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Study on the Recycled Composting System for Reducing Bulking Agent Cost[†]

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부자재 비용절감을 위한 순환퇴비화 시스템에 관한 연구

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적 요

본 실험은 고형퇴비화 처리용 부자재 비용절감 및 생물계 폐기물의 퇴비화 작업효율을 개선하기 위하여 연속 및 간헐통기 퇴적식 호기성 퇴비화 시스템에 필요한 기초 연구자료를 제공하기 위하여 수행되었다. 유우분과 왕겨 (Ⅰ) 그리고 유우분과 1차 순환퇴비 (Ⅱ) 및 2차 순환퇴비 (Ⅲ)를 전처리 혼합하여 12.3 ℓ 의 회분식 원통형 발효조 3개에 동일한 수준에 같은 성질의 실험재료를 넣어 10일간 실험하였다. 이때, 통기량은 연속통기 (CA)는 0.3~0.6 ℓ /min.kg.dm, 간헐통기 (IA)는 0.1~0.2 ℓ /min.kg.dm 범위로 5분 통기 55분 정지의 방법으로 퇴비화 처리하였다.

퇴비화 과정중 발효조의 내부 온도는 잡초종자 및 병원균 사멸을 위한 퇴비화 적정온도인 55~60℃를 연속통기 (CA)는 38~78시간, 간헐통기 (IA)는 37~98시간 유지하였다. 순환퇴비의 혼합량이 증가함에 따라서, 암모니아 휘산 농도는 증가하였으며, 연속 통기시 최고 농도는 110, 160, 287 ppm을 나타냈으며, 간헐 통기 방법을 이용한 퇴비화 경우는 52, 76, 420 ppm을 나타냈다. 이는 순환퇴비의 탄질비가 17.6, 22 그리고 16.5로 낮기 때문이다.

퇴비화 종료 후, 퇴비의 품질은 수분 함량 (MC)이 68~73%로서 40% 이하의 적정 수분 함량으로 건조가 필요하였다. 산도 (pH)는 7.9~8.7로서 적정 값 (8이하)보다 약간 높아 후숙 과정이 필요하였으며, 유우분에 순환퇴비를 부자재로 혼합한 실험 Ⅱ와 Ⅲ의 경우, 탄질비 (C/N)는 20이하로 적정수준을 나타냈다.

(핵심어 : 순환퇴비화, 부자재)

INTRODUCTION

Livestock agriculture in Korea has developed into an efficient industry over the latter half of the twentieth century. However, the prospects for the future are marred by an increasing number of environmental problems that stems from the large quantities of manures produced

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within several intensively farmed regions. Moreover, 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 a simple and economically attractive alternative for treating and stabilizing animal wastes, and there is a high degree of interest in the farming community to compost manure (Leger et al., 1991; Bishop et al., 1980). Composting reduces the weight, moisture content and bioactivity of manure as well as destroys pathogens (Rynk, 1992).

For cost efficient composting, an environment must be created that provides optimal nutrients, moisture, temperature, aeration, and pH so as to optimize growth rates of the microflora in the process. In order to optimize the economics of composting, high degradation rates and subsequent high quality end products must be achieved at low costs. It is important to reduce the capital and bulking amendment costs associated with manure composting.

Rice hulls are used widely as bulking amendment to substitute for sawdust in Korea. However, bulking amendments, in addition to frequently being scarce or expensive to purchase, increase capital costs.

Reusing recycled compost as a bulking amendment during solid composting contribute to the saving of capital cost for purchase. Therefore, it is important to develop technology for reusing recycled compost. Even though composting has a long history and has been the subject of much research and development, little is known about recycled compost.

The objective of this research is to investigate the effect of recycled composting system with continuous aeration (CA) and intermittent aeration (IA).

MATERIALS AND METHODS

1. Raw manure and bulking agents

The raw manure used in these experiment was selected from Holstein cattle which were approximately 550 kg per live weight, 5 years old and housed in free stall barn from the farmstead of Sunchon National University. The dairy manure was obtained from milking room of the farmstead in a few days before an experiment started. Approximately 0.8 kg samples were collected into sampling bag for analysis.

