Biofiltration Using Stabilizing Compost of Ammonia Gas from Composting Manure

축분 퇴비화 암모니아 가스의 안정화 퇴비에 의한 생물학적 탈취처리

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Abstract

Hog manure amended with sawdust (moisture 56~60% wet basis, C/N 19-21) was composted in pilot-scale vessels using continuous aeration(CA) and intermittent aeration(IA) for 3 and 4 weeks. In two subsequent runs of the same duration, composts resulting from each of the first runs were used as a biofilter on the exhaust gas from newly composting material. Conditions between each of these paired sets appeared to be similar. Ammonia was released from the biofilter material during the first week of stabilization while the compost produced ammonia after the first week of composting. In both cases substantial absorption, 61~96 %, of ammonia production from the composting raw material was achieved in the stabilizing material during the final weeks of operation and indicates the use of the stabilizing hog manure/sawdust compost as a biofilter can reduce ammonia emissions. Total NH_3-N emissions during run 2 in IA was less than 2/3 of those in CA. Dry solids loss for the stabilized compost (6~8 weeks) was 19~46%.

I. Introduction

Livestock industries have become increasingly aware of environmental issues of odor and nutrient management associated with the production, storage treatment and utilization of animal wastes (Boersma and Murarka, 1995; Kreis, 1978; O'Neill and Phillips, 1992; Sutton and Power, 1996). Particularly for concentrated animal feeding operations, manure utilization and emissions of NH_3, H_2S, volatile fatty acids and aromatic compounds (phenol, p-cresol, indole, skatole, etc.) are of concern(Schaeffer, 1977; Chen et al., 1994; Miller, 1993). These issues are major constraints to the profitability and growth of livestock industries.

Composting is the biological decomposition of organic wastes under controlled conditions to a state where storage, handling and land application

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Keywords : ccomposting, aeration, biofiltration, ammonia emission, decomposition, stabilization

can be achieved without adversely affecting the environment (Hansen et al., 1995). It is seen as one approach to nutrient management which also has the potential to produce a value added product (Keener et al., 2000). However, with composting NH_3 and other odors such as volatile fatty acids are either decomposed or emitted (Elwell et al., 2000).

The composting process is usually divided into two phases: an initial microbially active phase during which easily degradable substances are decomposed by an increasing microbial population (Hong, 1994) and a stabilizing (curing or maturation) phase that is characterized by the formation of humus compounds and loss of phytotoxicity (Witter and Lopez-Real, 1987). The initial decomposition phase will have elevation of temperature and may last from one day to a few weeks. During this phase there is a rapid accumulation of ammonium that may result in an elevation of pH and high ammonia losses.

Stabilized compost along with other media such as yardwaste, loam soil and woodchips has been used in biofilters to achieve odor removal and with proper design and operation can provide highly effective odor control (Janni and Nicolai, 1999). Biofilters operate most efficiently at a moisture content of 50 to 70% and a temperature between 15 and 35℃ (Haug, 1993). Biofilter performance seems to drop when temperature exceeds 40℃ and it is common for a biofilter to have a pH between 6.5 and 7.5 for proper microbial activity (Toffey,1997). Recent studies on biofilters for treating air from swine buildings and dairy manure holding pits indicated reductions of 55% in NH_3 and 85 and 88% in H_2S respectively (Janni and Nicolai, 1999). Hong (2001) presented data on ammonia emissions from hog manure composting under continuous and intermittent aeration. A study by Hong et al. (2001), indicated that biofilter with 50% woodchips and 50% manure compost by weight mixture had a 100% removal efficiency at a media depth in the range of 40 to 60 cm for ammonia odor removal from composting manure.

The goal of this research was to determine the potential for beneficial utilization of the stabilizing compost as a biofilter material during the composting of hog manure mixed with sawdust.

