# Effect of Compost Turning Frequency on the Composting and Biofiltration

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# 퇴비화 및 탈취처리에 퇴비 혼합 교반 빈도가 미치는 영향

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**Summary**

The effects of turning frequency of in-vessel composting on ammonia emissions during composting of separated solids from swine slurry/sawdust mixtures and performance of biofiltration using the chicken manure compost were investigated. Separated solids from swine manure amended with sawdust was composted in a 226 L laboratory-scale in-vessel reactors under various turning frequency and continuous airflow (0.6 L/min.kg.dm) for three weeks. Three laboratory-scale manure compost biofilters were built to treat effluent gas from the composting of separated solid from swine manure amened with sawdust process. These experiments were continued over a period of three weeks. The composting of separated solid swine manure amended with sawdust and manure compost biofiltration system were evaluated to determine the turning frequency type that would be adequate for the rate of decomposition and compost odour reduction. The compost odour cleaning was measured based on ammonia gas concentration before and after passing through the manure compost biofilter. The average ammonia odor reduction in the manure compost biofilter was 96.9 % at R1 (no turning), 99.4 % at R2(once a day turning) and 89.0 % at R3(twice a day turning), respectively. The efficiency of ammonia reduction was mainly influenced by the turning frequency.

(**Key words** : Aerobic biological treatment, Manure compost, Ammonia emissions, Biofiltration)

## INTRODUCTION

The control of ammonia emissions from livestock facilities is becoming an increasingly important issue in South Korea. The trend towards stricter odor emissions regulation is spreading throughout the world and leading to developments such as manure compost biofiltration for effective odor treatment (Hong et al., 2002). Biofiltration or biodegradation involves

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converting an organic contaminant to carbon dioxide and water using natural bacteria. When the contaminated air passes through a manure compost biofilter, the naturally presented micro-organisms also biodegrade air contaminants (Hong et al.,1998).

Ammonia volatilization tends to increase with increased aeration of composting materials, as a result of the higher gas exchange rates (Hong et al., 2000). The higher the C/N ratio, the more carbon is available, which keeps ammonia losses low. The higher the aeration rate was, the less the emission of methane and nitrous oxide became, but with a larger emission of ammonia (Hong et al., 1997).

The emission pattern of odorous compounds and greenhouse gases was different from the composting pile-type without forced aeration (Tamura et al., 1999).

Odors and ammonia generated from composting operations have become a major concern. Manure compost biofilters can reduce ammonia emissions from the composting process (Hong and Park, 2005). To date, most research in this area has been reported on ammonia gas control from composting manure. The odor removal efficiency of biofilters varies with the media characteristics including dimension and type of media, air flow rate, surface loading rate(= airflow rate/media surface area), retention time and on the media porosity and depth (Hong and Park, 2004; Hong et al., 2002).

Hong(2003) proposed that moisture content, pH, C/N ratio, soluble salts or electrical conductivity(EC) and temperature of the matured compost should be less than 40%(wb), 6～8, 20, 4.0(ds/m) and 55～60℃ at 3days, respectively. In order for a biofilter to operate efficiently, the manure compost biofilter medium must meet several requirements including moisture content(50～70% wb), resident time(120～180s), temperature(15～35℃), pH(6～9), pressure drop (< 400 Pa), media depth(400～60 0mm) and gas flow rates(0.78～1.2 m3/h) through biofilters (Janni and Nicolai, 2000; Hong and Park, 2003; Toffey, 1997; Rands et al.,1981).

Park et al. (2002) reported that the manure compost could be used as a biofilter medium for odor control during composting process. Leson and Winer(1991) recommended that industrial scale, open bed biofilters should be designed to operate at temperatures between 20 and 40℃. The most stable compost was found to have the best properties for long-term sustainable biofilter performance (Cardenas-Gonzalez et al., 1998). Turning frequency significantly affected the rate of decomposition. Without periodic agitation, the rate of decomposition slowed dramatically. Turning frequencies of composting material consistent with low odor levels varied with the feedstock mixture and bulking ratio (Buckner, 2002).

Manure compost is not widely used as a medium for microbial attachment in biofiltration systems. The objective of this study was to evaluate the effect of turning frequency on ammonia emissions during composting and to investigate the ammonia removal efficiency of using manure compost as a biofilter.

