1989; Martins and Dewes, 1992; Ekinci et al., 2000; Sommer, 2001). We hypothesize that the high C:N ratio lead to good N organization by the microbiological biomass, while nitrification was stimulated by the temperature decrease. This resulted in a drastic decrease of NH_4^+ in the solution, which is the precursor of NH_3 emission (Witter and Lopez-Real, 1987). For the Twc heap, the lower temperature (35-38 °C) and the lower free air space explain the lower ammonia emission. Nitrous oxide emission was higher in the heaps of cattle manure than in those of turkey manure, especially after the turnings. The nitrous oxide emission in the turkey manure was already high at the start, suggesting N_2O production in the manure before the compost pile was made. It decreased immediately after the pile was made. Nitrous oxide emission in the turkey manure was much lower than the ammonia emission (the NH_3: N_2O ratio being about 100:1 in the first few days), while the nitrous oxide emission in the cattle manure was similar or slightly higher than the ammonia emission after the first and the second turning. We assume that denitrification, not nitrification, caused the higher N_2O emission of cattle manure compared to turkey manure, though nitrifiers as well as denitrifiers could cause nitrous oxide emissions in all heaps. Denitrifiers are mostly heterotrophs relying on organic carbon to retrieve energy. The N_2O production should be proportional to the available carbon, as commonly identified (Burford and Bremner, 1975; Cabrera et al., 1994), and in our case the C:N ratio was higher in the cattle manure. In Figure 3, we see that turning, compaction, and addition of water highly modified the emissions. The turning increased the emissions but their order of magnitude was not changed, i.e. the carbon dioxide and water emissions of the cattle manure were higher, the ammonia emission was lower, the nitrous oxide emission was similar than those of turkey manure. The compaction and the addition of water reduced the emissions but did not change their order of magnitude. CO_2 and NH_3 emissions were reduced in a similar way by either compaction or addition of water (to about 50%), whether the heap was wetted or compacted. Compaction had a much higher effect than addition of water on the reduction of water loss (70-80% vs 10-30% of the total reduction) meaning that compaction should be done after turning when water has to be conserved when composting dry materials. Water addition also reduced the $[NNH_3 + NN_2O]:CCO_2$ ratio, meaning that the nitrogen conservation was higher.

Therefore, aeration management should take into account the carbon availability, and when composting materials with low availability, moist composting should be preferred in order to reduce polluting emissions.

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