Ⅱ. Materials and Methods

For this research study, the experimental treatment examined the effects of biofiltration using compost during its stabilization period. This pilot-scale work was conducted in 208 liter vessels that have been described elsewhere in greater detail (Hong et al., 1998). Preliminary runs (Hong et al., 1998; Elwell et al., 2000) had composted fresh hog manure/sawdust mix under continuous aeration(CA) and intermittent aeration(IA) replicated in two vessels each. For the work reported here, the vessels were paired as shown in Figure 1 so that the air supplied by the fans would first pass through an initial vessel containing raw hog manure/sawdust mix and then through a second vessel in which fresh compost from the preliminary run was stabilizing. Two runs were conducted, with run 1 (April 1997) using two pairs of vessels and run 2 (April 1998) using 4 pairs of vessels. In run 1 one pair of vessels was operated in the CA mode while the second pair operated under IA control with additional thermostatic override. In run 2 two pairs operated in the CA mode and two pairs operated in IA control pair (but no thermostatic override).

Fresh hog manure was collected from a livestock waste facility at the Agricultural Technical Institute of the Ohio State University and mixed with sawdust on a concrete floor using shovels. A

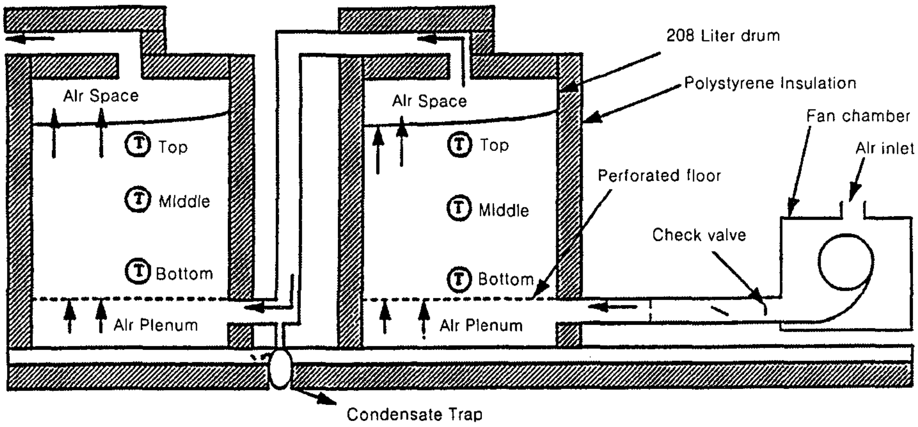

Fig. 1 Schematic diagram of the pilot scale composting system showing air supply system and temperature measurement points

total of 97 kg (75 kg hog manure and 22 kg sawdust) of raw compost mixture was used in each vessel. The properties of the raw materials are given in Table 1 and the properties of the mixes are shown in Tables 2 and 3 for the compost at time=0. C/N ratio, moisture content, and pH were about 20, 60% and 5.5 for all the compost mixes. Run 1 lasted 3 weeks and run 2 lasted 4 weeks. No remixing was done during the runs. Approximately 0.8 kg samples were collected from six arbitrarily selected points for each vessel at the start and the end of each run. The samples were analyzed for pH, total carbon (TC), total nitrogen (TN), C/N ratio and ash by the Research, Extension and Analytical Laboratory at the Ohio Agricultural Research and Development Center using standard laboratory techniques. Two additional samples for each vessel were obtained at the start and the end of each run and analyzed for moisture and particle size distribution (data not presented here due to space constraints). Moisture content was determined by drying the samples at 100°C for two days. Particle size distribution was analyzed in accordance with ASAE Standards (1997). All analyses were carried out in duplicate.

Two fans were connected to each vessel through

Table 1 Chemical and physical properties for materials for composting and biofilter in experimental runsl & 2