## MATERIALS AND METHODS

In order to determine the aerobic biodegradation in high rate composting of the separated solid manure from swine slurry and sawdust mixtures, The three reactors, 226 L working volume batch vessels(500 mm high) were loaded at around 62 kg(wet weight) of composting materials. Each reactor was built up with plastic pipe of 600 mm inside diameter and 50 mm thickness and insulated using polystyrene as shown in Fig. 1(schematic of the composter and biofilter design). The design of the compost and biofilter reactor vessels are summarized as follows: A steel plate with many perforated holes of 3 mm diameter (opening area>40% of total area) was installed above the bottom of each composter to aid aeration and support the compost mass. A handle at the top allowed turn over the compost reactor to be periodically turned manually. The height of air plenum chamber was 150 mm. This laboratory-scale compost (right) reactor vessels were built with a stainless cylinder and as shown in Fig. 1(photo). The three compost reactors (labelled as R1, R2 and R3) held approximately 226L of substrate each and were operated in parallel. Each was insulated by a polystyrene material in order to reduce heat losss, water condensation in the exit air stream and possible rewetting of the compost. The lower and upper sections were used as the inlet and outlet(head space: 450mm) zones. The center of the three sections were each filled with manure and sawdust mixtures (head of material: 500mm) supported by a stainless steel plate as a support grid. A valve at the bottom effluent outlet allowed leachate to be periodically drained from the reactors. Gas sampling ports for ammonia concentration were located upper section at the outlet zone. Air was supplied by an air compressor (Model:United ISO9001). The aeration rate was between 0.5 and 0.7L/min.kg.dry matter.

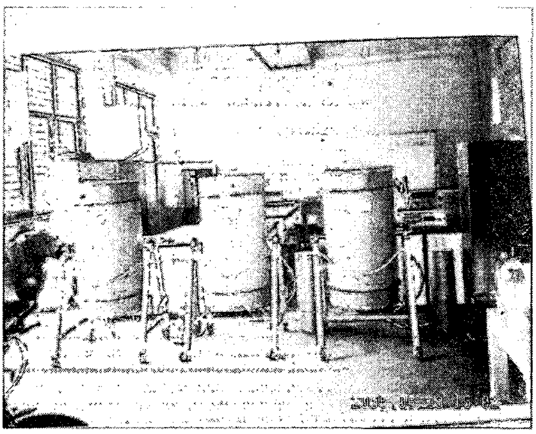

*Fig. 1. Photo of the three-laboratory scale composter and biofilter.*

The laboratory-scale biofilters (labelled as F1, F2 and F3) consisted of three parallel 190 mm inside diameter and 800 mm acrylic glass columns as shown in Fig. 1. The lower and upper sections were used as the inlet (bottom space: 15 cm) and outlet (head space: 15 cm) zones. The center three sections were each filled with manure compost biofilter media (head of biofilter: 50 cm) supported by a stainless steel plate as a support grid.

Changes in temperatures of the compost mass and ambient air were monitored in digital value and recorded on a computer continuously. Each vessel had one temperature sensor in it. Thermistor probes were inserted into the compost mass at center, respectively. Temperature readings was recorded for each vessel every 1 hour.

The exhaust gas from the composter was conducted into the manure compost biofilter vessels.

Table 1. Experimental design of composting manure and manure compost biofilter

| Set | Material and mixing ratio | Turning frequency | Biofilter media |
|---|---|---|---|
| R1 | Separated swine manure: sawdust (wet weight 10 kg : 3 kg) | No turning | Manure compost (F1) |
| R2 | 〃 | Once a day | Manure compost (F2) |
| R3 | 〃 | Twice a day | Manure compost (F3) |

Ammonia concentrations of exhaust gas from the composting decomposition and manure compost biofiltration process were obtained for each vessel twice a day using a gas detector (GASTEC 801) at intervals of 12 hours. The effluent gas was led into gas detector through a gas detection tube. Ammonia concentration was measured at the mid-line of the effluent gas from the composter and the exhaust air of manure compost biofilter.

Composting materials were made by hand mixing separated solid from swine slurry and sawdust. Separated solid manure was mixed manually with amendment of sawdust by wet weight ratio (kg) of manure to amendment as 10 : 3 presented in Table 1. The hog waste slurry was subjected to the separation process using a centrifugal liquid/solids separator (MCS-200). The total solids content of the separated solids was between 27 and 32%. The removal rate of the total solids by the liquid/solids separator was 50%.

Three types of turning frequency during in-vessel composting commonly were turning the composter twice a day(R3), once a day(R2) and no turn(R1), respectively. Chicken manure compost biofilter used as a biofiltration media in this study.

