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Article

Physical and Chemical Quality of Organic by Product Fertilizers by Composting of Livestock Manure in Korea

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Utilization of organic by-product fertilizers has many beneficial effects on agricultural activities and in aspects of the disposal of enormous amounts of livestock manure. Most of these beneficial effects are related to the improvement of soil condition, such as fertility status and physicochemical quality of soil. But, appropriate indexes are needed to effectively manage the quality of organic by product fertilizers amended on soil. To find chemical and physical standard to control the compost quality, the changes in chemical and physical characteristics of organic by product fertilizers during composting were investigated, and also an appropriate physical method for this end. The results showed chemical properties, such as humic acid content, OM/N ratio, cation exchange capacity and salt content, had significant relationships during the composting. The water content, particle and bulk densities, particle size and color indices, as physical properties, were also applicable factors for the quality control of compost.

Key Words : Organic by product fertilizer, Composting, Livestock manure, Physical standard, Color

Introduction

Livestock farming has been traditionally one of the most important agricultural practices in Korea though it generates enormous amounts of wastes. The manure contains high concentrations of organic matter, macro- and micronutrients, trace elements, and in some cases pathogenic organism (Tiquia et al., 1998). Livestock wastes have increased since the 1970s and now it occupies about 25% of the national BOD loading to water system in Korea (MOE, 2002). Composting can be an alternative method to treat livestock manure and maximize its beneficial effects by re use on agricultural lands. It is also encouraged to establish sustainable agriculture for farmers. Compost of livestock manure has a particular role in Korea, where the soils are poor in terms of organic matter content and some inorganic nutrients such as Ca (Cho, 2001), but rich in nitrogen and phosphorus, especially in the suburban upland and the orchard land (Park, 2001).

Today, about 80% of livestock wastes has been recycled to farmland by compost in Korea (MOE, 2002). Agricultural lands in Korea also need this type of input, as farmers have used chemical fertilizers for decades, without paying any attention to the long term implications to soil quality. But the acceptability of composting depends on how well the operational strategy being employed is developed, and how successful the composting process works (Tiquia *et al*., 1998). The principle requirement for the safe use of compost in soil is its degree of stability or maturity, which implies stable organic matter contents, and the absence of phytotoxic compound, and plant or animal pathogen. Thus, it is important to evaluate the maturity and quality of final product in order to protect crop and environment.

A number of criteria or parameters have been proposed to test compost maturity, although most of these refer to compost made from city wastes. Changes in organic carbon content of humic material and some chemical properties such as organic matter, nitrogen and cation exchange capacity (CEC) of organic by-product fertilizer, in relation to composting stages, can be used for management and quality control. The turnover rate of carbon and nitrogen in compost offers a new quality control indicator to soil management (Kubat, 1992). The final compost has to have a guaranteed standard not only for a safe agricultural use but also for a satisfactory fertilizing value (De Bertoldi *et al*., 1984). Some physical

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properties such as color, odor and temperature were suggested for quality control of organic by-product fertilizers to give a general idea of which decomposition stage had been reached. However, these parameters give a little information as to the degree of maturation and chemical parameters, such as C/N ratio, inorganic nitrogen, CEC and the degree of organic matter humification are more widely used (Bernal *et al*., 1998). For example, Chanyasak and Kubota (1981) used C/N ratio of 5-6 as an indicator of compost quality. Compost maturity can also be defined in terms of nitrification (Zucconi and de Bertoldi, 1987). Harada and Inoko (1980) used a CEC of 60 $cmol_c\ kg^{-1}$ as an indicator for the maturity of city wastes. Alternative biological methods (Kirchmann and Widen, 1994), involving seed germination and root length, were suggested by Zucconi et al. (1981). Zucconi and de Bertoldi (1987) used microbial stability as a maturity indicator.