		Moisture %	pH	TN %	TC %	C/N	Ash %	Density kg/m^3	NH_3-N %	NO_3-N μg/g
Experimental Run 1		75.0	6.5	3.62	43.2	12.0	17.20	940		
Hog Manure	Average									
Sawdust	Average	5.4	3.9	0.21	43.3	215.0	1.00	270		
Experimental Run 2										
Hog Manure	Average	75.7	5.7	4.07	42.5	10.5	16.04	940	0.79	164
	Std. Dev.	0.6	0.2	0.16	0.9	0.56	0.56		0.09	29
Sawdust	Average	9.4	4.1	0.26	46.6	0.90	0.90	271	0.00	0
	Std. Dev.	0.4	0.1	0.07	0.1	0.00	0.00		0.00	0

a 4.76 cm(ID) PVC pipe that was equipped with an orifice plate. Daily, manual readings of the pressure drop across the orifice plate were obtained for each fan of each vessel and used to determine air flow rate (Marugg, 1992). For the CA vessels, the low flow fan provided air at about 0.9 kg /h (≒13 l /min) for oxygenation of the compost until a thermistor controlled thermostat (set point 60℃) switched to the high flow fan providing air at about 2.1 kg /h (≒30 l /min) for cooling. For the IA vessels the low flow fan was off for 55 minutes in each hour and then a timer switched to the high flow fan for 5 minutes to provide air about 2.3 kg/h(≒33 l /min). However, for run 1 the thermostatic control provided high airflow when compost temperature in the initial vessel was above 60℃. In run 2 no temperature control was used for intermittent aeration.

Gas samples were drawn from each vessel in succession and dew point temperatures (EG & G Model 911 Dew All Digital Humidity Analyzer) of the input air and carbon dioxide and oxygen concentrations (Beckman Model 864 Infrared Analyzer and MSA Oxygen Analyzer 4000, respectively) of the outlet air for each vessel were obtained and recorded once each hour.

Each vessel had four Type-K thermocouples in it. There was one above the compost and three in the compost material. A thermocouple wires fixed to a support were inserted into the material at heights of 24, 48 and 73 cm in the compost material and the temperature was monitored during the composting period. Temperatures and fan operating times were recorded for each vessel except the one used for biofiltration in run 2 CA (due to limit channels with recording equipment). Data was recorded every 15 minutes with a Digi IV Kaye Data Logger and a MFE tape recorder.

Ammonia concentrations of exhausted gas from the composting and biofiltration process were obtained for each vessel once a day using boric acid traps and titration with hydrochloric acid (Hong et al., 1998). The flow rate through the trap was measured for each vessel using a direct reading ball flowmeter and was approximately 1 l /min. Traps were changed approximately every 24 hours.

Ⅲ. Results and Discussion

The properties of manure slurry and sawdust are given in Table 1. The raw manure had a C/N ratio of 11~12 and moisture content(MC) of 75%(wb) while the sawdust had a MC of 5~9% and a C/N of 193~215. The main reasons for choosing sawdust as the bulking agent was its availability and desirable properties of low moisture, high C/N ratio, and relatively small particle size with high biodegradability. For this study, the sawdust used also had a low pH of 3.9, which would minimize NH_3 emissions initially.

Tables 2 and 3 show the mean values for the physical and chemical composition of the hog manure/sawdust mixes for CA and IA composting before and after composting. The hog manure slurry was mixed with sawdust to achieve an initial MC and C/N ratios of 56~62% and 20~22, respectively, for composting. The C/N ratio, TC and particle size decreased as the raw mixture was composted, while pH and ash increased. The C/N ratio dropped from an initial values of 19.7 and 21.4 to final values of 16.9 to 19.3 in run 1, respectively. For run 2 the C/N ratio decreased from 22 to 14. The pH increased from an initial values of 5.5~5.9 to values of 7.7~8.5 at the end of the process. The TN and MC did not change significantly throughout the composting process except for run 2 (CA) where moisture dropped to 40 and 45% wet basis for composting/biofiltration during the four weeks of composting. Measured ash content increased 2% and 3.9% in run 1 for CA and IA, respectively. For run 2 ash content increased 5% and 6.7% for CA and IA, respectively. Dry solids loss based on ash values were estimated to be 19% and 31% in run 1 (CA & IA) and 38% and 46% in run 2 (CA & IA). Measured losses in run two were 29% and 49% (CA & IA). Initial particle size (data not shown) in run 1 was about 85% w/w<0.4 cm while in run 2 it was 36% w/w<0.4 cm. The small particle size fraction increased to ~2% in run 1 and to ~15% in run 2 as the mixture was composted while the density decreased. Results for this study showed only slight differences between the CA and IA composting process in terms of the physicochemical indicators. The exception was moisture loss in run 2.