The feed, compost mixes and compost biofilter media were analyzed for pH, moisture content (MC), ash, total carbon(T − C), total nitrogen(T − N), C/N ratio, soluble salts or electrical conductivity(EC), mass and density. The above parameters were analyzed by a standard method for soil chemical properties according to the Rural Development Administration(RDA, 1988). Each value was the average of three samples.

The means and standard deviations were calculated for all parameters. The data was subjected to analysis of variance (ANOVA) and the least significant (LSD) test was used to separate means ($p$>0.05).

## RESULTS AND DISCUSSION

### 1. Composting process evaluation

Temperature is a key factor in composting. It has been used as the most important indicator of the performance of the composting process. Optimal decomposition took place in the thermophilic range of 55 to 60℃ or above for at least 3 days in order to satisfy pathogen destruction guide lines(Hansen et al. 1995; Hong 1994). The temperature propiles depending on turning frequency of in-vessel composting manure such as R1, R2 and R3 are presented in Fig. 2. The center point temperature of the compost vessel rose rapidly within 2 days after the mixtures were placed in the composter and reached peak of 74℃. The compost temperature record showed that the R1 temperature decreased more quickly than the R2 and R3. A temperature drop and return to ambient temperature suggest that the compost has stabilized. All of the reactors attained thermophilic conditions(>40℃). However, the composting reactor in the R1

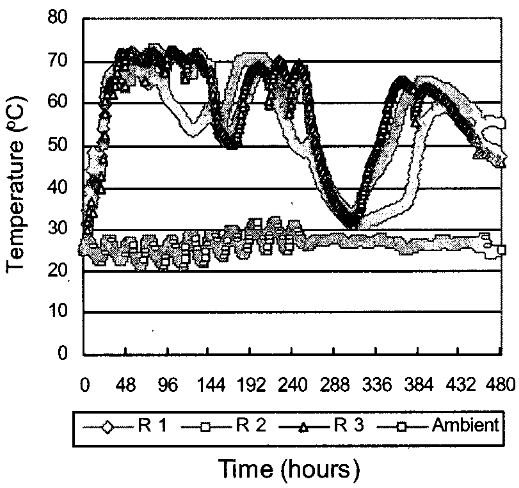


Fig. 2. Graphical records of daily compost mass and ambient temperatures during composting.

compost vessel did remain in the thermophilic condition lower than did those reactors with R2 and R3 conditions.

The quality and maturity of compost is ascertained by examining the composition of the compost. MC, C/N ratio, EC and temperature are the criteria commonly used.

The properties of the feedstock materials, initial and final manure composts are presented in Tables 2 and 3. The raw separated swine manure had a MC of 68%(wb) and C/N ratio of 12 while the sawdust had a C/N ratio of 350 and MC of 13.6%. The main reasons for choosing sawdust as the bulking agent were its availability and relatively optimum particle size with high biodegradability. The MC and density did not change significantly different for initial and final compost mixes. The pH increased from initial values of 8.9 to final values of 9.4 at the end of the process. Reducing the pH value of the feed substrate needed to be a more effective means for reducing ammonia emissions and compost temperature. Measured ash content decreased 2.5% (db). The EC dropped from an initial value of 2.2 to final value of 1.4 as a result

Table 2. Properties of raw materials used in compost mixes and manure compost biofilter

| Properties | Separated swine solid manure | Sawdust | Manure compost biofilter |
|---|---|---|---|
| MC (%, wb) | 67.8 ~ 68.2 | 13.5 ~ 13.6 | 69.3 ~ 70.1 |
| pH (−) | 8.7 ~ 8.8 | 4.4 ~ 4.6 | 9.4 ~ 9.5 |
| T−C (%,db) | 43.2 ~ 44.8 | 55.8 ~ 56.1 | 44.3 ~ 45.0 |
| T−N (%,db) | 3.62 ~ 3.68 | 0.16 ~ 0.18 | 2.36 ~ 2.54 |
| C/N (−) | 11.9 ~ 12.2 | 311.7 ~ 348.8 | 17.7 ~ 18.8 |
| Ash (%, db) | 10.1 ~ 10.7 | 2.8 ~ 3.3 | 6.9 ~ 7.0 |
| EC (ds/m) | 4.0 ~ 4.6 | 0.21 ~ 0.23 | 4.1 ~ 4.4 |
| Density (kg/m$^3$) | 755 ~ 760 | 235 ~ 240 | 720 ~725 |

