Characteristics of Food Waste Composting with Various Particle Sizes of Sawdust

Lee, Chang Hoon
Science for Bioproduction Environment, Faculty of Agriculture, Kyushu University | Department of Bio-Environmental Chemistry, College of Agriculture and Life science, Chungnam National University

Ko, Kwang-Kyun
Science for Bioproduction Environment, Faculty of Agriculture, Kyushu University | National Academy of Agricultural Science, RDA

Kim, Seok-Cheol
Science for Bioproduction Environment, Faculty of Agriculture, Kyushu University | Department of Bio-Environmental Chemistry, College of Agriculture and Life science, Chungnam National University

Kim, Sung Chul
Science for Bioproduction Environment, Faculty of Agriculture, Kyushu University | National Academy of Agricultural Science, RDA

他

https://doi.org/10.5109/1800846

出版情報：九州大学大学院農学研究院紀要. 62 (1), pp.123-129, 2017-02-24. Faculty of Agriculture, Kyushu University

J. Fac. Agr., Kyushu Univ., **62** (1), 123–129 (2017)

Characteristics of Food Waste Composting with Various Particle Sizes of Sawdust

Chang Hoon LEE[1,†], Kwang–Kyun KO[2,†], Seok–Cheol KIM[1], Sung Chul KIM[2], Jwakyung SUNG[1], Yoshiyuki SHINOGI[3] and Taek–Keun OH[2,*]

Science for Bioproduction Environment, Faculty of Agriculture, Kyushu University,
Hakozaki 6–10–1, Higashi–ku, Fukuoka city 812–8581, Japan
(*Received October 31, 2016 and accepted November 4, 2016*)

Sawdust is mainly used as a bulking agent with food waste for composting because of the advantages of absorbing water, providing porosity and adjusting C/N ratio. The objective of this study was to compare the composting properties in relation to the temperature, moisture content, nutrients and the compost maturation index (maturity) with the various particle size of sawdust. The physico–chemical properties of food waste composting shown the standards of organic compost, but there is a potential possibility of salt stress in crops due to the higher salinity of food waste. The smaller particle size showed a higher temperature and relatively easier to maintain a constant temperature. However, there was no significant temperature change on the various mixing ratios. pH, EC and moisture content in ratio of 7:3 as compared to the ratio of 6:4 showed slightly higher and till DAT 21 pH was dropped and then it was stabilized at 9.1 on DAT 56.There was no significant variation on change in pH, but the higher particle size showed the higher EC values in relation to the various mixing ratios. Therefore, there are positive effects on the standardization of the composting process for the quality control and the economics, as the food waste compost showed the higher maturity with the higher mixing ratio of sawdust and the smaller particle size.

Key words: Food waste, composting, sawdust

INTRODUCTION

The food waste means food in the dump as leftover food that occurs in the cooking and the distribution process, it makes up 28% of the total waste, accounted for the amount of 57% occurring on the cooking and the distribution process, 30% on the leftover, 13% on the storage and the disposal (Shin, 2013).

The most prominent characteristics of Food Waste in Korea are the higher salinity and the moisture content (approximately 70~80%) by the Korean food culture, such as Kimchi, Bean Paste, pickles, stew, soup and so on. In particular, the wastewater through the higher moisture content of food waste has become cause of the various environmental problems including of the microbial deactivation and the water pollution.

In the 1990s, the pollution occurring on incineration and landfill disposal of wastes has been becoming socially issued, the Food waste recycling has continuously risen in prominence regarding to undertaken the forbidding law on direct landfill of food waste in 2005, it has been prohibited the dumping of food wastewater into the ocean in 2013 and as well as the wastewater sludge in 2014. The government has been strongly recommended the environmental aspects to produce the compost and the feed through the Food waste treatment facilities and stated that the food waste as a raw material of by–product fertilizers under the fertilizer control act (RDA, 2010; Lim and Han, 2005; Shin, 2013).

The main treatment methods of the food waste are drying feed, aerobic composting, and anaerobic composting (Chang *et al.*, 2002). The method of the aerobic composting is to supply the air with mixing of organic waste, leaves, chaff, sawdust, coco peat and so on uses the fermented heat that occurs when the organics decompose into the minerals, CO_2, NH_3 and so on by the aerobic microbes in the fermenters (Kim, 2010). It has the advantages of higher quality with higher technological maturity and easy to manage on operation by lots of operational performance. In order to effectively producing is required proper ventilation through adjusting of the moisture content with the mixture of food waste, the subsidiary of woodchips, sawdust, straws, fullyfermented compost (Kim, 2010). According to Huh and Han (1999), food waste has the wide coverage due to less contents of phytotoxin but fertilizer efficiency is insufficient to use as a single raw material of composting. So it is essential to add feedstock for the optimal content components and the initial composting optimum conditions as by–product fertilizers. Therefore, on this research the selection of suitable auxiliary materials is required to use the food waste into the compost.