The patterns of average air flow, cumulative air flow, and average temperature in the compost during the composting decomposition and biofiltration process versus time are shown in Figs. 2 and 3. For run 1 average airflow rate per vessel

Table 2 Properties of compost mixes and biofilter during composting in experiment 1

ID	Time day	Moistrue %	pH	TN %	TC %	C/N	Ash %	Wet Density kg/m^3	DS loss	NH_3 loss gN/gDM$_0$
Continuous Aeration										
Compost	0.0	59.8	5.6	2.32	45.8	19.7	8.4	592		
	21.0	58.5	7.6	2.46	42.9	17.4	9.9	489	0.15	0.0032
Biofilter	21.0	54.6	7.6	2.36	43.0	18.2	11.0	391	0.24	
	42.0	61.3	8.5	2.42	41.0	16.9	10.4	403	0.19	0.0035
Intermittent Aeration										
Compost	0.0	56.0	5.9	2.12	45.4	21.4	8.8	527		
	21.0	56.1	7.6	1.98	42.1	21.3	10.4	427	0.15	0.0040
Biofilter	21.0	57.7	7.5	2.45	42.9	17.5	11.0	461	0.20	
	42.0	62.0	8.2	2.06	39.8	19.3	12.7	489	0.31	0.0033

1 Dry solids loss calculated using ash values (measured from experimental weights and moisture)

Table 3. Properties of compost mixes and biofilter during composting in experiment 2

ID	Time day	Moistrue %	pH	TN %	TC %	C/N	Ash %	Wet Density kg/m^3	DS loss	NH_3 loss gN/gDM$_0$
Continuous Aeration										
Compost	0.0	61.9	5.5	2.06	45.2	22.0	8.2	581		
	28.5	40.0	7.9	2.38	39.8	16.8	11.1	363	0.26(.20)	0.0030
Biofilter	28.5	57.4	6.6	2.73	42.6	15.6	12.4	399	0.34	
	57.0	45.2	7.7	2.74	38.8	14.2	13.2	314	0.38(.29)	0.0029
Intermittent Aeration										
Compost	0.0	60.5	5.5	2.12	44.3	20.9	7.8	542		
	28.5	56.0	7.6	2.31	42.0	18.2	10.4	533	0.26(.36)	0.0010
Biofilter	28.5	57.3	8.1	2.58	42.1	16.3	12.3	457	0.37	
	57.0	56.3	7.8	2.78	40.3	14.5	14.5	454	0.46(.49)	0.0023