The Korean commercial compost guideline, established in 1977, has been modified 13 times (MOAF, 2002) during the last 25 years. This guideline includes critical contents such as hazardous ingredients, organic matter, nitrogen, water content and also a list of organic sources that must not be used for composting. There are, however, still difficulties in quality management of immature compost and those with illegal raw materials. For example, the illegal use of industrial wastes takes places and causes some injury to crop plants and disturbance of soil fertility. The objective of this work is to find some effective idicators against problems from immature or illegal compost. The current quality status of compost produced commercially from Korea were evaluated and the relationship between physical and chemical properties were investigated for organic by-product fertilizers. For such purpose, water content, particle and bulk densities, particle size distribution and color indices, OM/N ratio, inorganic nitrogen, CEC and degree of humification in the compost samples were analyzed.

Materials and Methods

Samples used in the chemical quality analysis were collected from 100 of different sources among total 432 manufactures in Korea. Among them 7 representative composts were selected to investigate relationship between the physical and chemical properties, and samples were divided into eleven composting stages considering each composting process. These samples were collected from seven kinds of livestock composting facilities, which used different sources of livestock wastes, as shown in Table 1. The pH and EC of compost was measured using Orion 920A pH meter and Orion EC meter, respectively, on 1:10 water extracts. The moisture content was determined after drying at 105℃ for 24 hours. The total nitrogen content was determined by distillation method after Kjeldahl digestion using $CuSO_4$ and K_2SO_4 as catalyst (NIAST, 1996). The organic matter content was determined by loss on ignition at 430℃ for 24 hours (NIAST, 1996). The cation exchange capacity (CEC) was determined by the methods of Lax et al. (1986) using $BaCl_2$-triethanolamine. Samples for heavy metal content were digested in the ternary solutions, HNO_3:H_2SO_4:$HClO_4$ = 10:1:4, and measured using ICP-AES (JY 138 Ultrace, JOBIN YVON). The humic materials (humic acid, fulvic acid and humin) were extracted from compost by modified method of Hayes (1985). The organic carbon content of each humic material was determined by backtitration method after oxidation by $K_2Cr_2O_7$. The humification index (HI) and humification ratio (HR) were calculated by equation suggested by Inbar *et al*. (1990). The bulk density was determined by the method proposed by NIAST (1996). The viscosity of membrane filtered 1:5 water extract was measured by Ostwald type capillary viscometer. The

Table 1. Description of the organic byproduct fertilizers used in this study

Sample	Material (%, v/v)		Composting period (days)
	Manure Source	Adding material	
COM 1[†]	Pig manure (50)	Rice husk (50)	90
COM 2	Pig manure (50), Livestock waste (25)	Sawdust (25)	40
COM 3	Pig manure (25), Poultry manure (25)	Rice husk (50)	30
COM 4	Poultry manure (20), Pig manure (20), Livestock waste (20)	Sawdust (30), Bark (10)	45
COM 5	Poultry manure (20), Pig manure (10)	Saw dust (15), Dregs of oil and lees (55)	30
COM 6	Pig manure (60), Cattle manure (10)	Saw dust (30)	25
COM 7	Poultry manure (70)	Saw dust (30), Zeolite (trace)	40

[†] COM 1-7 means the organic by- product fertilizers used in the study.

relative spectral reflectance was measured using a COLOR 7200F (Color Techno System Co. LTD).

Results and Discussion

Amendment of organic by-product fertilizer in soil has many beneficial effects on conserving soil fertility. Most of these are due to quality improvement and nutrient enhancement of soil, which results in increase in crop yield and quality. In order to maximize beneficial effect of organic by-product fertilizer amendment, careful consideration to composting process, management and application is needed. Before developing an appropriate physical method to determine final quality of organic by-product fertilizer or compost maturity, physical and chemical properties of 100 commercial organic by-product fertilizers produced in Korea were analyzed.