According to Kim (2012), the sawdust is mainly used in Korea as auxiliary materials. It is adjustable the moisture content, the C/N ratio, sufficient the air flow and also provides the suitable microbial growth environment in an aerobic composting. By the lack of domestic production supplies, however, it is mainly imported from the countries where the shipping cost is cheaper, such as

[1] Department of Bio–Environmental Chemistry, College of Agriculture and Life science, Chungnam National University, Daejeon 305–764, Korea
[2] National Academy of Agricultural Science, RDA, Wanju, Jeollabuk–do, 565–851, Korea
[3] Science for Bioproduction Environment, Faculty of Agriculture, Kyushu University, Hakozaki 6–10–1, Higashi–ku, Fukuoka city 812–8581, Japan
[†] The authors contributed equally to this paper as a co–first author.
* Corresponding author (E–mail: ok5382@cnu.ac.kr) (T.K. OH)

Vietnam, China, Malaysia and so on. After the import in 2010 was relatively dramatic increased in comparison with 2009, the trend showed a gradual increase each year and based on 2012 the amount of monthly average import was 9,600 tons (Park *et al.*, 2014). In addition, it undergoes with the various particle sizes and the mixing process by the individual process of the treatment facilities for effectiveness and steady. Nevertheless, it is mainly used as auxiliary materials to date, because of the advantages of cheaper and enough supply.

The aim of the study was to compare the composting characteristics of food waste with various particle size of sawdust used as bulking agent.

MATERIALS AND METHODS

Composting apparatus

Fig. 1 shows a schematic diagram of the composting apparatus used in this study, with a volume of about 11.6 L and dimensions of 270 × 270 × 250 mm (length × width × height) of Styrofoam container. It has connected the rubber hose and the air pump (1.3 L/min) at the bottom, the air outlet was made at the regularly spaced intervals for the smooth air flow. In this experiment, the air was supplied into the composting apparatus to support aerobic microbial activity. The temperature sensor was installed to avoid being stained with the contents at the top, and enable to measure daily basis. The composting machine was in continuous operation from October 27, 2015, to December 24, 2015. The compost pile was turned every week during the 56 day composting process.

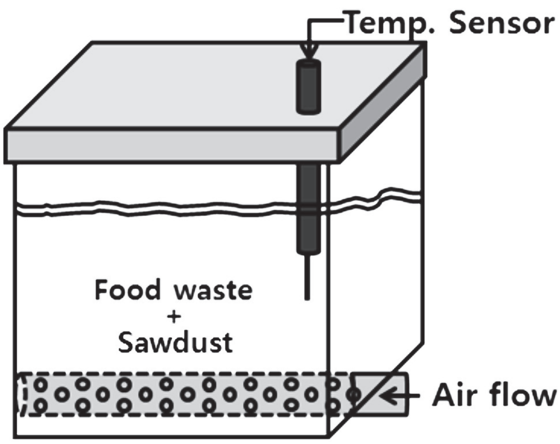

Fig. 1. Experimental apparatus for food waste composting.

Food waste and sawdust

Food waste was collected by the department of environmental treatment, Daejeon City Corporation in Korea. Food waste dehydrated from the facilities was used for composing. The water content of food waste was artificially controlled approximately 74% and removed the hardness or/and bulky bones and shellfish. The food waste showed slightly acid (pH 5.1) and higher electrical conductivity (EC). A total of 10 samples of sawdust were collected from 5 food waste treatment facilities and sawdust distributor. The moisture content of sawdust was varied from 26.19% to 44.47%. There was no significant by the particle sizes in relation to the pH of sawdust, but it showed decreasing on EC values and increasing on the moisture content with the higher particle size (Table 1). For composting, the sawdust samples were categorized by the various particle size using the sieve and set up as the controls by the various mixing ratios (Table 2).

Mixing Ratio

The mixed ratio of the sawdust as a bulking agent to food waste was used 7:3 and 6:4 from the previous study (Kang *et al.*, 2003), because it is hard to control the microbial growth environment and has a risk of large amount of leachate and odor if the ratio of food waste in the mixture is too high or low.

Supplementarymaterials

The supplementary materials were quicklime, manures, microbial agent, and molasses.