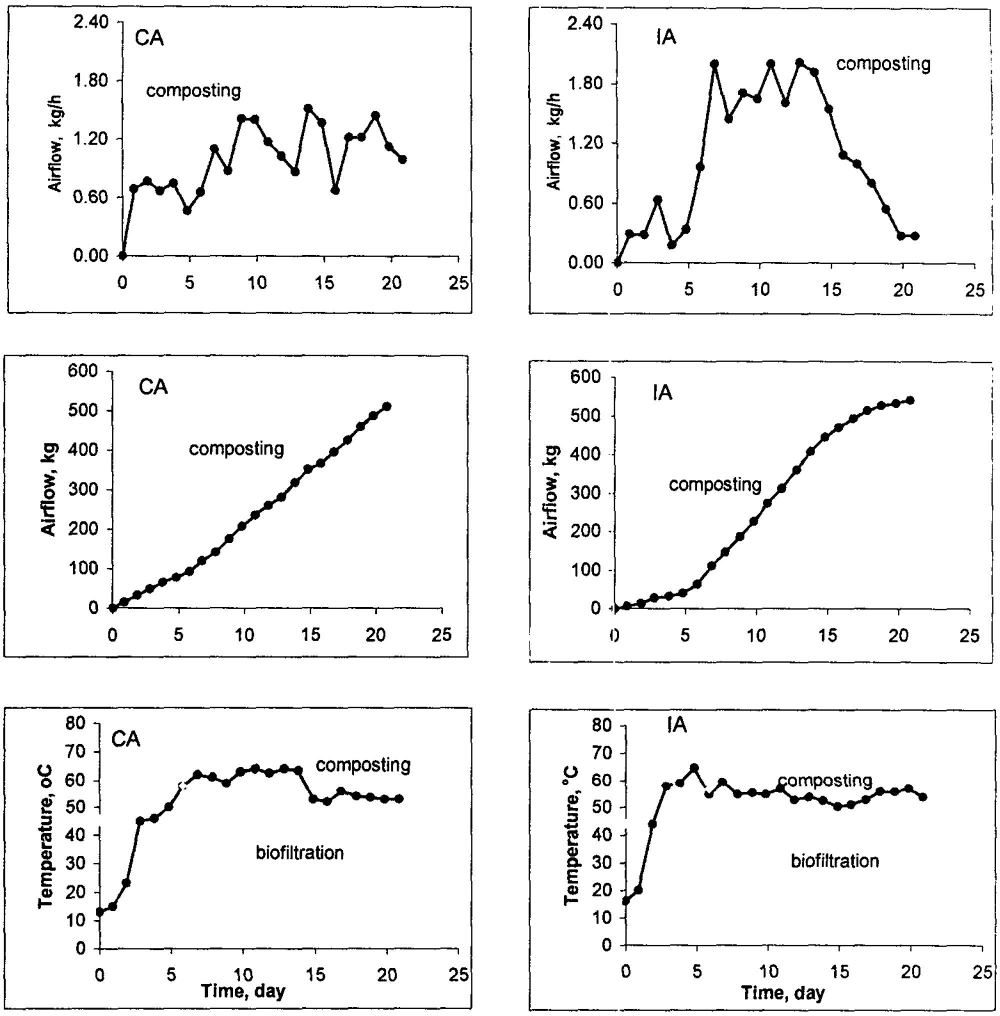

Fig. 2 Airflow rate, total airflow and temperature during compostion and biofiltration with continuous and intermittent aeration for experimental run 1 (April, 1997).
Initial Dry matter was: Composting: CA-41.8; IA-38.2; Biofiltration: CA-35.1; IA-31.9

during composting/biofiltration was between 0.6~1.5 kg/h (CA) and 0.02~1.9 kg/h (IA). For run 2 average air flow rate during composting/biofiltration was between 0.6~0.8 kg/h (CA) and 0.25 kg/h (IA). Cumulative air flow for both CA and IA in run 1 was nearly equal over the three week test period and was the result of intermittent airflow also using temperature control. However for run 2, cumulative airflow for IA was only 1/4 that of CA and agrees with similar work of Hong et al.(1998) and Elwell et al.(2000). The CA and IA processes were found to be very successful in reaching and holding composting pile temperatures above 55°C during runs 1 and 2. Figure 3 shows the average temperature during composting and biofiltration for the each of the CA and IA groups

