Int. J. Environ. Res., 9(3):907-912, Summer 2015
ISSN: 1735-6865

Co-composting of Greenhouse Pepper Plant Residues and Separated Dairy Manure: Process Dynamics

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Received 22 Sep. 2014; Revised 28 Nov. 2014; Accepted 4 Dec. 2014

ABSTRACT: The aim of this study was to determine the optimum mixture ratios for composting separated cattle manure and pepper plant residues. Five 127 liter laboratory-scale bioreactor were used to investigate of separated dairy manure addition on the composting process of greenhouse pepper plant residues. Cattle manure is considerably rich in nitrogen.However, composting with cattle manure alone is not suitable due to its low C/N ratio and FAS (free air space) value.For this reason, greenhouse pepper plant residues was added as a source of carbon in order to balance the C/N ratio and FAS value of the mixture. During the composting process, the process temperatures, CO_2 concentrations moisture and organic matter content of the mixtures were monitored. Results showed that a mixture consisting of 60% cattle manure and 40% greenhouse pepper plant residues allowed for the highest process temperature and organic material decomposition. Consequently, this mixture was determined as the optimum mixture for the composting process.

Keywords: Composting, Greenhouse pepper plant residues,Separated dairy manure, FAS, C/N ratio

INTRODUCTION

The disposal of organic wastes is unavoidable since population growth and rapidly increasing urbanization have increased waste generation in the world. The demand for industrial and agricultural production has continuously increased energy as well as the quantities of waste. Organic wastes originating from urban and agricultural sources are a significant cause of environmental pollution. Landfilling, incineration, pyrolysis, anaerobic digestion and composting are the methods used to dispose of organic wastes(Kulcu and Yaldiz, 2004). Composting, which can be defined as aerobic biological treatment, is sustainable management of wastes (Bonoli *et al.*, 2012). Compost can be used for improving soil structure, which can act as a soil conditioner or fertilizer (Zaha *et al.*, 2011; Zorpas *et al.*, 2000).In the process of decomposition of the organic wastes, microorganisms use oxygen in the environment and then decompose the organic structure, and at the end of the reaction, CO_2, water and heat are generated (Kulcu and Yaldiz, 2005; Negro *et al.*, 1999).

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The main factors influencing the composting process are carbon/nitrogen (C/N) ratios, temperature, water content, oxygen/carbon dioxide concentration in the composting matrix, porosity, and free air space (FAS) (Adhikari *et al.*, 2008; Chang and Hsu, 2008; Kumar *et al.*, 2010; Zhentong, 2013). The carbon/nitrogen (C/N) ratios of mixtures directly affect the microbiological activity during the process. N is the building block for microorganisms, whereas C is the energy source. Hence, a C/N ratio of about 30 is preferred for mixtures that will be used in composting processes. The FAS value represents the air space ratio in compost mixtures. The proper aeration of the composting material will only be possible if enough porosity and FAS are provided. Temperature changes especially during the thermophilic period and highly affects pathogens reduction, Moisture content (MC) greatly affects the physical and chemical properties of raw materials. The FAS value is especially important for static composting systems. The best FAS value varies according to the physical properties of the materials used in the composting processes. Researchers have carried out studies to determine the best FAS value for different wastes. Jeris and Regan (1973) examined the effect of FAS on the oxygen consumption rates of mixed refuse samples. Approximately 67% moisture content (wet basis) and 30% FAS were found to be optimum. About 95% of the maximum oxygen consumption rate was maintained when the FAS was between about 20% and 35%. Working with garbage and sludge mixtures, Schultz (1962) concluded that a minimum of 30% FAS should be maintained. Kulcu and Yaldiz (2003) found the optimum FAS value to be 33.62% for grass and leaf wastes. Kulcu and Yaldiz (2007) stated that the optimum FAS value was 32.8% for goat manure, wheat straw, and pine cone mixtures. Jolanun and Towprayoon (2010) created 5 different FAS ratios in compost mixtures that were prepared using clay residues and food waste, and they examined the effect of the FAS value by carrying out experiments in compost reactors. During their experiments, they prepared mixtures with FAS values of 22.5%, 26.8%, 31.6%, 37.2%, and 43.3%, and they determined that the most successful composting process was actualized at an FAS value of 31.6%. In the composting, since characteristics of process largely depend on the mixture characteristics, optimum ratios of mixture for composting process must be determined by experimental studies.