Table 3. Initial and final properties of compost mixtures

| Properties | MC (%, wb) | pH (−) | T−C (%, db) | T−N (%, db) | C/N (−) | Ash (%, db) | EC (ds/m) | Density (kg/m$^3$) |
|---|---|---|---|---|---|---|---|---|
| Initial | 67.46 | 8.9 | 42.08 | 2.36 | 17.8 | 10.0 | 2.2 | 440 |
| Final | | | | | | | | |
| R 1 | 64.25 | 9.0 | 47.90 | 2.94 | 16.3 | 6.0 | 1.2 | 310 |
| R 2 | 63.19 | 9.3 | 45.90 | 2.54 | 18.1 | 9.5 | 1.4 | 320 |
| R 3 | 67.00 | 9.4 | 45.62 | 2.36 | 19.3 | 7.0 | 1.5 | 340 |
| Ave. | 64.81 | 9.2 | 46.47 | 2.61 | 17.9 | 7.5 | 1.4 | 320 |

of leaching. The separated solid swine manure amended with sawdust of density of 440 (kg/m$^3$), while the density of final compost material became lower to 420 kg/m$^3$.

## 2. Ammonia emission

The ammonia concentrations in the inlet and exhaust air of the manure compost biofilter during 20 days are plotted in Fig. 3, 4 and 5. The ammonia concentrations of three compost mixes before and after biofiltration are summarized in Table 5. The ammonia concentrations in the

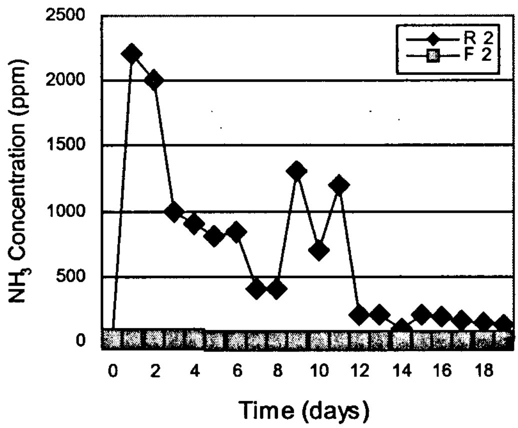


Fig. 4. Ammonia concentrations of the exhaust air of the compost reactor(R2) and the manure compost biofilter(F2).

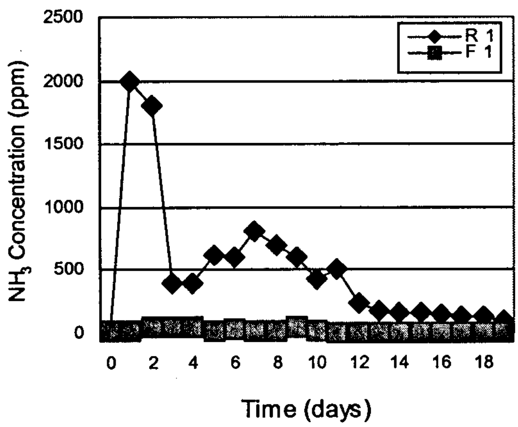


Fig. 3. Ammonia concentrations of the exhaust air of the compost reactor(R1) and the manure compost biofilter(F1).

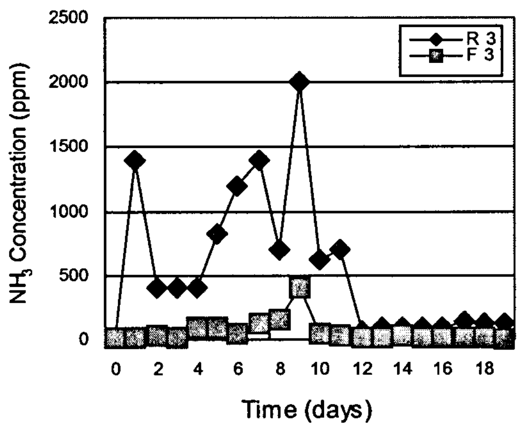


Fig. 5. Ammonia concentrations of the exhaust air of the compost reactor (R3) and the manure compost biofilter(F3).