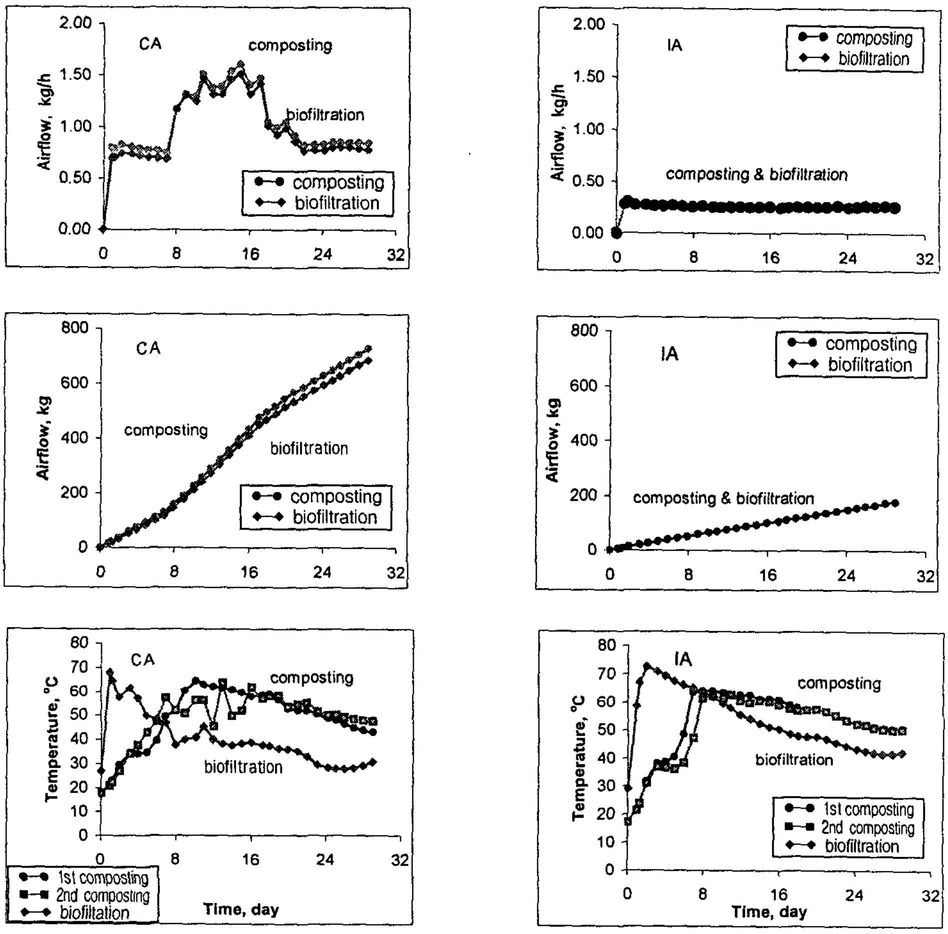

Fig. 3 Airflow rate, total airflow and temperature during composting and biofiltration with continuous and intermittent aeration for experimental run 2 (April, 1998).
Initial dry matter was: Composting: CA-38.5+0.4; IA-37.7+0.6; Biofiltration: CA-32.5+1.7; IA-35.6+0.0

of vessels in run 2 (The first and second composting temperture in compost mass represented trapezium and rectangle symbols, respectively). Biofiltration temperature during the CA and IA stabilization process in run 1 dropped to 17~20℃ on the 13th~the 15th days and remained close to the ambient (not shown) at the 21st day. For run 2 biofiltration temperatures rose to 70℃ and then dropped to below 45℃ for CA by day 8 and day 21 for IA.

Ammonia gas concentration and rate of NH_3-N emissions during composting and biofiltration are shown in Figs. 4 and 5. Ammonia gas concentrations were highest in the biofiltration and occurred during the first week of composting/biofiltration. Results showed ammonia gas concentrations in biofiltration process reached 2,500 ppm (CA) and 2,800 ppm (IA) but less than 1,100 ppm in composting (all treatments). However, ammonia concentrations during the biofiltration