The choice of bulking agent depends on the availability and the cost of a material in given area. Amounts and properties of the raw materials used are given in Table 1, 2 and 3.

2. Composting system design

In order to determine the recycled composting system for reducing bulking agent cost, three 12.3 ℓ vessel composter (250 mm deep and 250 mm in diameter) were built and loaded with around 6kg of composting materials. Each composter was built of plastic pipe of 250 mm inside diameter and 5 mm thickness and insulated using polystyrene as shown in Figure 1. A steel plate with many perforated holes of 3 mm diameter (opening area >40% of total area) was installed 50 mm above the bottom of each composter to aid aeration and support the compost mass.

The vessels were insulated to minimize heat

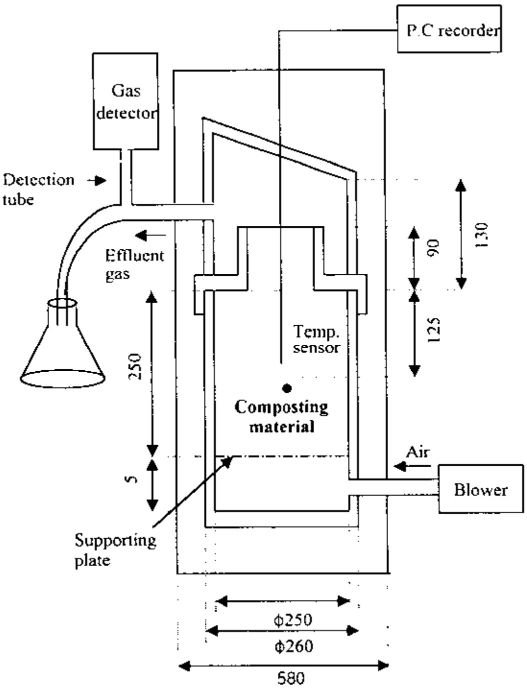

Fig. 1. Schematic diagram of 12.3 ℓ composter. (Unit : mm).

loss through the wall and closed by insulated lids. Each of three vessels was covered with 70.5 mm of polystyrene insulation board. Outside was constructed of 120 mm in thickness plywood chamber by 840 mm high. The top was capped with a 120 mm in thickness plywood with a 100 mm in diameter.

Temperatures on the composting process were measured from the center composting materials. Type-K thermocouples attached datalogger were used to record temperature. Temperatures were monitored continuously and recorded every hour throughout the composting period.

For the continuous air flow tests, the compressor provided about 0.3 to 0.6 ℓ/min.kg.dm per vessel for oxygenation of the compost. For the intermittent aeration, the blower provided about 0.1 to 0.2 ℓ/min.kg.dm for five minutes and there was no air flow for 55 minutes of each hour.

Ammonia concentration was measured using a gas detector (Model GASTEC 801) at intervals of 12 hours.

Condensed water from the effluent gas was captured in the head cover of the composters and was weighed at the end of the composting process.

Composting was performed for ten days.

3. Laboratory analysis

Analysis for the physical and chemical characteristics was done for the feedstock materials and the finished compost. Composite samples from each of the three vessels for two experimental runs were analyzed in triplicate. With the exception of bulk density, loss of mass and condensed water, all of the physical and chemical parameters were evaluated using standard laboratory technique as given in accordance with Standard methods of Soil Analysis (1989).

Loss of mass was determined by weighing the material before and after composting. Bulk density (BD) was calculated from the mass and the known volume of the material.

At least three replicates of each experiment were done, statistical analyses computed. The ANOVA-test for significance was also applied to some of the data.

RESULTS AND DISCUSSION

1. Initial properties of the feedstock materials

The experimental study was conducted to

evaluate the effects of continuous aeration (CA) and intermittent aeration (IA) mode on recycled composting system for reducing bulking agent cost. Two runs (run No. 1 and 2) were performed with three laboratory scale vessels.