Commercially available quicklime was added 3% (90 g) of the total weight of the mixture for stability by the initial heat and pH control. As the formula (1) the Exothermic Reaction between quick lime and water was used.

$$CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(s) + 277.9\ kcal/kg \quad (1)$$

The manures was collected from agricultural center, Nonsan livestock cooperative in republic of Korea, made up 25% pig droppings(pig feces), 25% cow manure, 20%

Table 1. Characteristics of food waste composting materials

Materials		pH (1:10, H_2O)	Electrical conductivity (dS m^{-1})	Moisture content (%)
Food waste		5.10±0.18	56.10±10.30	74.03±1.99
Sawdust	Control	5.25±0.13	6.80±0.50	29.76±1.39
	< 1 mm	5.31±0.04	16.30±0.30	26.19±1.12
	1~2 mm	5.22±0.05	7.10±0.40	36.57±1.21
	2~5 mm	5.20±0.03	4.80±0.20	44.47±1.01
	> 5 mm	5.28±0.03	2.50±0.30	40.40±0.97

Table 2. Sawdust sample of various particle sizes

Unit: % / 100g

Sawdust sample		Particle size distribution (%)				
		< 1.0 mm	1.0~2.0 mm	2.0~3.0 mm	3.0~5.0 mm	5.0 mm >
Food waste Treatment Facilities	A city	32.63	27.76	16.69	7.29	7.10
	B city	21.63	20.55	14.22	13.55	30.22
	C city	59.83	36.00	3.11	0.87	0.14
	D city	30.66	47.17	14.11	3.95	4.11
	E city	47.26	36.81	8.88	1.52	5.53
	Average	38.40	29.55	11.40	1.38	9.42
Sawdust distributor	E distributor	23.60	45.83	21.50	4.97	4.28
	F distributor	54.52	19.73	13.41	6.13	5.76
	G distributor	46.34	47.24	4.66	1.34	0.42
	H distributor	65.88	28.88	3.40	0.95	0.72
	I distributor	19.02	29.73	17.56	13.45	20.24
	Average	41.87	34.28	7.81	5.37	6.28
Total average		40.14	33.97	11.75	5.40	7.85

chicken manure, 17% sawdust, 2% farm meat, 3% spent mushroom media, 3% rice bran and 5% animal by–product and contains the organic matters over 30%. It was added 90 g (3% of the total weight of mixture) and used as the spawn in the process for the microbial growth environment. The commercially available effective microorganisms were added at the rate of 1% of the total weight. To dissolve the sugar in 70 ml of the distilled water used to feed microbes as Molasses.

Physico–chemical Analyses

Sample properties including pH, EC, and moisture content were analyzed by the protocol of the NIAST (National Institute of Agricultural Science and Technology, 2000) and the previous study (Jackson, 1958; Chang *et al.*, 1995; Chang *et al.*, 2008). 3 g of the dry samples of food waste were diluted 10times within 30 ml of the distilled water and it was shaken for 30mins by shaker and then pH and EC values were measured by the pH/Conductivity meter (Horiba F–54 BW). The moisture content was determined after drying the samples under the 105°C in the dry oven for 24 hrs.

Maturity

The maturity tests were carried out with two mechanical methods; Solvita and CoMMe–101 (E&A Tech.); and germination index test every 7 days in the composting period.

Solvita test was conducted at room temperature according to the instruction manual (Woods End, 2000). Firstly, moisture content of a screened sample was regulated by a squeezing. Then, the sample was incubated in 200 mL container with Solvita reactor for 4 hours at room temperature. After that, the carbon dioxide and ammonia levels in the sample were measured using Solvita® DCR (Digital Color Reader). The maturity index level was determined through comparison between the standard color chart and the measured DCR value (Changa *et al.*, 2003).

CoMMe–101 test was also used to determine the maturity of the compost by the method of Kwon (2011). This test was similar with the procedure of Solvita measuring the amount of the carbon dioxide and ammonia levels in the compost, but for the comparison study. After removal of the foreign substances and adjusting the moisture to 40% or more, it was determined by using Kit A & B at different reaction time (1, 2, and 4 hours).

