Estimation of nitrogen loss from pilot and large scale composting by ammonia measurement and N/P ratio changes

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Introduction

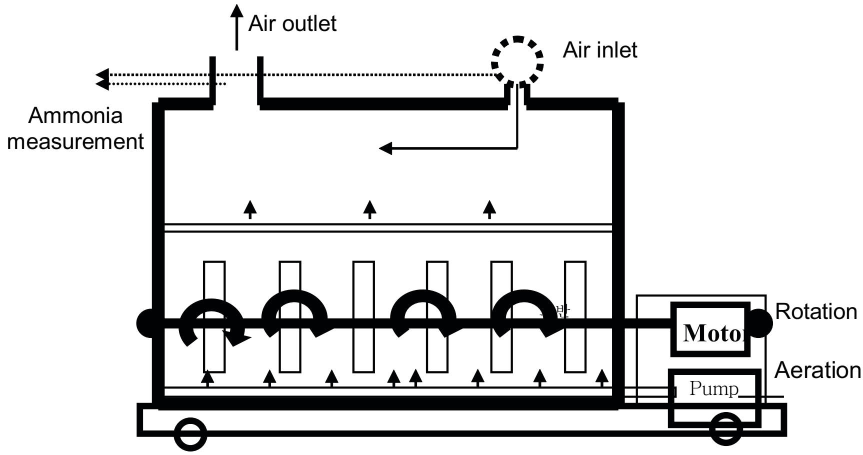
Korea has relatively high livestock density. In 1.8 million hectares of agricultural land, the number of swine, cattle and poultry were 9.4, 2.5 and 119 millions in 2006, respectively. Ministry of Agriculture estimated about 44 million tons of animal manure produced in 2006, and more than 80% of animal manure produced in Korea was processed as composts. Because of handling and sanitary problems, farmers prefer compost rather than liquid manure for fertilization. However, it causes some problems, ammonia emission and unbalanced N:P ratio for fertilization in most cropping systems. More than 60% of agricultural land in Korea was estimated for phosphorous surplus, mainly caused by over dose of compost. More than one thousand of commercial composting factories and many farm scale composting facilities are under operation, and most of composting processes are open types with forced aeration. It assumed that ammonia emission rate during composting was relatively high in such conditions. But, nitrogen loss during composting process, mainly by ammonia, has not been well elucidated. Many experiments on ammonia emission during composting process were conducted in small scale (Jeong and Kim, 2001). Ammonia emission is influenced by composting scale and composting file types (Fukumoto et al., 2003). Also, depending on manure types, animal housing and manure treatment methods, ammonia emission rates are varies. There are many technical problems in measuring ammonia during open type large scale composting. Nitrogen loss could be estimated by using the fact that phosphorous is immobile contrast to nitrogen during composting. Moreira (2006) measured volatile nitrogen loss from dairy manure in a barn by using the change of N:P ratio. The objective of this study was to estimate the nitrogen loss during small and large scale composting processes by using direct measurement of ammonia and the change of N:P ratio in composting material.

Materials and Methods

For pilot scale composting, composting chamber was constructed (Fig. 1). About one cubic meter of composting was conducted with 10 L min^{-1} aeration alternately every 15 min for 25 days. For composting, 350 kg of solid part of pig slurry and 64 kg of saw dust were mixed, and its moisture content was 65%. Composting materials were mixed by rotation once a day for 15 min. Ammonia emissions were measured using an open chamber techniques with forced aeration. Concentrations of ammonia were measured every 30 minutes at the air inlet and outlet of the composting chamber using a photoacoustic infrared gas analyzer (INNOVA). Also, ammonia emissions were measured by acid trap (0.05 N H_2SO_4) at same ammonia gas sampling positions of composting chamber. The quantity of emitted ammonia was calculated by multiplying the ammonia concentration with air volume in every 30 min for gas analyzer, and every 24 hours for acid trap.

For monitoring of nitrogen loss in large scale composting process, a typical composting factory in Korea was chosen. Composts were produced in open type by rotary device with forced aeration, and composting file was 6 meter wide and 65 meter long. At the beginning of composting, solid fractions from liquid/solid separation process of swine manure slurry were mixed with sawdust and other livestock manure and settled without rotation for 2 weeks. Then, pretreated materials were transferred to main composting facility, and composted for 60 days in summer and for 80 days in winter season. No leachate was produced in compost file during composting process. Compost samples were collected in different places which represent composting periods.

