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A Comparative Study on the Aerobic Biodegradation of the Continuous and Intermittent Aeration in Bin Composting System

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Abstract □ Composting of hog manure amended with sawdust trials lasted three weeks and used pilot-scale in bin composting system. Results showed that the rise temperature and carbon dioxide evolution in compost during the composting decomposition process were affected by the acration method, pH, C/N, moisture content, bulk density and particle size distribution. No significant differences existed in biophysical properties of the compost produced from the continuous and intermittent aeration method. The intermittent aeration was very successful in compost odor control and required less time to reach stability than the continuous aeration.

Keywords □ solid compost, decomposition, stability, positive aeration, continuous aeration, intermittent aeration.

I. Introduction

Composting is a safe and effective way of handling the biodegradable fraction of the waste stream. Nutrients(C/N), pH, moisture content, temperature and aeration(oxygen) affect decomposition rates, odor generation, and cost of composting. For cost efficient composting, optimal conditions for nutrients, moisture, temperature, aeration and pH should be provided for best growth rates of the microflora in the process. The composting microflora utilizes the degradable constituents in wastes as an energy source and releases CO_2, H_2O, NH_3, and biological heat as principal products(Hansen et al, 1995). The final product should be stable, and therefore can be applied to the soil to improve its physical, chemical and biological properties.

Large scale composting is intensive in labor, equipment and energy utilization. Economic composting requires high quality of end products at low cost and high degradation rates.

Numerous researchers including Rynk(1992) have studied composting process control parameters such as temperature, moisture content, C/N, and pH for optimal treatment of various materials.

Aeration is one of the most important controlling factors in composting system. Air flow through the bed provides oxygen for the microbes and removes CO_2 and heat. Aeration and the corresponding airflow pathways control the spatial distribution of degradation rates, temperature and moisture losses(Hong, 1994; Stentiford et al., 1985).

The results of some of these studies for the optimum condition of temperature, moisture, aeration rate and mode, particle size, depth of bed, oxygen levels, and pore porosity are outlined below. Typically a moisture level of 55~65%(wb) should be maintained for reasonable composting(Hong, 1994). Stentiford et al.(1985) found that pathogen reduced at a uniform & high temperatures for a certain periods(e.g. 72 hours, at temperature>55℃ for bin composting systems) in the composting process. Usually aeration rate of 0.5L/min./kgDM. would be optimal. From the point of view porosity and aeration, the ideal sizes of particles range from 0.1 to 1.0cm(Haug, 1993). A well oxygenated condition was defined when the oxygen level was maintained at 17% (Finstein and Miller, 1985). Optimum pore porosity was found to be in the range of 28~32%(Jeris and Regan, 1973).

The objective of this study was to evaluate the effects of aeration mode and raw mixtures parameters on the operation efficiency with respect to temperature and CO_2 evolution during the composting process.

Ⅱ. Materials and procedures

Hog manure mixed with sawdust was composted in pilot scale bin digester by the CA(continuous aeration) and IA(intermittent aeration) modes. The main reasons for choosing sawdust as the amendment were (1) sawdust is rich in carbon(C/N=215) and can be used to adjust C/N ratio of the raw manure; (2) sawdust is acidic(pH=3.0) and helps conserve nitrogen; (3) sawdust has the ability to absorb large amounts of water because of low wet density(270kg/m^3) and fine particle size which facilitates the aeration.

Fresh hog manure was collected from a pig housing and mixed with sawdust on a concrete floor using shovels. The amounts and properties of the raw materials are given in Tables 1 and 2. Two runs of experiments were conducted for each CA and IA aeration mode. There are some differences in composting materials between run No. 1 and No. 2 as shown in Tables 1, 2 and 3.

All runs lasted for 21 days and no mixing was provided during the runs. Approximately 0.8kg 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 nitrogen, total carbon and ash in the Research, Extension and Analytical Laboratory at the Ohio Agr. Res. & Dev. Centr. Two additional samples from each

Table 1. Feedstock materials used in compost mixes

	Wet weight(kg)		
Test of runs	Hog manure	Sawdust	Water
No. 1	75	22	-
No. 2	61(16^a+45^b)	27	18

a: feeder pig manure, b: sow manure

Table 2. Properties of feedstock materials used in compost mixes

			Hog manure^c	
Property^a	Hog manure^b	Sawdust^{b,c}	Feeder pig	Sow
pH(-)	6.5	3.0	5.5	7.3
MC(%, wb)	75.0	5.4	72.1	76.8
VS(%, db)	82.8	90.0	81.6	76.9
T-C(%, db)	43.2	43.3	43.66	37.75
T-N(%, db)	3.62	0.21	3.65	2.83
C/N(-)	11.93	206.2	11.96	13.34
Wet density(kg/m^3)	940	270	-	-

a: Each composition value is the average of two samples.
b: Test Run No. 1, c: Test Run No.2.