Furthermore, the Germination Index, are mainly used in maturity test, was obtained by growing the seeds of radish (*Raphanussativus* L.).As shown in formula (4), it is calculated as a value (%) multiplied by Germination Ratio and the Root elongation as the formula using the germination rate and the initial state of growth.1g of compost with approx. 50% moisture was diluted with 50 ml of distilled water in a beaker, at 80°C the composting components are extracted from it for 2 hrs. After filtration with a Whatman No. 2 filter paper, the remaining is added 5 ml to the filter paper on Petri Dish. The number of seeds is 30 per petri–dishes. It is germinated for the total 5 days in a growth chamber set to 8 h of light phase at 28°C and 16 h of dark phase at 25°C with 75% relative humidity. The relative germination ratio (GR), relative root elongation (RE), and germination index (GI) were calculated as follows:

$$\text{Germination ratio (GR)} = (\text{Germination rate of treatment} / \text{Germination rate of control}) \times 100 \quad (2)$$

$$\text{Root elongation (RE)} = (\text{Root length of treatment} / \text{Root length of control}) \times 100 \quad (3)$$

$$\text{Germination index (GI)} = GR \times RE \times 100 \quad (4)$$

RESULTS AND DISCUSSION

Temperature

There are heat, evaporation and more through the aerobic compost process that decomposes the organic matter into minerals, NH_3, CO_2 and so on by microbes. The composting process usually includes the mesophilic, thermophilic and maturing stages. In the initial stage, reaction of the lime and the decomposition of easily degradation products such as sugar or starch by the mesophiles under thermophilicis increasing the reaction rate and it rapidly rises the temperature 50°C or more. The thermophiles are furious activity and dominate under thermophilic and hyperthermophilic temperature ranges (50°C or more). It gradually declines the mass through the decomposition of the remaining less degraded matters such as cellulose, hemi–cellulose, lipid, lignin and protein, thus the temperature gradually falls by reduction of the microbial activity (Jung *et al.*, 2002).

Temperature profiles for the six treatments composted are presented in Fig. 2 and Fig. 3. After composting started, the temperature increased quickly in all treatments to about 55–65°C within the first 2~3 days of processing. It was due to by the exothermic reaction of quicklime, the effect of the high rate composting by microorganisms, and the decomposition of organic matters.

Afterwards, the temperature decreased due to the weakening of the activity of thermophilic microorganisms (Li *et al.*, 2008). After the first turn over (DAT 7), the temperature increased again. It means that the heat more than 40°C regenerates through redistribution of the organic matters needful to the decomposing process and improving the air permeability. And then, the temperature decreased slowly to ambient temperature level reflecting stability. There were no significant differences among the mixing ratio on the temperature rise and re–heating. However, the ratio of 6:4 had less temperature change of the mixture by the ambient temperature change compared to the ratio of 7:3 and it shows higher re–heating temperature by the turning with the larger particle size. It is determined that the initial reaction efficiency is improved by higher air permeability (aeration or ventilation) and contact area with the larger particle size.

In addition, after the rapid temperature rise, the temperature of <1mm sample was relatively maintained as about 0.5°C higher compared to the others. It is determined that the larger particle size has less effect from the ambient temperature. As a result, the smaller particle size helps to maintain the temperature above 20°C in the maturing stage.

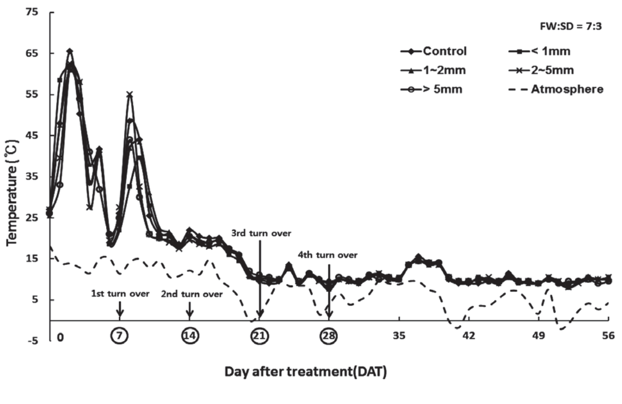

Fig. 2. Variation of temperature during food waste composting (FW:SD=7:3).

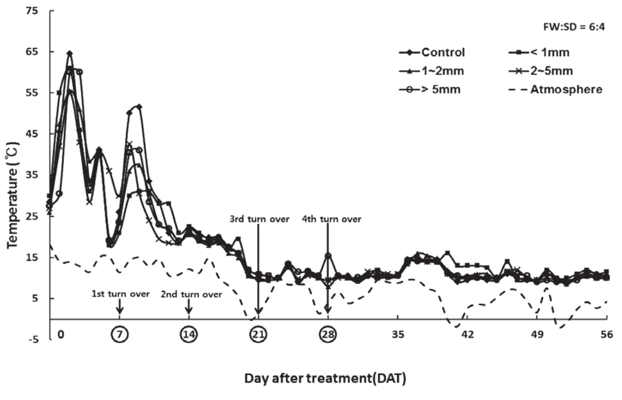

Fig. 3. Variation of temperature during food waste composting (FW:SD=6:4).

