Ammonia Emission during Positive Aeration on Composting Dairy Manure Amended with Rice Hulls

우분과 왕겨 혼합물의 송풍식 통기 퇴비화 과정 중 암모니아 휘산 실험

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요 약

퇴비화 과정 중에 암모니아 휘산은 퇴비 내의 질소성분을 유출시키고 있는 동시에 악취를 발생한다는 측면에서 바람직하지 못하다. 아직까지 암모니아 휘산을 방지할 수 있는 방법은 개발되어 있지 않다. 본 연구는 퇴비화 과정에서 온도, 암모니아 휘산 및 엔탈피의 변화를 분석하였다. 퇴비화 온도가 높을 때에는 암모니아 휘산도 많이 발생하였으나 퇴비화 15일 후 온도가 63℃로 하강함에 따라 암모니아 휘산은 줄어들기 시작하여 온도가 60℃ 이하로 떨어지는 21일부터는 거의 발생하지 않았다. 퇴비화 온도에 의하여 퇴비화 진행과정과 암모니아 휘산의 추이를 추정할 수 있었다.

I. Introduction

The animal industry of Korea is getting to be intensive farming where large number of animals are kept in a narrow area without crop land to receive animal wastes.

Composting is an important process for agricultural waste treatment and in the preparation of horticultural media and agricultural soil amendments. One of the main current problems during composting is a generation of odors. The interest in odor control of composting facilities has increased dramatically in recent years. Because of this concern, the development of highly efficient and cost effective systems are necessary for the treatment of odors generated at composting process.

Factors involved in odor generation include initial substrate chemical composition, oxygen diffusion rates, moisture contents, temperature achievement etc.(Kirchman and Witter, 1989; Kack et al., 1993; Walker, 1993). More fundamental research is needed to understand the nature of composting odors.

The composting greenhouse may provide an optimal environment where the composting process can be performed and its byproducts

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such as heat and CO_2 gas utilized to give better condition for plant growth. However, adequate control system has not been developed on account of the absence of correct understanding of ammonia emission.

The objective of this study was to investigate the thermal and chemical properties required to define the ammonia volatilization in non-agitated batch composter with an intermittent aeration. Also it was intended to evaluate the effect of aeration rate on the ammonia emission and to suggest suitable conditions to decrease ammonia emission in the full scale composter.

II. Materials and methods

Raw cattle manure was mixed with rice hulls by the wet volumetric ratio of two(manure) to one(rice hulls). The moisture content of initial admixture was about 65 percent by wet basis. Admixture of raw materials was composted for 42 days of primary aeration and curing stage from June 6 to July 17, 1996.

Batch composter was made as cube(1.5m × 1.5m × 1.5m) with wooden material and installed inside the laboratory(Fig. 1). An aerated pipe of 10cm(inside diameter) was installed above the bottom of the reactor floor to aid aeration. After composting temperature reached 50°C under continuous aeration, intermittent aeration with 15 minutes' aeration and 45 minutes' rest was supplied by the turbo fan(0.75kW) on a positive pressure mode. Aeration rate was 0.1m^3/min. per 1m^3 of admixture. The batch composter had a actual loading capacity of 1.5m × 1.5m × 1.4m(3.15m^3, 1.3 ton).

The ammonia volatilization was ascertained by examining the biothermal and chemical characteristics of composting process. Analyzed data for physicochemical parameters of initial and final compost were the criteria commonly