Table 1. Ratios of feedstock materials used in compost mixes

Test of runs	Test series	Wet weight (kg)		
		Dairy manure	Rice hulls	Recycled compost
No. 1 (CA)	Ⅰ	15.0	2.5	-
	Ⅱ	16.3	1.8	1.8
	Ⅲ	15.5	-	5.2
No. 2 (IA)	Ⅰ	16.0	2.6	-
	Ⅱ	18.0	2.0	2.0
	Ⅲ	14.0	-	4.7

Table 2. Properties of feedstock materials used in compost mixes for run No. 1

Property	Dairy manure	Rice hulls	Recycled compost (Test Ⅱ, Ⅲ)
pH(-)	6.50	6.30	8.13
MC(%, wb)	82.38	9.28	48.37
Ash(%, wb)	2.45	14.06	9.14
T-C(%, db)	41.57	38.77	38.64
T-N(%, db)	2.30	0.66	2.20
C/N(-)	18.07	58.74	17.56

Table 3. Properties of feedstock materials used in compost mixes for run No. 2

Property	Dairy manure	Rice hulls	Recycled compost	
			Test Ⅱ	Test Ⅲ
pH(-)	6.52	6.79	8.41	8.58
MC(%,wb)	79.90	10.04	12.57	33.71
Ash(%,db)	1.98	14.73	12.62	11.63
T-C(%,db)	44.47	41.41	40.43	38.08
T-N(%,db)	2.65	0.72	1.84	2.31
C/N(-)	16.78	57.51	21.97	16.48

The amount of dairy manure, rice hulls or recycled compost in the composting materials in each of the trials are listed in Table 1. The initial moisture content in these experiments was approximately 70%.

Table 2 and 3 show physicochemical properties of raw materials used in compost mixes for run No. 1 and 2.

2. Temperature profiles

The temperatures of ambient air and compost materials, the relative humidity of room during composting are presented in Figure 2 and 3.

Run No. 1 trial was controlled using a continuous aeration (CA), and run No. 2 was

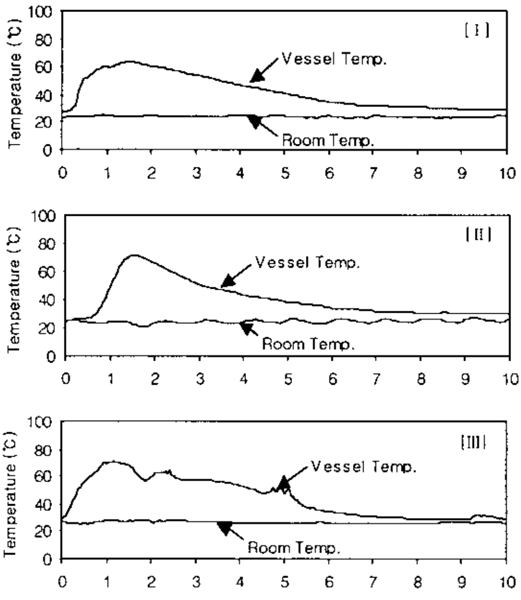

Fig. 2. Average compost temperature and room temperature profiles from laboratory vessels with test series Ⅰ, Ⅱ and Ⅲ during continuous by aerated (CA) composting (run No. 1).

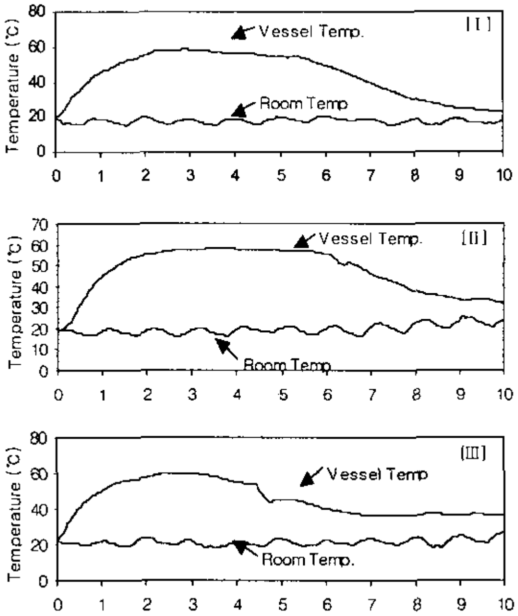

Fig. 3. Average compost temperature and room temperature profiles from laboratory vessels with test series Ⅰ, Ⅱ and Ⅲ during intermittent by aerated (IA) composting (run No. 2).

controlled using a intermittent aeration (IA). Compost temperatures were measured in the middle of the compost mass.