Physico–chemical characteristics

pH

The variations of pH level during the composting process are shown in Fig. 4 and 5. The initial pH (DAT 0) for the food waste mixture was an alkaline with level 8.8~9.2. It is the possibility of the effects of lime, that is for the initial heat and adjusting the lower pH of food waste, and manures as the spawn. The pH was slight decreased till DAT 21, but from the thermophilic stage it tends to increase. According to Kang *et al.* (2003), after pH was dropped by generation of the volatile organic acid in the

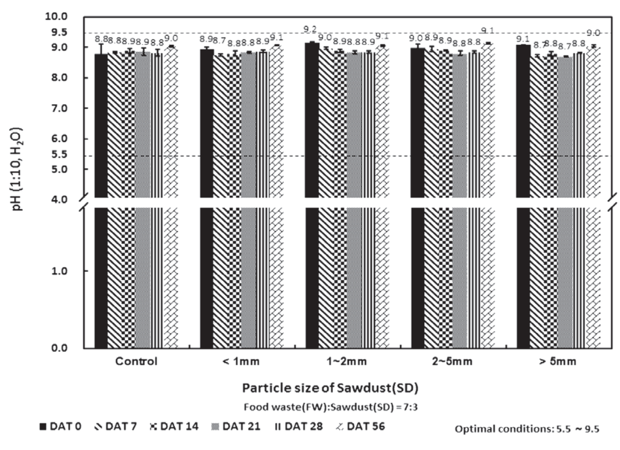

Fig. 4. Variation of pH during food waste composting (FW:SD=7:3).

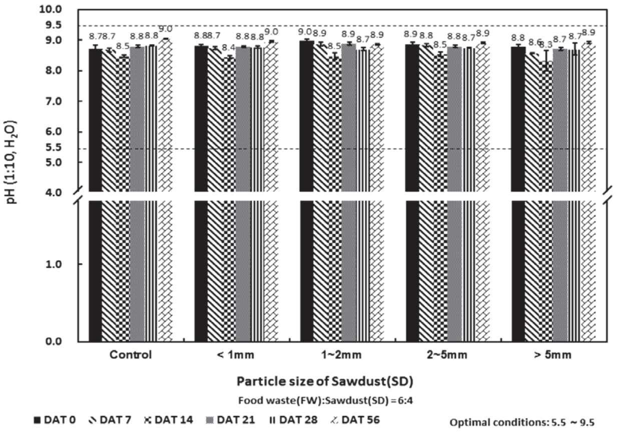

Fig. 5. Variation of pH during food waste composting (FW:SD=6:4).

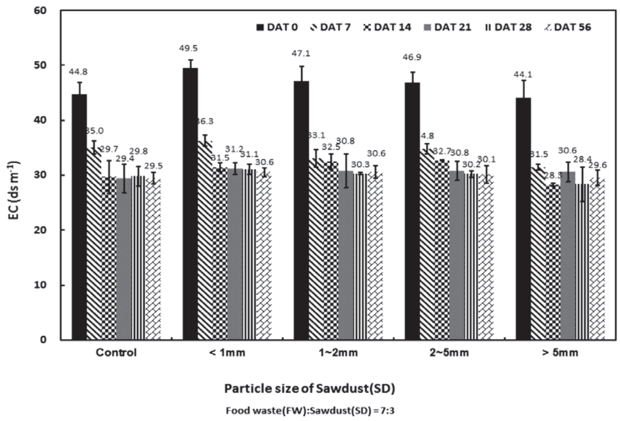

Fig. 6. Variation of EC during food waste composting (FW:SD=7:3).

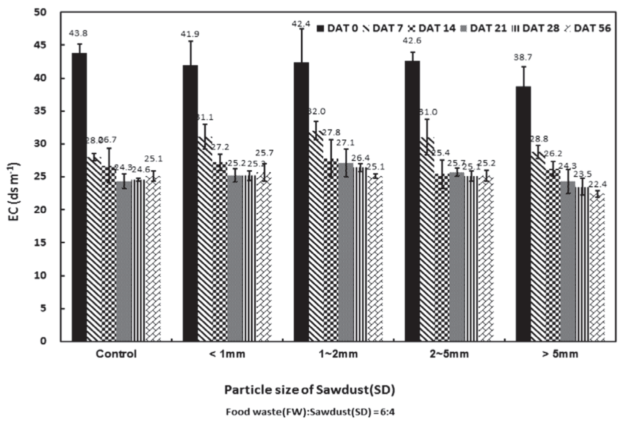

Fig. 7. Variation of EC during food waste composting (FW:SD=6:4).