Pepper production of Turkey was reported as 468 350 tons in greenhouse in the year of 2012 (Turkstat, 2012). Pepper is the most commonly grown vegetable crop in greenhouses. Greenhouse pepper production represented 8% of the total greenhouse vegetable production in Turkey. Although wastes or residues of pepper production can be composted, it should be co-composted with other wastes due to their chemical and physical properties. Alkoaik and Ghaly (2006) reported that dairy manures (used as inoculum and N source) and greenhouse tomato residues-wood shaving (used as FAS balancing and C source) mixtures is suitable for composting.

The objective of this study is to determine the optimum mixture ratio of pepper residues and separated dairy manure for composting. In mixtures, separated dairy manure was used as an inoculum and a nitrogen source, greenhouse pepper residues were used as bulking agent. Greenhouse pepper plant wastes and separated dairy manure ratios were changed in the mixtures to adjust the FAS levels. Mixtures that were prepared at 5 different FAS ratios were composted to determine the mixing ratio that yields the best FAS value for the composting of the wastes used in the trial.

MATERIALS & METHODS

Physical and chemical properties of separated dairy manure and pepper residues used in this study are given in Table 1. Nitrogen contents of separated dairy manure and pepper residues were 1.92% and 1.15%, respectively. The FAS values of the wastes used in the trials are quite different. Whereas FAS value was measured as 38.65% for pepper wastes, this value was measured as 21.96% for separated dairy manure. Pepper residues also are rich in organic matter. These wastes were mixed at five different ratios based on dry matter content of materials for composting (Table 2). C/N ratios and FAS values of the each mixture are listed in Table 2. C/N ratios and FAS values measured in R5 reactor were the highest among the other reactors due to the amount of pepper residues used in this reactor. Conversely, these values in R1 reactor were the lowest because of the amount of separated dairy manure used.

Table 1. Physical and chemical analysis of raw materials used in the study

Material	C/N (%)	N (%)	P (%)	K (%)	EC (dS/cm)	pH	FAS (%)	OM (%)
Sep. Dairy Manure	21.79	1.92	0.22	0.86	2.22	7.13	21.96	75.32
Pepper Residues	42.13	1.15	0.17	2.66	0.36	3.58	38.65	87.21

Table 2. Properties of the mixtures in the composting reactors

Reactor No	Sep. Dairy Manure (%)	Pepper Residues (%)	FAS (%)	OM (%)	C/N -
R1	80	20	25.99	77.69	24.44
R2	70	30	27.85	78.89	25.95
R3	60	40	29.62	80.08	27.60
R4	50	50	31.30	81.27	29.41
R5	40	60	32.91	82.45	31.42

Composting process was carried out in the laboratory-type composting reactor systems. Composting reactors were made of plastic material insulated against heat transfer and had an effective volume of 127 liters. Aeration inside the reactors was performed by 3-phase radial fans. Temperature was measured at three different points inside the reactors on a vertical axis passing through the central point (Fig.1). Location of the thermocouples was depicted at Fig.

Management and monitoring of the process in the composting system were carried out by the use of PLC-based (programmable logic controller) process control device. Flow rate of the air blown into the reactor by fan is measured by a flowmeter and the result of the measurement is transmitted to the PLC unit. By the use of the aeration value entered to the interface, PLC unit determines the optimum air flow rate and alters frequency to provide the optimum flow rate according to the data obtained from the flow meter. Frequency tuner adjusts the frequency of the electricity current conveyed to fan and enables them to perform aeration at the adjusted flow rate level. Aeration ratio was adjusted to 0.4 L air.min^{-1} .kg$_{om}^{-1}$in the tests (Kulcu and Yaldiz, 2004; Sonmez, 2012). Furthermore, aeration period in these experiments was adjusted to 15 minutes on per hour. PLC unit also measures the temperature of the piles. Temperatures of composting measured were recorded once in every 15 minutes.The carbon dioxide concentrations of the air within the pile were measured on a daily basis during the composting process by digital gas analyzer having infrared CO_2 sensor. Composting experiments were conducted for 21 days. Moisture content (wet basis) of the experimental materials was analyzed by drying oven method at 105 ºC for 24h (APHA, 1995). Organic matter content of the material was measured by burning oven at 550 ºC for 5h (APHA, 1995). The organic matter (OM) was calculated according to the following equation (Eq. 1):

$$OM\ (\%) = ((W_{105} - W_{550})/W_{105}) \qquad (1)$$

W_{105}=Oven dry weight of mass at 105 ºC
W_{550}= Furnace dry weight of mass at 550 ºC