Table 3. Initial and final physicochemical properties of compost mixtures

Parameter	Run No. 1		Run No. 2	
	Initial	Final	Initial	Final
pH(-)	6.0~6.2	7.4~7.8	7.1~7.9	6.8~7.2
C/N(-)	17~19	17~19	22~27	19~22
Moisture, %(wb)	55~65	53~59	59~62	54~61
Wet density, kg/m^3	513~531	441~525	518~529	376~462
Particle size, <0.2cm, %	53~59	64~67	60~68	62~70

vessel were obtained at the start and the end of each run, and analyzed for moisture and particle size distribution. Moisture content was determined by drying the samples at 100℃ for two days. Particle size distribution was analyzed in accordance with ASAE Standards (1997). All analyses were carried out in duplicate.

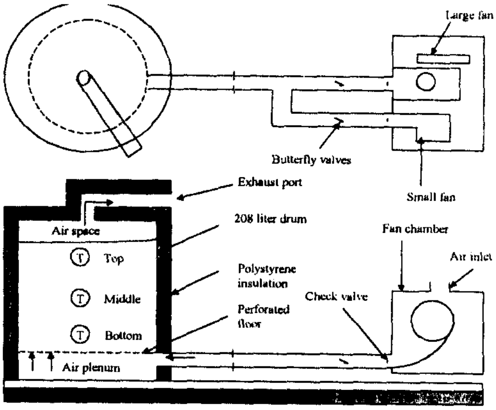


Fig. 1. Schematic illustration of a reactor vessel

The pilot-scale vessels(Fig. 1) were 208L barrels, 57cm in diameter and 73cm deep (Hong et al., 1998). Each barrel was insulated by 50mm of polystyrene in order to reduce heat loss, water condensation in the exit air stream, and possible rewetting of the compost. A perforated galvanized steel grate formed a plenum at the barrel's base to distribute air uniformly through the compost. Two fans were connected to provide air to each barrel through a 4.76 cm(ID)PVC pipe that was equipped with an orifice plate. Daily readings of the pressure drop across the orifice plate were obtained manually for each fan of each barrel and used to determine airflow rate (Marugg et al. 1993). For the continuous air flow tests, the low flow fan provided about 11L/min. per barrel(0.27L/min.kgDM) of air for oxygenation of the compost at the beginning. When compost temperature increased above 60℃, a thermistor controlled thermostat switched to the high flow fan which provided about 36L/min per barrel(0.91L/min.kgDM) of air for cooling. For the intermittent air flow tests, the low flow fan was left off and there was no air flow for 55 minutes of each hour. Then a timer switched on the high flow fan for five minutes to provide air at about 37.5 L/min per barrel(0.95L/min.kgDM).

Gas samples were drawn from each barrel in succession and dewpoint temperatures(EG & G Model 911 Dew All Digital Humidity Analyzer) of the input air, carbon dioxide and oxygen concentrations(Beckman Model 864 Infrared Analyzer and MSA Oxygen Analyzer 4000, respectively) of the outlet air for each barrel were obtained and recorded once an hour. Each barrel had five type-K thermocouples in it: one above the compost, three in the compost material and one in the air plenum. There was also a thermocouple to measure room temperature. Thermocouples were inserted into the material at heights of 24, 48 and 73 cm. Temperature readings and fan operating times were recorded for each vessel every 15 minutes with a Kaye Digi III Data Logger and a MFE tape recorder.

At the end of each run, all data were stored in computer files. These data were then processed by computer programs written for this purpose(Marugg 1992). These programs computed heat and air flows, ammonia-nitrogen lost and material balances throughout the composting runs.

III. Results and discussion

An analysis of the mean values for the physicochemical components of the raw materials in compost mixes is presented in Table 2. The hog manure had a C/N ratio of 12 and moisture content of 75%(wb).