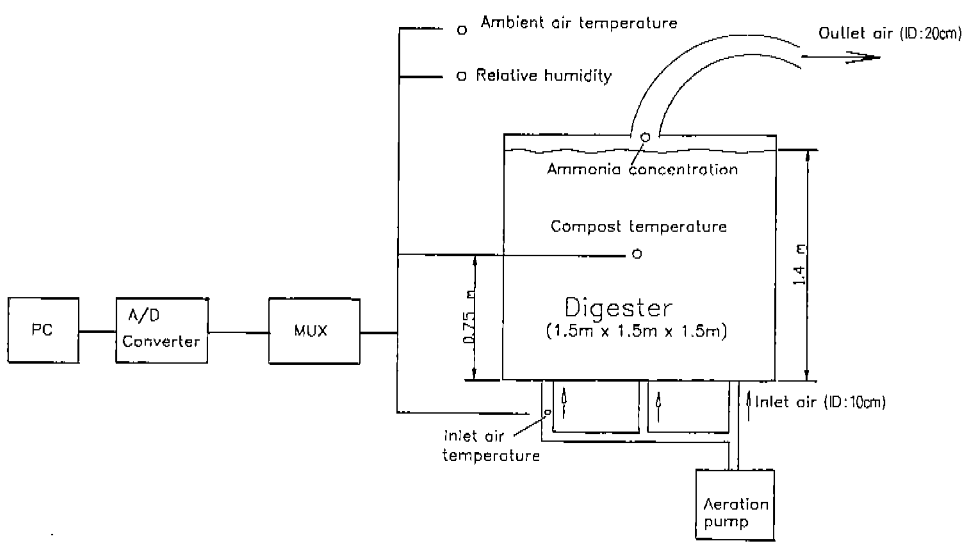

Fig. 1. Schematic diagram of measuring system for composting in digester

used for analysis of the soil chemical properties in the ORD(Office of Rural Development in Korea, 1988).

Chemical properties of compost material were measured weekly until the experiment was ended on July 17, 1996. Approximately 0.7kg samples of material were collected from five arbitrarily selected points below 50cm from the top surface of compost mass and these samples were used to analyze chemical composition.

The temperature and relative humidity in the inlet air and temperature in compost mass are shown in Fig. 1. Data were obtained every one hour using the sensor Pt100 for compost temperature, semi-conductor type sensor for ambient temperature and relative humidity.

A rubber hose with 20cm(inside diameter) was installed above the top center of the composter to discharge ammonia gas. Ammonia concentrations in the head space gas were obtained at non-aeration time once a day using ammonia gas detector(Model: GASTEC No.3L).

Ⅲ. Results and discussion

The temperatures of ambient air, inlet air and compost mass, the relative humidity of ambient air during composting for the period of 42 days are presented in Fig. 2. The ambient air temperature varied between 22℃ and 42℃ but the inlet air temperature of the composter remained between 20℃ and 38℃. Likewise, the relative humidity of the ambient air remained generally constant at 50%~70%. The temperature in compost mass ranged from 33℃ to 67℃.

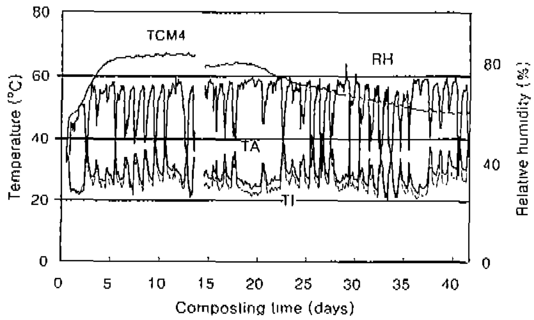

Fig. 2. Temperature and relative humidity profiles during composting. TA: Ambient air temperature, TI: Inlet air temperature, TCM4: Composting temperature, RH: Ambient air humidity

Temperature in compost mass rose rapidly to the thermophilic region over 45℃ after 6 hours and reached 65℃ after 6 days. The composting piles reached the maximum temperature of 67℃ at 11th day and continued on above 65℃ from the 6th to 14th day.

Temperature, ammonia and increased enthalpy during the composting process are shown in Fig. 3. The ammonia levels increased rapidly in the first 2 days of composting as the temperature of compost mass increased, then varied between 114 and 117ppm on the 4th to 6th day. When temperature exceeded 65℃ on the 6th day, the ammonia emission started to decline. However, the ammonia emission maintained above 25ppm until the 14th day. Stabilization of the ammonia emission was started from the 15th day of the primary aeration. From that time, the ammonia emission maintained below 25ppm of maximum safe concentrations of ammonia gas(ASAE, 1997b). Ammonia emission could hardly be detected after 21th day as the compost temperature declined below 60℃. The

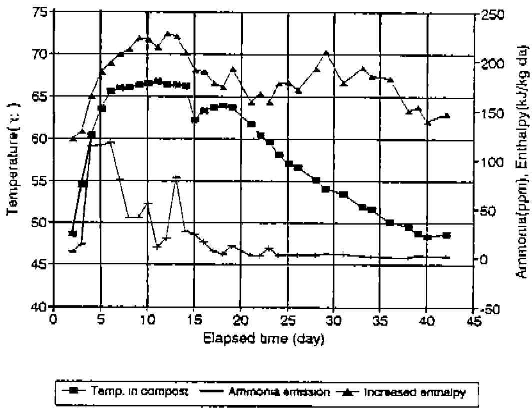

Fig. 3. Changes in temperature, ammonia and increased enthalpy during composting

high ammonia emissions could be detected ranging from 114ppm to 117ppm on the 4th to 6th day of composting.