Composting temperatures for run No. 1 reached the thermophilic range (>40℃) within 9, 21 and 6 hr, which those for run No. 2 reached within 18, 19 and 12 hr (Fig. 2 and 3).

The initial rapid rise of compost temperature is a result of the high decomposition rate made possible by the availability of easily decomposable material in wastes (starches, sugars, proteins, amino acids, etc) (Golueke, 1977).

The composting temperatures for run No. 1 reached the maximum values of 64, 72 and 71 ℃ at 36, 37 and 30 hr. Also, for run No. 2 maximum values reached 59, 58 and 60℃ at 68, 88 and 63 hr. The higher value of maximum temperature was attained at the tests Ⅱ and Ⅲ amended recycled compost than trial Ⅰ for run No. 1.

The maintaining period of optimum temperature (>55℃) to destruct pathogens was from 38 to 78 hr for CA (run No. 1), from 60 to 98 hours for IA (run No. 2). Shorten duration for CA is due to cooling the compost mass by CA, and we conclude that IA is the more desirable than CA as that provides longer period to kill pathogens. Final temperatures at 10 day were from 29 to 30℃ (run No. 1), from 23 to 37℃ (run No. 2).

The temperature record showed that continuous aeration had a cooling effect. The maximum temperatures for the IA method were lower than that for CA method, because the air was not constantly supplied.

3. Ammonia emissions

The emission of ammonia increases as a result of the microbial metabolism of protein. Graphical histories of ammonia emission for CA (run No. 1) and IA (run No. 2) composting were presented in Figures 4 and 6, respectively. Figures 5 and 7 represented comparison of average cumulative NH_3-N emitted for CA and IA during composting process.

In the case of run No. 1 as shown in Figure 4, the more recycled compost mixed, the higher ammonia emitted. The maximum ammonia emissions were 110, 160 and 287 ppm. At the end of 10 days of composting, the ammonia concentrations were 28, 95 to 137 ppm.

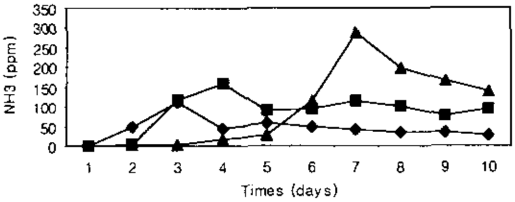

Fig. 4. Average ammonia emissions from laboratory vessels with test series Ⅰ, Ⅱ and Ⅲ during CA.
(◆-◆ : Ⅰ, ■-■ : Ⅱ, ▲-▲ : Ⅲ)

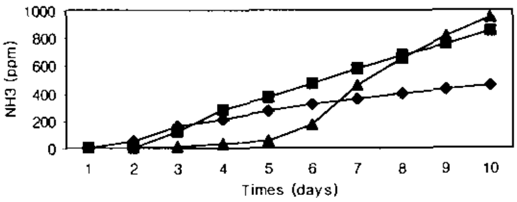

Fig. 5. Comparison of average cumulative ammonia emissions from laboratory vessels with test series Ⅰ, Ⅱ and Ⅲ during CA.
(◆-◆ : Ⅰ, ■-■ : Ⅱ, ▲-▲ : Ⅲ)

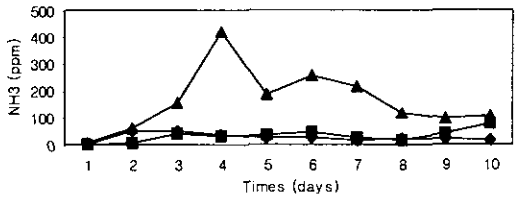

Fig. 6. Average ammonia emissions from laboratory vessels with test series Ⅰ, Ⅱ and Ⅲ during IA.
(◆-◆ : Ⅰ, ■-■ : Ⅱ, ▲-▲ : Ⅲ)