The seven kinds of organic by-product fertilizers among 100 samples, considering the composition of raw material and productivity, were selected to evaluate changes of chemical and physical properties during composting. Each organic by-product fertilizer was collected at eleven composting stages that were divided by the decomposition periods. Table 2 shows tendency index which describes changes in chemical properties of organic by-product fertilizers during the composting process. As decomposition proceed water content, NH_4^+-N and OM/N ratio decreased significantly, while nitrogen content increased with time. The pH and EC values were not significantly changed during whole composting stages. For chemical properties of organic by-product fertilizer, humic material (humic acid, fulvic acid and humin fraction) extracted from each composting stages were analyzed for organic carbon content. The organic carbon of fulvic acid either slightly decreased or remained unchanged during composting, while that of the humic acid increased consistently during composting process. Hue and Liu (1995) reported that the humic and fulvic acid were decreased with decomposition. According to Yang et al. (1999), the humic acid content was increased while that of the fulvic acid decreased in composting process of piggery manure. The above result for humic material could represent the real state of compost, as most of compost made in Korea is originated from pig manure. The change in humic material concentration resulted in an increase in humification ratio (HR) and humification index (HI). Theses indices were found to be correlated significantly with chemical properties such as the OM/N ratio and CEC of organic by-product fertilizers. The OM/N was decreased with composting time and correlated with HI (r = 0.48-0.82) and HR (r = 0.48-0.83). The CEC was increased with time and correlated with HI (r = 0.42-0.86). As the EC, pH and nitrate concentration were highly influenced by kind of raw materials and composting system, these values showed little relationship to the stages of composting. The CEC and humification index showed values representing degree of composting in organic by-product fertilizers (Table 2). The relative viscosities, as physical parameters, of the water soluble substances of the samples were 1.01-1.50 times higher than that of distilled water. It was suggested that the relative viscosity might be affected by the water soluble humic materials, inorganic salts, and extremely fine particle contents,

Table 2. Tendency index for the chemical properties of organic by product fertilizers during composting

Parameters	Tendency							Tendency Index
	COM 1	COM 2	COM 3	COM 4	COM 5	COM 6	COM 7	
pH (1:10 with H_2O)	1	0	0	0	0	1	0	0.29
EC (dS m^{-1})	1	0	1	0	0	1	1	*
Water content (%)	1	1	1	1	1	1	0	0.86
NO_3^--N (mg kg^{-1})	1	1	1	1	1	0	1	*
NH_4^+-N (mg kg^{-1})	1	1	1	1	1	1	1	1
NH_4^+-N / NO_3^--N	1	1	1	1	1	1	1	1
T N (%)	1	0	1	1	1	1	1	0.86
OM (%)	0	0	0	0	0	0	0	0
OM / N	1	0	1	1	1	1	0	0.71
CEC ($cmol_c$ kg^{-1})	1	1	1	1	1	1	1	1
Humification index	1	1	1	1	1	1	1	1

* Tendency, changes of physico chemical properties during composting; -1, decreased during composting; 0, unchanged during composting; 1, increased during composting; *, no tendency. They were determined using the correlation coefficients for each physical and chemical parameter with composting time (days).

changing the flux of the water via a capillary tube. Figure 1A shows the representative relative spectral reflectance curve of the organic by-product fertilizer used in this experiment. The measured spectrum values from 400 nm to 700 nm increased exponentially with increasing the wavelength. Each spectrum of the samples was fitted well to the expression Y = a exp (bX). The relative spectral reflectance values of the samples at the same wavelength decreased as the decomposition proceeded as shown in COM3 (Fig. 1B). As the composting stages of the samples increased, the color of the fertilizer darkened. Yang *et al.* (1999) also reported similar results with bark compost. This result corresponds well to the humification process of organic fertilizers. Samples containing significant amounts of humic materials absorbed at long wavelengths (nm) more strongly. The differences in the relative spectral reflectance between the composting stages were higher at the 700 nm than 400 nm for all the samples used in the study. Fig 2 shows the distribution patterns of