Initial and final properties of the mixtures before and after composting are given in Table 3. Initial moisture content and wet density were not significantly different between test run No. 1 and 2. However, pH, C/N and particle size distribution were different between the two runs. Run No. 2 had a higher C/N ratio than that of run No. 1. The ratio of fine particles(<0.2 cm) was also higher in run No. 2.

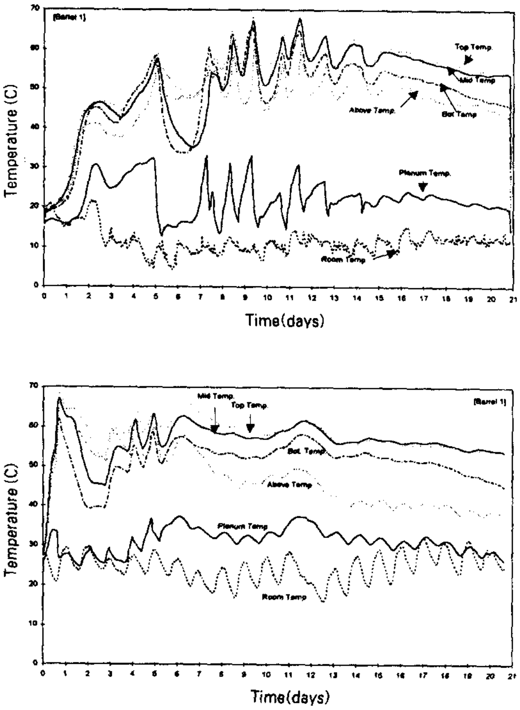


Fig. 2. Changes in compost temperature at various pile locations while composting with continuous aeration; Run No. 1(upper), Run No. 2(lower).

Graphical histories of compost temperatures, CO_2 and O_2 concentrations for CA and IA composting are presented in Fig. 2~Fig. 5, respectively. Temperature was found to vary with aeration method and location in the barrel. The temperature record showed that continuous aeration had a cooling effect. The fluctuation in the temperature of compost followed those

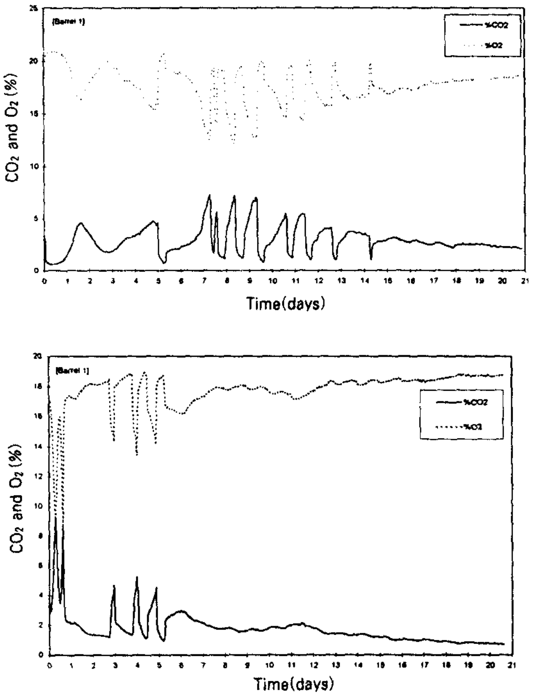
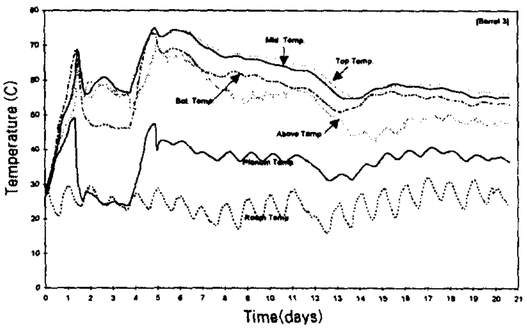


Fig. 3. Oxygen and carbon dioxide histories while composting with continuous aeration; Run No. 1(upper), Run No. 2(lower).



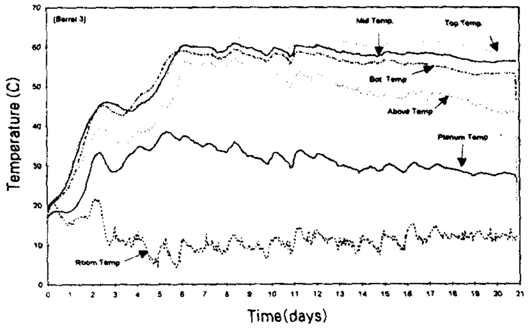


Fig. 4. Changes in compost temperature at various pile locations while composting with intermittent aeration; Run No. 1(upper), Run No. 2(lower).