initial stage and it was rise again. Generally, the pH in composts is influenced by three acid–base systems: the carbonic system with carbon dioxide (CO_2), ammonium (NH_4^+)–ammonia (NH_3) system, which is formed when protein is decomposed, and several organic acids system, which is formed during fermentation of organic matter (Sundberg, 2003). Therefore, during successful composting, the food waste is decomposed and the pH increases. At DAT 456, the pH was stabilized at level 9.1 and the pH rise has been reported as the ammonia effect by proteolysis. There was no significant shift in pH on the various mixing ratios and particle sizes of sawdust but the general pH was lowered with the higher mixing ratio as Fig. 4. Overall, the pH in all treatments increased to 8.9–9.1 by the end of the composting process and consistently had pH values in the optimum range of pH 5.5~9.5.

Electrical conductivity (EC)

In the beginning of the composting, the initial EC values of food waste mixtures showed the extreme higher salt concentration of 44.1~49.5 dS m^{-1}. It is estimated to be the influence of salinity of food waste. The higher EC values in the initial stage were rapidly dropped, it slowed down from DAT 14 and then it was dropped to 29.5~30.6 dS m^{-1} at DAT 56.There was no significant variation on EC in relation to the particle size of sawdust, but in overall the smaller particle size showed the higher EC value as Fig. 6 and Fig. 7. It is assumed to be favorable for the elution of salt due to the smaller particle size of sawdust relatively contains more salt. The basis of EC in food waste composting has not been specified, but it affects the quality of compost. According to the study of Lee and Chang (1998), there is a potential possibility of salt stress in crops when long–term use of high salinity compost to soil. Mengel *et al.*(2001) also observed that excessive salinity in compost could cause phytotoxicity directly. Therefore, it should be necessary to use the mixture of less salinity as manures or dehydration process with washing salt accumulation before the composting process.

Moisture content

The moisture content is closely related to the ratio of oxygen utilization of the microbes, higher content level generates leachate and a stench in the initial stage due to poor ventilation of the small gap between the particles and the aerobic composting is become difficulty by the anaerobic condition. Also, the activity of the microbes is decreased under the content of 40% or less because of reduction of the water–soluble nutrients. It means that the moisture content in compost should be controlled to the optimum condition range of 50~65% in regard to the study of Jeon and Hur (1996). As shown in Fig. 8 and 9, the moisture content decreased gradually throughout composting process. It may be associated with changes in temperature during composting process. Also, it could be due to water being utilized by the living organisms present in the compost (Rahel and Mulugeta, 2013). There was no significant in relation to the various mixing ratios and the particle sizes, but the groups of the ratio of 6:4 had slightly less moisture content compared to the ratio of 7:3(Fig. 8 and Fig. 9). The moisture content in the all groups was within the range of the optimum condition of the initial stage. At DAT 56 it has satisfied the compost quality standards (below 55% or

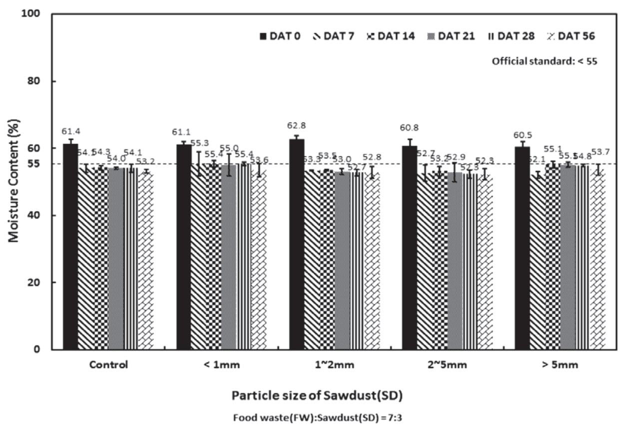

Fig. 8. Variation of moisture content during food waste composting (FW:SD=7:3).

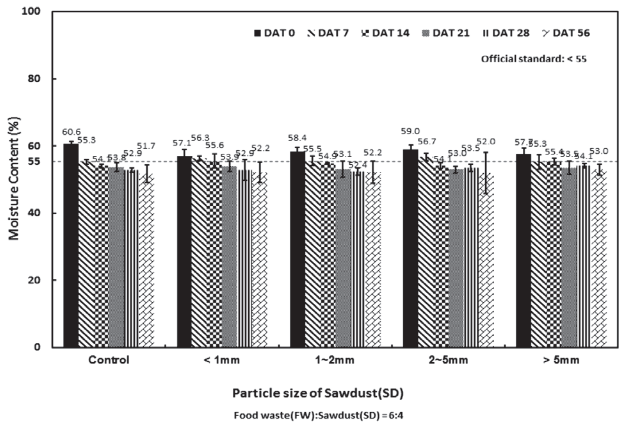

Fig. 9. Variation of moisture content during food waste composting (FW:SD=6:4).

less) under South Korea's Wastes Control Act.