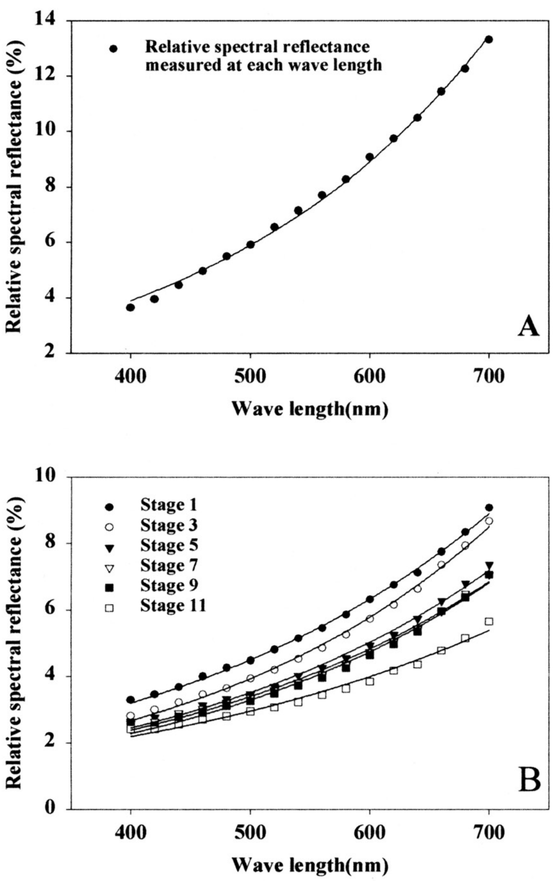

Fig. 1. Relative spectral reflectance curve by wavelength. (A , Relative spectral reflectance curve of the organic by-product fertilizers at each wavelength, expressed as Y = a exp (bX); B, The changes of relative spectral reflectance curves of COM 3 by composing stages; COM3, pig manure (25%), poultry manure (25%), chaff (50%), and over 30 days total composting period, 3 days / stage.).

the relative spectral reflectance measured at 700nm for commercial organic by-product fertilizers. The mean value, upper (+standard deviation) and under (-standard deviation) limits are the relative spectral reflectance measured at 700 nm for the organic by-product fertilizers at 11th composting stage. Among one hundred commercial organic by-product fertilizers, about 40 samples had higher values than the upper limit. These results were due to the variations in the raw materials, and improper use of the annex materials, for composting. Thus, the use of the relative spectral reflectance for the physical quality management of organic by-product fertilizers requires strict regulations of the annex materials. The Munsell color notation, measured by the spectral reflectance ratio in manure, ranged from yellow (Y) to yellow-red (YR). The brightness value ranged from 2 to 6, but most of the sample values were in 2 or 3. These values decreased as the decomposition proceeded. The relative spectral reflectance, estimated at 700nm and the color difference, expressed by ΔE^*ab showed decreasing tendencies with the composting stage. The particle size weighted bulk density (PWBD) of COM 5 and COM 6 increased during the composting period. This may have been the result of the lignin and mineral additives contained in the initial decomposition process (Table 4). The PWBD of the organic by-product fertilizers showed no significant changes during composting. The correlation coefficient between the bulk density (r^2=0.67) and organic matter content was smaller than the values between the PWBD and the organic matter content (r^2=0.78). Table 5 shows the changes in the particle size index for the organic by-product

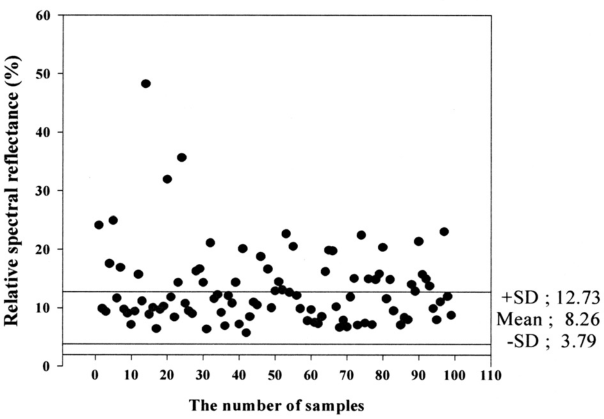

Fig. 2. The distribution of relative spectral reflectance measured at 700 nm for commercial organic by-product fertilizers. (Mean 8.26, for the relative spectral reflectance of the samples measured at 700 nm of the organic by-product fertilizers at 11th composting stage).