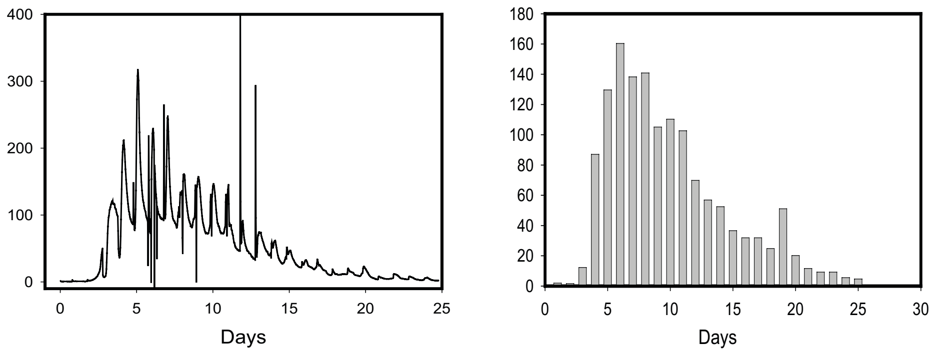
Fig 1. Diagram of pilot scale composting utility



Ammonia emissions in pilot scale composting

Pilot scale composting experiments were conducted twice in summer and late fall. After composting started, temperature reached 75°C in 5 days, ammonia emission rate increased rapidly in 3 days. Sudden spikes in ammonia concentration were shown often when gas analyzer was used for ammonia measurement. It was caused by the case of ammonia measurement during composting materials were mixing for 15 min every day. In summer experiment, 40 % of total nitrogen in composting materials was lost by ammonia emission when measured by photoacoustic infrared gas analyzer. And, acid trapping method showed 37 % of nitrogen loss by ammonia emission in the same experiment. The difference might be caused by the handling of samples for acid trapping or others.

Fig 2. Ammonia emissions measured by photoacoustic infrared gas analyzer(left) and acid trapping(right)

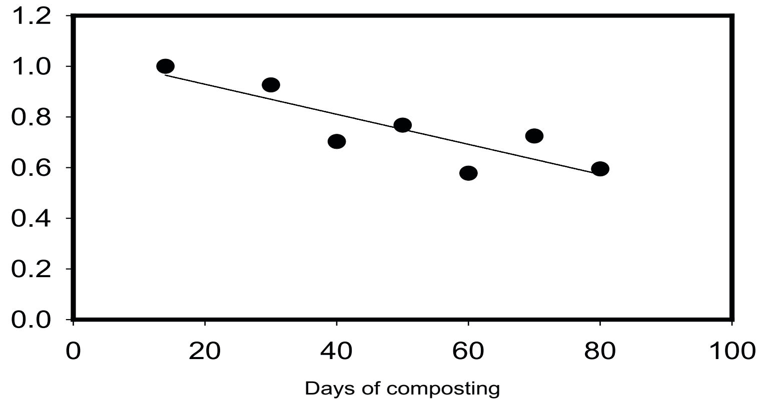


In second experiment in late fall, only photoacoustic infrared gas analyzer was used for quantifying ammonia emission. In the experiment, 35% of total nitrogen was emitted by ammonia. Difference between summer and fall experiments may be caused by outside temperature of compost reactor. Lower temperature possibly impacted on the lower emission rate in late fall season experiment. In pilot scale composting experiments, nitrogen loss by ammonia emission reached between 35 and 40% in a month of composting periods.

Estimation of nitrogen loss by N:P ratio changes in large scale composting

Because direct measurement and quantification of ammonia loss during large scale composting process is difficult, simple measure was tried to estimate nitrogen loss. For the estimation of total nitrogen loss during composting, changes of N:P ratio before and after composting process could be a simple solution, though it includes nitrogen loss by denitrification besides ammonia volatilization. Analysis of composts for N:P ratio was conducted twice, summer and late fall. Composting processes were finished in 60-65 days in summer season, and 80 days in fall and winter season. Though composting periods were differ in two seasons, nitrogen losses were about 40 % based on N:P ratio changes. Many factors affect on ammonia emission during composting. It includes aeration, C:N ratio, size of composting files and types of law materials for composting (Kirchmann et al., 1989). Composting facility in this experiment is most common in Korea, which is open type with continuous mixing by rotary device and with forced aeration.

Fig 2. Estimation of nitrogen loss by using the changes of N/P ratio during industrialized composting process with forced aeration



Nitrogen amount of animal manure in Korea, which was available for agriculture except waste water process, was estimated 270 thousands tons in 2006. Since the most of animal manures for fertilization are processed as compost, roughly 100 thousands tons of nitrogen could be lost before it reaches the agricultural fields, if above experimental data were accepted as general in Korea. Even this amount of nitrogen loss will be increased if nitrogen loss in animal housing and during field application were included in this figure. This emission rate from livestock industry is relatively high compared to other EU countries (Hutchings et al. 2001).

Conclusions

Because of agricultural crop production system in Korea, which has small agricultural land and high livestock intensity, composting became a major animal manure treatment system. Experiment conducted in pilot scale and a typical composting factory in Korea showed relatively high ammonia emission and nitrogen loss (35-40% of total N). Although, environmental impacts caused by ammonia emission and deposition have not been evaluated yet in Korea, large quantity of nitrogen/ammonia loss rate during current composting system tells us the necessity of introducing some technical and policy measures to reduce ammonia emissions during animal manure treatment in Korea.

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