Organic material loss values (k) were calculated f according to the following equation (Haug, 1993) (Eq. 2):

$$k = \frac{[OM_m(\%) - OM_p(\%)].100}{OM_m(\%).[100 - OM_p(\%)]} \qquad (2)$$

OM_m : OM content at the beginning of the process
OM_p : OM content at the end of the process

Normality of k values was tested using Anderson-Darling procedure and homogeneity was tested using Bartlett procedure. Loss of organic matter (k) was subjected to ANOVA one-way analysis of variance to test differences and Duncan Multiple Range Test was used to establish the significance of differences among treatments. All analyses were performed using SAS statistical package (SAS, 1995).

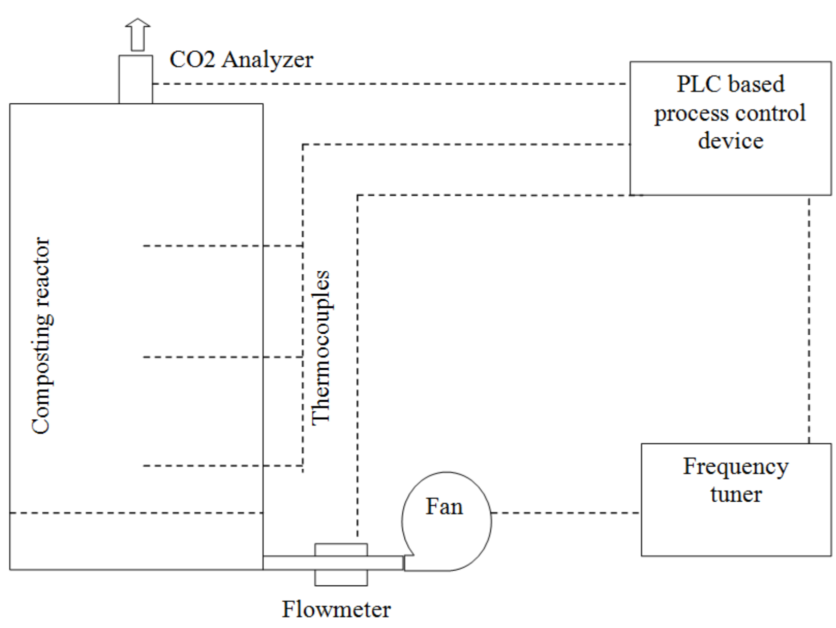

Fig. 1. Schematics of laboratory-type composting reactor systems

RESULTS & DISCUSSION

Fig. 2 shows the changes in the reactor temperatures as a function of composting time.Temperatures of R2, R3, R4, R5 reactors reached thermophilic phase (>55 ºC) after 4-5 days of composting which reflected active microbial decomposition in the composting mixtures. The rapid rise in temperature was due to the breakdown of the easily decomposable fractions of the mixtures (Yamada and Kawase, 2006). During the first days of the process, it was observed that temperatures increased rapidly in all of the reactors, reaching a peak between the 5th and 8th days of composting, after which the temperatures began to decrease. Based on Fig. 2, temperature in reactor R2, R3, R4 and R5 stayed at 56°C for at least first 3 days and the temperature in the R1 reactor increased only up to 55.34 °C at the 8th day and then decreased rapidly. It is clear that, R3 yielded higher process temperatures than the others.