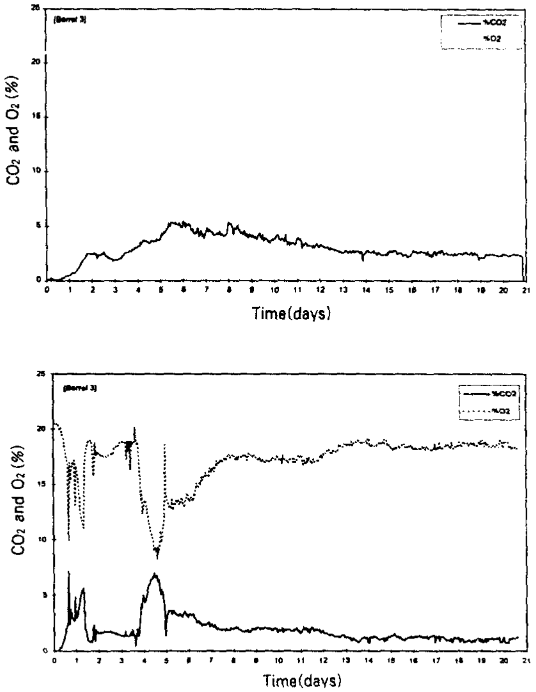


Fig. 5. Oxygen and carbon dioxide histories while composting with intermittent aeration; Run No. 1(upper), Run No. 2(lower).

of the top surface, but the temperatures of the IA method were lower than that of CA method, because the air was not constantly supplied.

On account of the optimum properties of the initial pH and C/N ratio, the active composting process in run No.2 was finished within 7 days as shown in Fig. 3. Therefore, the optimum conditions for raw material mixtures such as pH and C/N ratio are required for efficient composting.

The temperature in compost piles reached to the thermophilic ranges within 1 to 5 days after aeration began. Run No.1 required 5 days and run No.2 required 1 day to reach 55℃ for CA mode as shown in Fig. 2. The temperature curve pattern of IA composting was similar to that of CA though there was a little difference in fluctuations as shown in Fig. 2 and Fig. 4. The IA composting was successful in reaching sufficient temperature above 55℃ long enough to kill pathogeon.

The rise in temperature was the result of biological decomposition of organic matter as indicated by the CO_2 evolution or O_2 consumption. CO_2 evolution peaked and then declined when the temperatures reached their maximum, which indicated that temperature variation was greatly affected by the aeration mode and initial properties of raw material mixes. Also the curve pattern of the CO_2 was different according to the aeration mode and initial properties of raw material mixes. Variation in CO_2 evolution conditions through the composter had a significant effect on the temperature(Hong et al., 1997). This report was similar to our results. Maximum CO_2 production rate ranged from 4.5 to 10.8% per volume during active period of 40~70℃. The maximum CO_2 generation in effluent gas was 4.5~9.1% per volume within the 5 days in the run No. 2, and 4.5~10.8% per volume within the 10 days in the run No. 1. A rapid CO_2 and temperature drop indicated that the compost had stabilized, and temperature gradually decreased to about ambient temperature(Marugg et al., 1993; Hong et al., 1983). The CO_2 evolution time in CA was longer than that in IA. It showed that the IA composting mode required shorter time to reach stability(Hong, 1998). There were appreciable differences in the CO_2 evolution curves and temperature profiles between the CA and IA process. Maximum O_2 concentration of 19.0~21.4 % per volume were found within the first four days. O_2 concentrations in runs No. 1 and No. 2 reached a constant level of about 18.5 and 21.0% by volume, respectively.

Ⅳ. Conclusions

This study was conducted to investigate the effect of initial parameters on the temperature, carbon dioxide production for the composting process of CA and IA aeration mode.

Comparison of CA and IA methods of composting hog manure mixed with sawdust showed that intermittent aeration(IA) was a satisfactory method to compost. It maintained high temperatures(>55℃) long enough to kill pathogen. A constant oxygen level was achieved more rapidly in IA composting than in CA. Based on the temperature and CO_2 concentration curves profile, IA treatments could be superior to CA in terms of compost stability and nitrogen conservation. CO_2 evolution from the compost mass during composting can be a good index of stability.

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