Table 3. The changes in particle size weighted bulk density (PWBD) of the organic by product fertilizers during composting stages

Composting Stage	Particle size fraction (mm)						PWBD
	2~0.5		0.5~0.25		0.25~0.045		
	Fraction	BD	Fraction	BD	Fraction	BD	
	g	g/cm^3	g	g/cm^3	g	g/cm^3	g/cm^3
1	5.91	0.24	1.97	0.24	0.80	1.33	0.34
3	7.16	0.35	1.29	0.30	0.55	1.01	0.38
5	6.48	0.36	1.65	0.30	0.90	0.98	0.41
7	6.30	0.36	1.63	0.30	0.93	1.16	0.43
9	6.03	0.35	1.88	0.30	1.03	1.06	0.42
11	4.06	0.35	1.62	0.31	1.96	1.55	0.65

Fraction was calculated from the gram of fraction divided by 10 grams of organic by-product fertilizer; BD, bulk density; COM 5, pig manure (10), poultry manure (20), sawdust (15), dregs of oil and less (55), a 30 day total composting period, 3 days / stage.

Table 4. The changes in the particle size index (PSI) for the organic by product fertilizers during the composting stages

Composting Stage	COM 1	COM 2	COM 3	COM 4	COM 5	COM 6	COM 7
	---------- PSI (mm) ----------						
1	0.76	0.92	0.85	0.98	0.83	0.82	0.79
3	0.89	0.82	0.99	0.82	0.95	0.75	0.76
5	0.86	0.83	1.00	0.82	0.89	0.92	0.77
7	0.84	1.05	1.00	0.72	0.86	0.88	0.76
9	0.86	0.99	1.02	0.73	0.84	0.81	0.76
11	0.79	0.77	1.02	0.74	0.60	0.75	0.81

fertilizers over the composting periods. Generally, as decomposition proceeds, large particles are degraded into smaller particles, thus, the expected particle size will decrease. However, the particle size was not decreased with increasing composting period. Both of the particle size and chemical properties of the particles affect the microbial degradation process. Organic debris, containing cellulose, hemicellulose and pectin, can be easily broken down by microbial attack but lignin-containing particles will not be degraded as the composting of the organic by-product fertilizers proceeds.

For the proper management of the organic by-product fertilizers, strict governmental regulations should be established containing physical criteria with chemical parameters. This will ensure that the adverse effects are minimized, while the many beneficial effects of organic by-product amendment of soils are maximized.

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가축분뇨를 원료로 하는 부산물 비료의 부숙화에 따른 물리화학적 특성변화

이창호 · 옥용식 · 윤영만 · 김대연 · 임우길 · 엄기철[1] · 김정규[*]

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다량으로 배출되고 있는 축산분뇨를 퇴비화 하여 농지로 투입하는 것은 토양의 물리화학성 개선 등의 유효한 효과가 있지만, 적절한 부숙화 과정을 거치지 않은 미부숙 물질을 투여하면 나쁜 영향을 끼치게 된다. 축산분뇨를 이용한 부산물 비료의 제조에 있어서 적절한 부숙도 관리가 중요한 이유이다. 따라서 축산부산물을 주원료로 하고 부재료와 부숙 기간을 7가지 단계로 달리한 부산물비료를 대상으로 부숙화에 따른 화학성의 변화 경향 파악과 색도, 점도, 입도, 용적밀도 등의 물리성 변화를 아울러 조사하여, 부숙도에 대한 판정지표를 추출하고자 하였다. 휴민산 함량, 유기물/질소 비율, 양이온치환용량, 염함량 등의 화학성이 부숙정도와 밀접한 관련이 있었으며, 물리적 특성에서는 수분함량, 입자밀도 및 용적밀도, 입경별 분포, 색도 등이 부숙도의 판정지표로 사용할 수 있음을 알 수 있었다.