Maturity

Compost maturity is one of the significant parameters affecting the successful use of compost in agriculture. The compost maturity can be estimated by following methods: oxygen consumption rate, seed germination rate, respiration rate and earth worm response. However, maturity test using only one method does not reflect the actual extent of maturity (Kwon *et al.*, 2010). Hense, this study was conducted to evaluate the compost maturity using two mechanical methods (Solvita and CoMMe–101) and germination test.

The maturity results of the compost processing showed on Table 3. On DAT 7 the germination index (GI) in all groups was over the criteria, 70, except > 5 mm sample in 7:3 ratio and 2~5 mm sample in 6:4. The GI was rapidly increased till DAT 21 and then gradually decreased the rate of rise. On DAT 56 it was 140 or more in all treatments. It with the various particle size of sawdust was rised up to the particle size of 1~2mm but was decreased in the other treatments. By CoMMe–101, all treatments were beyond curing stage except 2~5 mm sample in 6:4 ratio on DAT 7, from DAT 14 the smaller particle size has higher maturity and from DAT 28 all groups completed the curing stage. By Solvita, the smaller particle size has the higher maturity, on DAT 21 all groups showed above an index of 4 and at DAT 56 it was above an index of 7 which is testable on the crops without any major problem. It is assumed that the particle size of sawdust is related to the rate of maturity because the samples with the ratio of 6:4, less decomposing of the food waste than the others, had the higher maturity and the samples with the size of 1~2mm had the higher maturity. It is determined that the three methods are able to be the indication of the composting maturity but there is no correlation between these. Therefore, it is necessary to note upon the selection of the methods.

Table 3. Maturity of food waste ompost with various particle sizes of sawdust

Sample		Compost maturity														
		[a]GI(%)					CoMMe–101					Solvita				
		[b]DAT 7	DAT 14	DAT 21	DAT 28	DAT 56	DAT 7	DAT 14	DAT 21	DAT 28	DAT 56	DAT 7	DAT 14	DAT 21	DAT 28	DAT 56
7:3	Control	[c]84	98	107	109	157	curing	cured	cured	cured	cured	4	4	6	7	7
	< 1 mm	80	95	109	124	168	curing	curing	cured	cured	cured	4	4	6	6	7
	1~2 mm	86	109	133	138	175	curing	cured	cured	cured	cured	4	5	7	7	7
	2~5 mm	70	82	99	119	167	curing	curing	curing	cured	cured	3	3	4	6	7
	> 5 mm	67	81	121	124	140	curing	curing	cured	cured	cured	3	3	5	6	7
6:4	Control	77	97	121	124	154	curing	cured	cured	cured	cured	4	4	6	7	7
	< 1 mm	75	105	133	135	173	curing	cured	cured	cured	cured	4	5	7	6	8
	1~2 mm	82	101	129	143	181	curing	cured	cured	cured	cured	4	5	7	7	8
	2~5 mm	61	97	121	129	168	active	curing	cured	cured	cured	3	4	5	6	7
	> 5 mm	83	92	132	128	142	curing	curing	cured	cured	cured	4	4	6	7	7

[a] G.I., germination index. [b] DAT, day after treatment
[c] Compost maturity assessment, G.I. > 70%, CoMMe–101 maturity level>cured, Solvita> 4

CONCLUSIONS

The purpose of this study was the comparison of the composting properties in relation to the temperature, the moisture content, the nutrients and the compost maturation index (maturity) with the various particle size of sawdust. The lower mixing ratio of sawdust was sensitive to the ambient temperature change but there was no significant temperature change on the various mixing ratios. In addition, the smaller particle size showed a higher temperature and relatively easier to maintain a constant temperature. And there was higher re–heating temperature by the turning with the larger particle size. Shifts in pH, EC and moisture content in ratio of 7:3 as compared to the ratio of 6:4 showed slightly higher and till DAT 21 pH was dropped and then it was stabilized at 9.1 on DAT 56. There was no significant variation on shift in pH, but the higher particle size showed the higher EC values in relation to the various mixing ratios. The physico–chemical properties of food waste composting shown the standards of organic compost, but there is a potential possibility of salt stress in crops due to the higher salinity of food waste. Therefore, it is determined that there are positive effects on the standardization of the composting process for the quality control and the economics, as the food waste compost showed the higher maturity with the higher mixing ratio of sawdust and the smaller particle size.