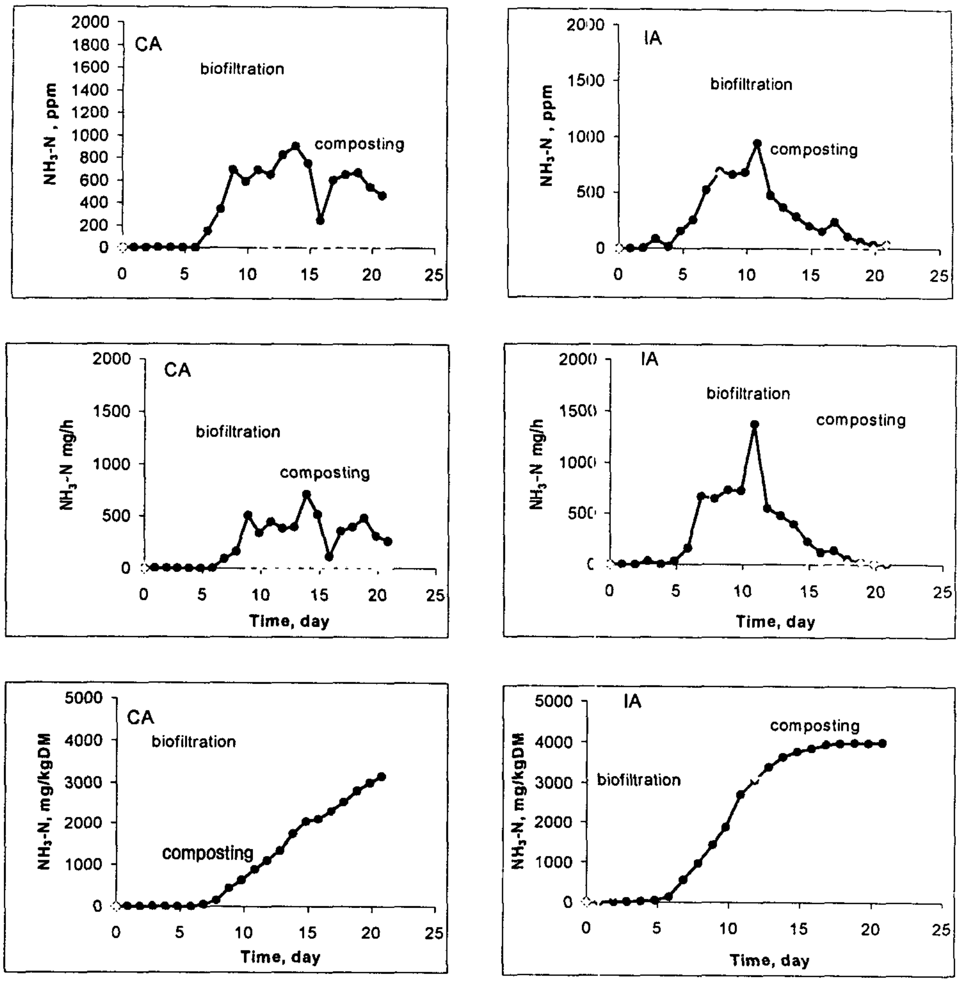

Fig. 4 Ammonia values during composting and biofiltration with continuous and intermittent aeration for experimental run 1 (April, 1997).

Initial dry matter was: Composting: CA-41.8; IA-38.2; Biofiltration: CA-35.1; IA-31.9

process dropped to less than 100 ppm on the 13th ~the 15th days for both CA and IA.

The NH_3-N emission rates showed similar shapes in CA and IA composting and in CA and IA biofiltration. However, peak value of NH_3-N emissions during run 1 were observed at composting (both CA and IA) 1,300 mg/hr and biofiltration 1,700 mg/h. For run 2, peak values of NH_3-N emissions during composting were 550 for CA and 340 mg/h for IA. For run 2 peak values of NH_3-N emissions during biofiltration were 2,900 for CA and 840 mg/h for IA.

Results on ammonia concentrations and the transition of temperatures during composting/biofiltration suggest: 1) only partially matured compost would be made after 3~4 weeks of composting and 2) to produce a stabilized material suitable for biofiltration would require at least one