Ammonia emission irritates the eyes at about 50ppm and the respiratory tract is affected at around 100ppm(ASAE 1997a). Therefore, the control of ammonia emission within a optimum range for the plant in the composting greenhouse could achieved after 15 days of the composting process.

Ammonia emission and temperature in compost level histories obtained during the study is shown in Fig. 3. Ammonia emission during composting with primary aeration and curing stage was evaluated using temperature changes in compost. During the batch-procedure, ammonia volatilization reached its peak 117ppm on the 6th day, afterwards it declined rapidly at 66℃. The ammonia emissions rose rapidly in the thermophilic region of 55℃～60℃ from 13ppm at 3rd day to 114ppm at 4th day. These results show that rapid rise in ammonia emission appeared between the 3rd and 4th day of composting due to increase in compost temperature.

The relationship between ammonia emission and the increase in enthalpy during composting are shown in Fig. 3. As the enthalpy levels increased rapidly, there was a rapid increase in temperature. The enthalpy in head space and inlet air were obtained from the psychrometric chart using the measured data of temperature and relative humidity at those space. The increased enthalpy in the Fig. 3 represents a difference of enthalpy between head space gas and inlet air. When the increased enthalpy eventually exceeded 200kJ/kg.da after 6th day of composting, the ammonia concentrations started to decline. The high ammonia emission readings indicated effective composting. The high ammonia emission was obtained in the range from 114ppm to 117ppm while the increased enthalpy changing from 165 to 198kJ/kg.da on 4th to 6th day of the primary aeration stage.

Table 1 shows variations of biochemical components during composting for five weeks. C/N ratio of the initial mixtures was as high as 35.2. Composting reaction was slow as shown in the temperature profile of compost mass in Fig. 3. Although higher temperature in compost mass was the result of heat accumulation, decrease in the C/N ratio over time was due to the constituents of rice hulls. C/N ratios within the range from 25 to 30 indicates an efficient process(Rynk et al., 1992). Mixtures of materials with C/N ratios higher than 30 require longer composting period for the microorganisms to use the excess carbon. When the C/N ratio is low below than 25, there is too much nitrogen and it would likely be lost to the atmosphere in the form of ammonia gas(USEPA, 1992). This may lead to ammonia odor problems during composting process. The initial pH

Table 1. Results of analysis on compost materials

Item	Composting times(weeks)					
	0	1	2	3	4	5
Moisture content, %(wb)	67.3	65.5	64.6	63.0	62.4	62.8
pH	8.3	8.9	8.8	8.3	8.1	7.7
T-C, %(db)	47.2	47.1	46.7	46.5	46.3	46.2
T-N, %(db)	1.34	1.30	1.36	1.38	1.40	1.44
C/N	35.2	36.2	34.3	33.7	33.1	32.1
VS, %(TS)	85.0	84.8	84.1	83.8	83.4	83.2

T-C: Total carbon, T-N: Total nitrogen,
VS: Volatile solids

value was measured as 8.3 of higher value than recommend as around 7. This higher value might be due to the degradation of organic matter in the pretreatment and a increase in the nitrogen in NH_3 form.

As described above, the temperature of the compost could be used as an index to estimate the progress of decomposition. It was concluded that lower ammonia emission during composting was detected because the initial C/N ratio of composting material was high as 35.2 and the ammonia was absorbed in the upper layer of the compost mass. The high C/N ratio of initial material required longer period of over five weeks for composting process.

As organic matter decomposed, there was a relative increase in the ash content. The content of total carbon decreased while total nitrogen increased a little due to the use of rice hulls.

Ⅳ. Conclusions

Mixtures of dairy manure and rice hulls were composted by a positive aeration method to verify the characteristics of ammonia emission during solid composting process. The results of this study are summarized as follows:

The ammonia gas levels during intermittent aerated composting increased rapidly in the first 2 days of primary aeration stage and maintained at 114 and 117ppm for a period from 4th to 6th day. When the compost temperature exceeded 65℃ on the 6th day, the ammonia emission started to decline and could hardly be detected from the 21th day of composting.

The high ammonia concentrations ranged from 114ppm to 117ppm on the 4th to 6th day of composting with high compost material temperature above 60℃. Stabilization of the ammonia emission was started from the 15th day of the primary aeration stage.

Mixtures of composting materials with high C/N ratios of 35.2 required longer composting times for the microorganisms to use the excess carbon.

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