Fig. 3 Illustrates the changes that occurred in the compost moisture (wet basis). During the composting process, it was observed that the compost moisture at each reactor decreased more rapidly depending on aeration and heat generation. Moisture content was the lowest in R3 (52.11%) and the highest R1 (56.01%) after 21 days of composting. Many researchers emphasized the importance of moisture content, and stated that 50-70% moisture content (wet bass) is suitable for efficient composting (Richard *et al.*, 2002). In this study, the moisture content (min 52-56% wet basis) was not limiting factor for microbial growth and was in the optimum range at all times.

The microorganisms which are active during the composting process ensure the decomposition of the materials by breaking down carbon bonds. Decomposition of organic matter is directly related to the microbial respiration (Paredes *et al.*, 2002). It was visually inspected that the OM values decreased continuously during the process, depending on the activity of the microorganisms. It was also observed that the decrease in the OM levels were the highest in the R3 among the reactors (Fig. 4).

Table 3 presents k values calculated from the decomposition of organic material at the end of composting. Results showed that the highest level of decomposition occurred in the R3 reactor, and that this reactor was sequentially followed, in terms of k by the R3, R5, R2 and R1 reactors. The R3 reactor considered as class "a" based on the results of the statistical analyses and it was determined that this reactor had the highest k.

Fig. 5 shows evolution of CO_2 concentrations of the air samples taken from the reactors during the composting process. CO_2 production caused by mineralization of organic matter in the substrate. In parallel to the changes observed with the composting temperatures, the carbon dioxide values increased rapidly during the first days of the process and began to decrease afterwards. CO_2 concentration reached its highest value in R3 reactor than the others. CO_2 concentration increased after the first 3 days and decreased after 10th day in all the aerated reactors.

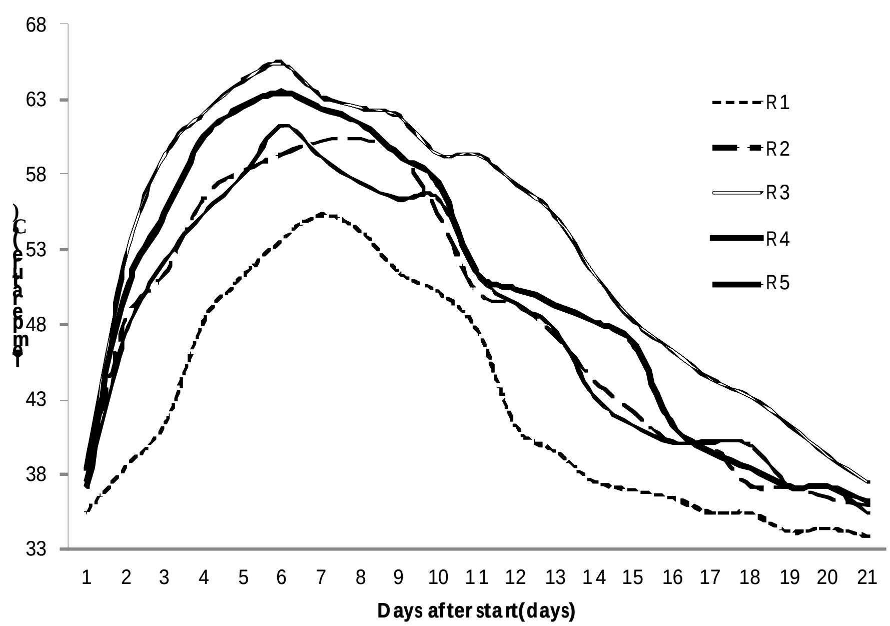

Fig. 2. Temperature changes in all reactors during composting process

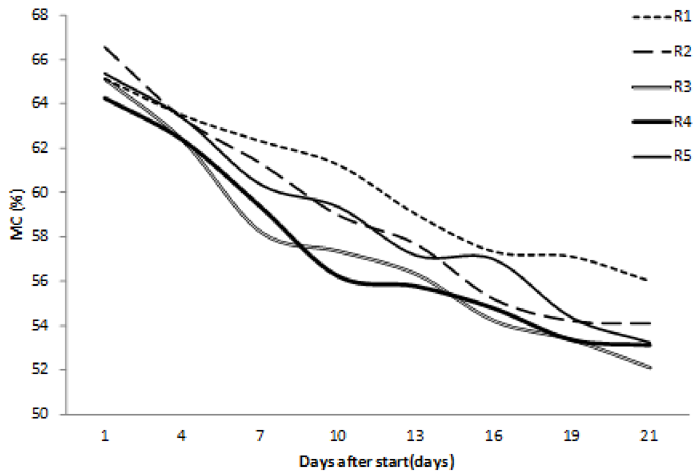

Fig. 3. Moisture content (wet basis) as a function of time for all reactors during composting

