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The composting of agricultural wastes and the new parameter for the assessment of the process

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ABSTRACT

The aim of this study was to determine the optimum mixture ratios for composting cattle manure and greenhouse waste, and to ascertain the usability of the value of the area lying below the temperature as a function of time for assessing the success of the composting process. Dairy manure is considerably rich in nitrogen. However, composting with cattle manure alone is not suitable due to its low C:N ratio. For this reason, greenhouse waste was added as a source of carbon in order to balance the C:N ratio of the mixture. Experiments were performed in laboratory-type composting reactors. 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 waste allowed for the highest process temperature and organic material decomposition. Consequently, this mixture was determined as the optimum mixture for the composting process. Based on the experiments, the area lying below the temperature as a function of time was also determined as a suitable parameter for assessing the success of the process.

1. 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 required as well as the quantities of waste. Organic wastes originating from urban life and agricultural activity are a significant cause of environmental pollution. Composting plays an important role in the management of organic waste, which is the biochemical degradation of organic materials to a sanitary, nuisance-free, humus like material (Ozdemir et al., 2004; Dadhich et al., 2012). Composting has been defined as a controlled microbial aerobic decomposition process with the formation of stabilized organic materials that may be used as soil conditioners and/or organic fertilizer (Sönmez, 2012; Bari and Koenig, 2001; Hoyos et al., 2002; Sarangi and Lama, 2013).

Greenhouse cultivation is prevalent in Turkey, especially in the southern regions of the country. The total area used for greenhouse cultivation in Turkey is 59 961 ha. The area dedicated to greenhouse production in the Mediterranean region of Turkey is 47 216 ha, corresponding to 79% of the total area of greenhouse cultivation in Turkey (TurkStat, 2011). There is currently no established procedure being implemented in Turkey for the management and use of greenhouse wastes. These waste materials are being either stored in landfill area or, in most cases, disposed into stream sides with little or no control. Considering that they also contain agricultural chemicals, these waste materials also present a serious threat for the environment. Due to its high content in plant nutrient elements and organic mass, greenhouse wastes are suitable for composting. However, composting of greenhouse wastes on its own requires more time than the one which is carried out as co-composting of manure. This is because the level of nitrogen and microorganisms in greenhouse wastes are very low (Sönmez, 2012). Therefore, composting such wastes together with animal manure will allow microbial activity to develop more rapidly.

The number of livestock in Turkey is 285 342 363 as of 2011 (TurkStat, 2011). A significant portion of this quantity consists of poultry, sheep, goats and cattle. The amount of manure produced annually by livestock raised in Turkey to 237.67 million tons in 2011. Nearly 82% of this quantity is produced by cattle. In Turkey, livestock manure is decomposed, used as fuel or stored with little or no control. The process of composting represents an important

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Table 1
The mixture ratios and properties used in the laboratory-type composting reactor systems.

	Animal manure	Greenhouse waste	R1	R2	R3	R4	R5
Animal manure (dry weight %)	–	–	80	70	60	50	40
Greenhouse waste (dry weight %)	–	–	20	30	40	50	60
Organic matter (%)	50	85.3	75.70	76.42	80.68	72.14	74.98
Total nitrogen N (%)	1.12	1.45	1.19	1.22	1.25	1.29	1.32
Total P_2O_5 (%)	0.88	0.63	0.83	0.81	0.78	0.76	0.73
Total K_2O (%)	1.49	2.32	1.656	1.74	1.82	1.905	1.99
Total CaO (%)	21.42	4.19	17.97	16.25	14.53	12.81	11.08
Total MgO (%)	1.05	0.43	0.93	0.86	0.80	0.74	0.68

alternative for the management of cattle manure (Kulcu and Yaldiz, 2008).

During the composting process, microorganisms release heat and energy by decomposing organic material. The heat generated during the process increases the temperature of the compost pile, which ensures the inactivation of pathogenic microorganisms (Epstein, 1997; Rantala et al., 1999). For this reason, measuring the temperature of the pile when assessing the process of composting is very important. The depletion of the oxygen within the pile by microorganisms leads to the formation of anaerobic conditions, which, in turn, will decrease the decomposition rate, lower the temperature and contribute to the formation odor. It is, therefore, necessary to prevent the formation of anaerobic conditions by ensuring a regular circulation of air within the pile. Ensuring controlled conditions during the composting process is of great importance when attempting to determine the suitable mixture ratios. Therefore, laboratory-type reactor systems are used to determine optimum mixture ratios of composting in this study.

Parameters, for instances, process temperature, organic matter and dry matter loss were used for evaluation of composting process. Graphical presentation of composting process temperature involves measured compost temperature as a function of time. Statistics of time series of compost temperature to compare different treatments on composting process is difficult and not practical. Therefore, statistical analysis may not apply for the compost temperature as a function of time. On the other side, to evaluate the composting process, chemical, physical and microbiological analysis of heterogeneous mixture of compost samples may yield an average value with a high standard deviation due to the inherited variation of biological compost samples. In order to obtain true value of sample, either the number of samples or the amount of sample should be increased. This sometimes is tedious and painstaking. For example, dry matter and organic matter loss are calculated based moisture and ash content of compost samples. Heterogeneity in the mixture of compost samples in terms of moisture and ash content may lead to misinterpretation of process. Therefore, γ, which is area lying below the temperature as function of time, is obtained from the numerical integration of compost temperature as function of time to compare different applications on composting process. Then, statistical analysis could be applied to γ parameters.

The objective of this study is to determine the optimum mixture ratio of cattle manure and greenhouse wastes for composting and develop new kinetic parameter for assessment of composting process. Temperature is the main indicator of composting process and evaluation of composting is carried out via plotting of temperature curves ignoring statistical analysis. For this reason, temperature curves are converted to the numerical values, which is area lying below the temperature as function of time (γ). γ values can be analyzed with different statistical methods and it provides more reliable assessment than temperature graphics. In this study different assessment methods (temperature graphs, evolution of organic matter loss and statistical analysis of γ values) were compared according to their achievement.

2. Materials and methods

Cattle manure and greenhouse waste were used in the composting experiments. The cattle manure and greenhouse wastes were maintained by Research and Application Farm at Akdeniz University, Antalya, Turkey. Five different mixture ratios were selected based on the chemical analyses performed on the materials used for composting. The mixture ratios used in the experiment is given in Table 1.

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 L. 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 in Fig. 1.

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 fans 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 fans 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; Turan and Ergun, 2008). Furthermore, aeration period in these experiments was adjusted to 15 min per hour. Temperatures of composting measured were recorded once in every 15 min (Fig. 2). 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. Moisture content of the experimental material was analyzed by drying oven method daily and followed during the process. Experimental material was dried at 105 °C to the constant weight (APHA, 1995). Organic substrate content of the material was measured by burning oven. Material was burned at 550 °C for 4 h (APHA, 1995). Based on the outcome of the composting process, the optimum mixture ratio for the selected waste was determined by evaluating the temperature change, the change in organic material and dry material contents, and the change in CO_2 values (which are the indicator parameters of the process) that occurred as a result of the composting process.

Composting experiments were conducted for 21 days. In order to determine the optimum mixture ratio, according to the data