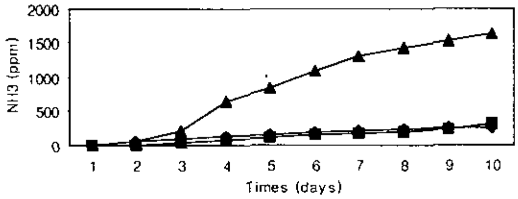

Fig. 7. Comparison of average cumulative ammonia emissions from laboratory vessels with test series Ⅰ, Ⅱ and Ⅲ during IA.
(◆-◆ : Ⅰ, ■-■ : Ⅱ, ▲-▲ : Ⅲ)

Also, the ammonia curve pattern of IA composting in run No. 2 was similar to that of CA though there was a little difference in fluctuations as shown in Figure 6. The maximum ammonia emissions were 52, 76 and 420 ppm. At the end of 10 days of IA composting, the concentrations were 13, 76 and 106 ppm.

These indicates that the ammonia emissions were greatly affected by the initial properties of raw material mixes. When the C/N is to low, the microorganisms will incorporate part of the nitrogen and part will be deaminated and lost as ammonia (Petra, 1988).

Comparison of CA and IA methods of composting dairy manure mixed with recycled compost showed that IA is a satisfactory method to compost. According to these results, IA conditions produce less ammonia than CA conditions. This suggests that the pertinent mixed ratio of recycled compost was 1:1 by wet weight basis (rice hulls : recycled compost).

4. Chemical and physical properties during composting process

During composting by CA, physicochemical properties of initial and final ingredients are shown in Table 4. Fresh compost was required drying, because of moisture content of the composts was above 70%. The pH of the samples showed a smooth rising trend, from a mean values of 6.6, 6.1 and 7.9 to a final mean values of 7.9, 8.2, 8.3. A similar effect was observed regarding the nitrogen content of the samples. Otherwise, the total carbon content continued to decrease for all (test Ⅰ to Ⅲ) of the composts. C/N ratio of test Ⅲ, in which the recycled compost was used completely as bulking agents, was below 20.

During composting by IA, physicochemical properties of initial and final ingredients are shown in Table 5. Run No. 2 was quite similar to run No. 1 for all composts. The more recycled compost mixed, the higher pH, the more amount of ash observed. With the

Table 4. Composition of initial and final ingredients during composting for run No. 1

Parameter	Test Series					
	I		II		III	
	Raw	Fresh	Raw	Fresh	Raw	Fresh
MC (%, wb)	71.21	71.11	74.01	72.85	74.20	73.39
T-C (%, db)	40.94	39.28	41.23	38.80	40.02	38.79
T-N (%, db)	1.60	1.87	1.69	1.98	2.44	2.36
C/N (-)	25.58	21.05	24.39	19.63	16.40	16.42
pH (-)	6.63	7.94	6.06	8.22	7.86	8.25
Ash (%, wb)	4.55	4.63	4.01	4.50	4.30	4.99
Density (kg/m^3)	463	413	514	461	540	480

Table 5. Composition of initial and final ingredients during composting for run No. 2

Parameter	Test Series					
	I		II		III	
	Raw	Fresh	Raw	Fresh	Raw	Fresh
MC (%, wb)	70.15	69.33	67.42	67.25	70.70	69.69
T-C (%, db)	41.26	40.37	42.48	39.29	40.16	38.02
T-N (%, db)	1.83	1.77	2.03	2.04	2.38	2.60
C/N (-)	22.55	22.81	20.93	19.29	16.87	14.75
pH (-)	6.71	8.44	7.04	8.67	8.28	8.61
Ash (%, wb)	3.76	4.60	3.95	4.99	4.20	5.49
EC (mS/cm)	4.27	2.90	3.50	2.55	3.80	3.95
Density (kg/m^3)	465	436	465	432	469	419

Table 6. Loss in mass and condensed water generated

Test of runs	Test series	Mass (kg)			Percent loss (%)	Condenced water (gr)
		Initial	Final	Loss		
No. 1 (CA)	I	5.69	5.09	0.61	10.52	40
	II	6.33	5.67	0.65	10.32	20
	III	6.65	5.91	0.73	11.03	20
No. 2 (CA)	I	5.72	5.36	0.36	6.29	30
	II	5.72	5.31	0.41	7.16	30
	III	5.74	5.16	0.58	10.10	30

exception of MC and pH, composition of the final ingredients, during the composting process using recycled compost, was near the optimal range.