ACKNOWLEDGMENT

This work was carried out with the support of the "Cooperative Research Program for Agriculture Science & Technology Development (Project No. PJ01092502)," Rural Development Administration, Republic of Korea.

REFERENCES

Changa C. M., P. Wang, M. E. Watson, H. A. J. Hoitink and F. C. Michel Jr. 2003 Assessment of the reliability of a commercial maturity test kit for composted manures. *Compost Science & Utilization*, **11**(2): 125–143

Chang K. W., C. G. Phae and H. G. Choi 2002 Food waste Recycling Laws and Recycling Standard Process. *J. of KOWREC*, **10**(2): 7–16 [in Korean]

Chang K. W., J. H. Hong, J. J. Lee, K. P. Han and N. C. Kim 2008 Evaluation of Compost Maturity by Physico–chemical Properties and Germination Index of Livestock Manure Compost. *J. of Soil Sci. Fert.* **41**(2): 137–142 [in Korean]

Huh M. and J. Y. Han 1999A Basic Experimental Study on Composting of Garbage Wastes by Coconut Peat. *J. of KOWREC*, **7**(2): 105–111 [in Korean]

Jackson M. L. 1958 *Soil Chemistry Analysis*, Prentice–Hall, Inc. Englewood Cliffs, New Jersey

Jeon B. G. and D. Hur 1996 A Fundamental Study on Composting of Garbage. *J. of KOWREC*, **4**(2): 19–25 [in Korean]

Jung J. O., H. K. Kwon and J. H. Lee 2002 An Influence of Mixing Material Characteristics on the Composting of Food Waste. *J. of Env. Hlth.*, **28**(5): 22–27 [in Korean]

Kang C. M., B. M. Kim and I. H. Jeong 2003 The study of Efficient Treatment Conditions on the Composting of Food waste. *J. of KOWREC*, **11**(2): 117–124 [in Korean]

Kim B. T. 2012 Analysis of Drying Efficiency for Circulating and Falling Movements on Indirected Drying Process of Food Waste. *J. of KORRA*, **20**(4): 106–117 [in Korean]

Kim I. K. 2010 *A Study on Composting of Food Waste–Water using Sawdust and Cocopeat as Bulking Agent*, PhD thesis, Kyung–buk national university graduate school [in Korean]

Kwon S. I., K. R. Kim, S. G. Hong, W. K. Park and D. B. Lee 2010 *Comparison study between the methods for compost maturity determination*. 19th World Congress of Soil Science, 1–6 August 2010, Brisbane, Australia

Lee S. S. and K. W. Chang 1998 Changes of Soil Chemical Properties and Uptake of Salts by the Plants according to the Application of the Food Waste Compost. *J. of KOWREC*, **6**(2): 59–67 [in Korean]

Li, Xiujin, Zhang Ruihong and Pang Yunzhi 2008 Characteristics of dairy manure composting with rice straw. *Bioresource Technology*, **99**(2): 359–367

Lim D. K. and S. K. Han 2005 Production of Compost Using Food waste and Activation Scheme for Using Products. *J. of KORRA*, **13**(2): 32–51 [in Korean]

Mengel K., E. A. Kirkby, H. Kosegarten and T. Appel 2001 *Principles of Plant Nutrition*. Fifth. The Netherlands: Kluwer Academic Publishers

NIAST (National Institute of Agricultural Science and Technology) 2000 *Method of Soil and Plant analysis*. RDA, Suwon, Korea, 103–147. [in Korean]

Park J. K., S. T. Seo, S. C. Park and H. S. Lee 2014 A study on developing fly ash and bulking agent for composting swine manure. *J. KSEA*, **20**(1): 65–70 [in Korean]

Rahel G. and K. Mulugeta 2013 Microbiological and Physico–chemical Analysis of Compost and its Effect on the Yield of Kale (*Brassica oleracea*) in Bahir Dar, Ethiopia. Ethiop. *J. Sci. & Technol.*, **6**(2): 93–102

RDA(The Rural Development Administration) 2010 *Fertilizer regulations*. Rural Development Administration, Suwon, Korea [in Korean]

Shin J. S. 2013 *Direction of Organic waste Recycling Policy*. J. of KORRA, Symposium and presentation, spring, 82–107 [in Korean]

Sundberg C. 2005 *Improving Compost Process Efficiency by Controlling Aeration, Temperature and pH*. PhD thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden

Woods End 2000 *Guide to Solvita® Testing for Compost Maturity Index*. Mt Vernon, ME. Manual provided with Solvita® compost test master kit purchased from Woods End Research Laboratory Inc.