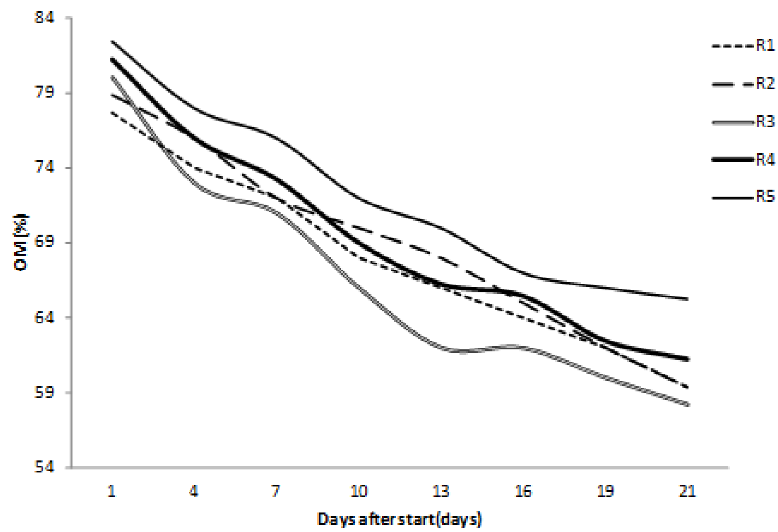

Fig. 4. Organic matter content changes in mixtures during composting

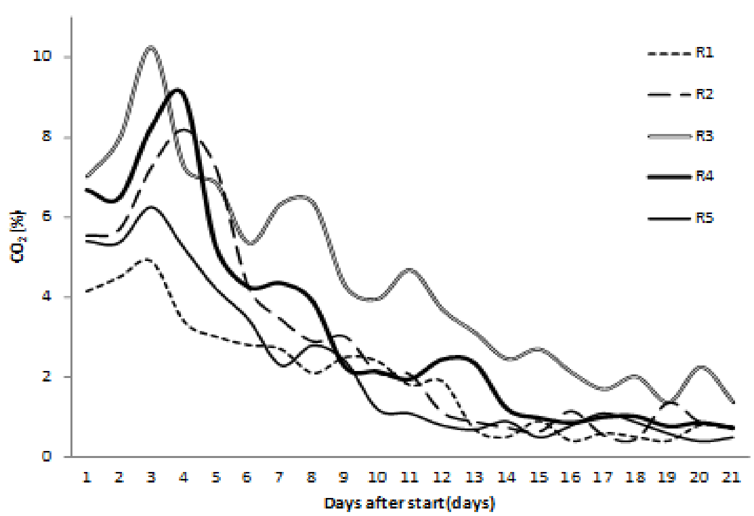

Fig. 5. Carbon dioxide (CO_2) concentration in the composting matrix

Table 3. Results of k of composting mixtures at the end of experiment and its statistical analysis (P<0.01)

	R1	R2	R3	R4	R5
k (%)*	58.11±4.40d	60.91±2.14c	65.34±3.07a	63.59±2.25b	60.04±2.67c

*-There were no statistical differences between the values categorized with the same letter, while the differences between the values categorized with different letters were statistically significant

CONCLUSIONS

Based on the experiment that performed regarding the composting of separated dairy manure and greenhouse pepper residues, it was determined that these wastes can be composted together. It was also determined that the best composting process could be obtained by mixing these wastes at a ratio of 60% separated dairy manure and 40% greenhouse pepper residues by dry weight. Results of the experiments showed that the composting process was adversely affected when the FAS value decreased below 29.62%. Results indicate that problems related with aeration in terms of penetration of air in composting matrix occur when FAS values decreases below 29.62%.

ACKNOWLEDGEMENT

This study was supported by Research Fund of Suleyman Demirel University, Isparta, Turkey.

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