5. Loss in mass and condensed water

Loss of mass and condensed water generation during composting by CA and IA are presented in Table 6. Loss of mass was determined by measuring the difference of mass in the vessels before and after composting.

During composting by CA, mass loss was approximately ranged from 0.61 to 0.73 kg representing from 10.52 to 11.03% loss, and for IA the value was in the range of 0.36 to 0.58 kg representing from 6.29 to 10.10% loss. The more recycled compost mixed, the more loss of mass was observed.

Condensed water from 20 to 40 g was generated during ten days of composting.

SUMMARY

This study was initiated to investigate the influence of biophysical condition on the composting characteristics, and conducted to develop technology for using recycled compost as a bulking agent cost to reduce operating cost.

Two methods of aeration, continuous aeration (CA: run No. 1) and intermittent aeration (IA: run No. 2) were performed with three 12.3 liter laboratory scale vessels for ten days. Manure and rice hulls were mixed for thirst trial (Ⅰ), rice hulls and recycled compost after first trial were mixed for second trial (Ⅱ), dairy manure and only recycled compost after second trial were mixed for third trial (Ⅲ). During the composting process, temperatures of the compost mass and ammonia emissions were measured. The quality and maturity of compost were ascertained by examining the characteristics and composition of the compost. Also, loss of mass was determined by measuring the mass of materials in the vessels before and after composting.

The results in this study are as follows:

1. The periods of optimum temperature (>55℃) to kill pathogens were maintained from 38 to 78 hours for CA and from 60 to 98 hours for IA.

2. The more recycled compost mixed, the more ammonia emitted. The maximum ammonia emissions were 287 ppm at CA and 420 ppm at IA.

3. Biofiltration system was required for the composting system using only recycled compost as an amendment, because the ammonia emissions was produced above 100 ppm at the end of composting process.

4. The quality and maturity of compost:

- Fresh compost, were required drying, because moisture contents of the compost were approximately 70% in all tests.
- The pH values were observed to rise smoothly, from 7.9 to 8.3 at CA and from 8.4 to 8.6 at IA.
- The C/N ratios of the fresh compost were ranged form 21.05 to 16.42 for CA and from 22.81 to 14.75 for IA. The final C/N ratios for test Ⅱ and Ⅲ were below 20.

REFERENCES

1. Bishop, J. R., A. B. Bodine and J. J. Janzen. 1980. Composted solids from

manure can be used in free stalls. Hoard's Dairyman. 125 : 1320 - 1321.

2. Goleuke, C. G. 1977. Biological processing : Composting and hydrolysis. In : Handbook of Solid Waste Management, D. G. Wilson (Ed). New York. van Nostrand Reinhold. : 197 - 225.
3. Leger, D. A., N. K. Patni and S. K. Ho. 1991. In Proc. of the National Workshop on Land Application of Manure. Ottawa, Ontario, Canada : Canadian Agricultural Research Council.
4. Petra, K. 1998. The composting of poultry manure with special reference to nitrogen and bulking agents. Ohio Agricultural Research and Development Center. Wooster, Ohio : 1 - 36.
5. Rynk, R.(Ed.). 1992. On-farm Composting Handbook. NRAES-54, Ithaca, N.Y. : Northeast Regional Agricultural Engineering Service.
6. Sartaj, M., L. Fernandes and N. K. Patni. 1997. Performance of forced, passive, and natural aeration methods for composting manure slurries. Transactions of the ASAE. 40(2) : 457 - 463.