Table 4. Initial and final properties of manure compost biofilters

| Properties | MC (%, wb) | pH (−) | T−C (%, db) | T−N (%, db) | C/N (−) | Ash (%, db) | EC (ds/m) | Density ($kg/m^3$) |
|---|---|---|---|---|---|---|---|---|
| Initial | 69.76 | 9.5 | 44.64 | 3.7 | 12.1 | 7.0 | 4.1 | 720 |
| Final | | | | | | | | |
| R 1 | 70.00 | 8.9 | 42.83 | 4.4 | 9.7 | 8.0 | 5.1 | 410 |
| R 2 | 70.63 | 9.2 | 43.12 | 3.8 | 11.4 | 7.5 | 4.9 | 430 |
| R 3 | 71.65 | 9.3 | 42.63 | 4.1 | 10.4 | 7.5 | 4.5 | 430 |
| Ave. | 70.76 | 9.1 | 42.86 | 4.1 | 10.5 | 7.7 | 4.8 | 420 |

Table 5. Summary of average ammonia concentrations in the inlet and exhaust air of manure compost biofilter

| Biofilter(unit) | | F1 | F2 | F3 |
|---|---|---|---|---|
| 1st − week | Inlet (ppm) | 948.6 | 1165.4 | 862.9 |
| | Exhaust (ppm) | 33.0 | 11.7 | 61.4 |
| | Reduction (%) | 96.5 | 99.0 | 92.9 |
| 2nd − week | Inlet (ppm) | 400.0 | 585.7 | 611.4 |
| | Exhaust (ppm) | 12.0 | 0.3 | 100.6 |
| | Reduction (%) | 97.0 | 99.9 | 83.5 |
| 3rd − week | Inlet (ppm) | 128.0 | 160.0 | 116.0 |
| | Exhaust (ppm) | 0 | 0 | 13.2 |
| | Reduction (%) | 100 | 100 | 88.6 |
| Total Inlet (ppm) | | 10,080 | 13,058 | 10,900 |
| Average Inlet (ppm) | | 504.0 | 652.9 | 545.0 |
| Total Outlet (ppm) | | 315.0 | 84 | 120.0 |
| Average Outlet (ppm) | | 15.8 | 4.2 | 60.0 |
| Average Reduction (%) | | 96.9 | 99.4 | 89.0 |

exhaust air from the manure compost biofilter were averaged 15.8 ppm for the F1, 4.2 ppm for the F2 and 60.0 ppm for the F3 when the corresponded concentrations in the inlet air averaged 504.0 ppm, 652.9 ppm and 545.0 ppm, respectively. The average ammonia reduction rates were 96.9 %(R1), 99.4 %(R2) and 89.0 %(R3), respectively. Results of ammonia emissions and temperature profiles during composting and biofiltration suggest that manure compost is a good biofilter for remaining down to the maximum allowable ammonia concentrations of 50 ppm. Ammonia was significantly ($P<0.05$) removed. The biofiltration treatment using manure compost and once a day turning of compost material are effective in eliminating ammonia emission from composting manure.

Ammonia emission occurred during thermophilic stage (above 40℃) of composting, with 90% of the total ammonia emitted during 2 weeks composting. After the thermophilic stage, the composting material was kept for mesophilic conditions of composting (materials to below 40℃) during which time the materials were curing.

### 3. Evaluation of biofilter performance

C/N, pH, MC, temperature and aeration affect decomposition rates, odor generation and cost of composting. Our study investigate the influence of the different types of turning frequency on ammonia emissions during composting of separated solid from swine slurry amended with sawdust and biofiltration using manure compost for reducing ammonia from manure composting. Turning frequency significantly affected the compost odor removal efficiencies of manure compost biofilters from 89.0% (twice a day turning) to 99.4%(once a day turning).

The initial and final physicochemical properties of the manure compost used for biofilters are shown in Table 4. The initial manure compost biofilter had a MC of 70%(wb), a high pH value of 9.5 and a C/N ratio of 44.64. Density dropped from an initial value of 720kg/m$^3$ to final value 420 kg/m$^3$ in biofilters. The pH value decreased from initial value of 9.5 to final value of 9.1 at the end of the biofiltration process. Generally, MC in the range of 50 to 70% and pH between 7.0 and 8.5 are recommended for biofiltration (Toffey 1997). The T-N and EC increased as the manure compost biofilter absorbed ammonia, while the pH and C/N ratio decreased.

## CONCLUSIONS

Results of ammonia emissions and temperature profiles during composting and biofiltration suggest that manure compost is a good biofilter for remaining down to the maximum allowable ammonia concentrations of 50 ppm. Ammonia gas removal efficiency varied with turning frequency on composting process..

Ammonia gas removal was 96.9% in the manure compost biofilter (F1) and no turning (R1) composter, while an ammonia reduction were 99.4 % and 89.0 % in the manure compost biofilter F2 and F3 at the once a day (R2) and twice a day (R3) turning frequency composter, respectively.

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