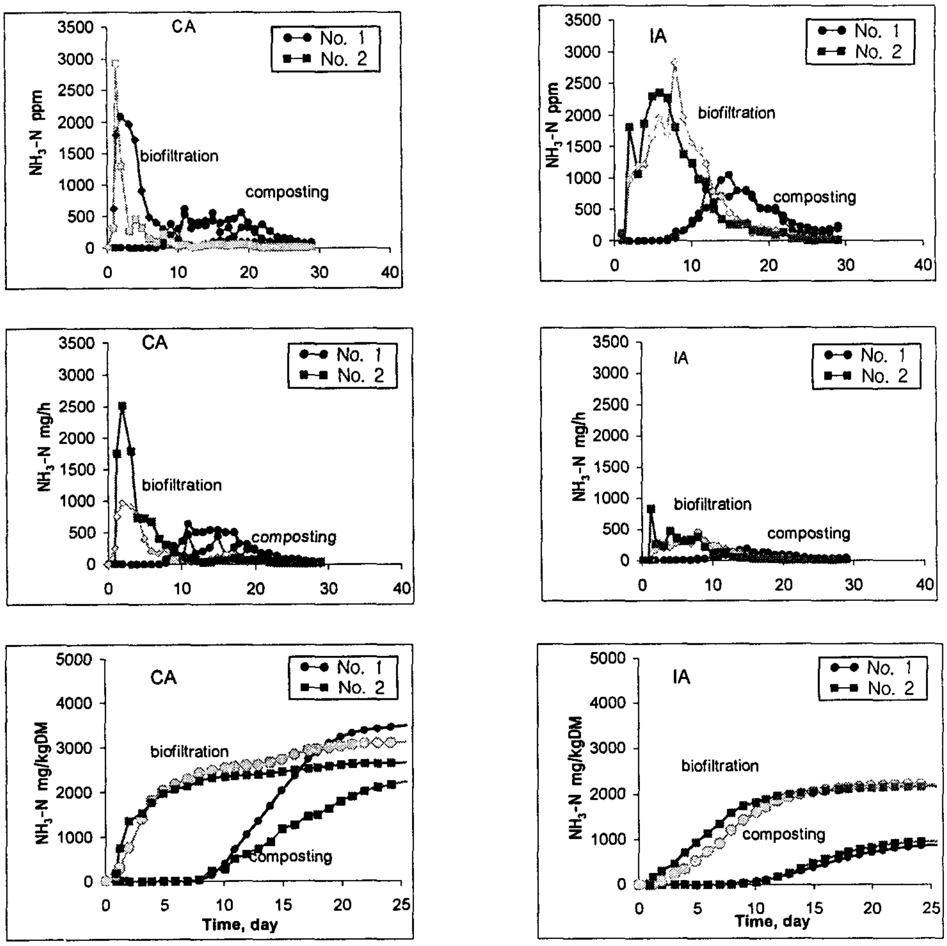

Fig. 5 Ammonia emission rate and total emissions during composting and biofiltration with continuous and intermittent aeration for experimental run 2 (April, 1998).
Initial dry matter was: Composting: CA-38.5+0.4; IA-37.7+0.6; Biofiltration: CA-32.5+1.7; IA-35.6+0.0

turning during the composting phase.

Cumulative ammonia-nitrogen emissions during the composting process using CA and IA are shown in Figs. 4 and 5. For run 1 the composting process showed CA had a lower emission rate than IA (3,100 vs. 4,000 mg NH_3-N/kgDM), but was still increasing at the end of three weeks. These results are different than those in run 2 and come probable from of the higher airflow for intermittent aeration as a result of temperature control. For run 1 emission values for the biofiltration were similiar for both CA and IA at 3,400mg NH_3-N/kgDM. Results on run 2 (The vessel Nos. 1 and 2 represented trapezium and rectangle symbols, respectively) gave average cumulative ammonia-nitrogen emission levels of 2,400, 1,000, 2,900 and 2,200mg NH_3-N/kgDM for composting (CA, IA) and biofiltration (CA, IA), respectively. These results indicate IA would give lower emissions, but that over the test period, ammonia emission from the biofilters for both CA and IA had exceeded the composting emissions. However, in the final two weeks, the cooled, biofiltration material (stabilizing compost) absorbed 74~96% (CA) and 61~89% (IA) of the cumulative ammonia emitted from the decomposition vessels.

Ⅳ. Conclusions

These results show that stabilizing manure compost holds out the promise of being a useful biofilter media for reducing ammonia emissions. However, for more effective composting, the manure/sawdust mix needs 4~6 weeks and should be turned several times for proper preparation it for biofiltration. If properly prepared, it can remove 61~96% of the ammonia emission at the composting process. IA was a more efficient method of composting the hog manure/sawdust mixture, requiring less than 1/4 of the airflow used for CA. Reducing aeration rate for the CA process might also achieve similar results in performance and reduced power cost.

Acknowledgements

This research was supported in part by the Korea Science & Engineering Foundation under the KOSEF/NSF Senior Scientist Exchange Program Agreement. Author is grateful to Dr. Harold M. Keener, associate professor, and Kamil Ekinci, graduate student for assisting with the compost biofiltration experiments.

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