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Influence on aeration rate on performance characteristics of cattle manure composting with different Carbon sources used as bulking agents

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Abstract: *A study on the effect of different aeration rates on the speed of composting process was carried with mixtures of cattle manure and three different carbon sources (sawdust, rice pods and sunflower husks) under controlled laboratory conditions. The performance characteristics of composting process were evaluated in terms of the evolution of temperature (T), pH, electrical conductivity (EC) and organic matter (OM) content.*
The single, one-time filling of the composting reactors with the compost mixture showed better performance characteristics over the gradual filling of the reactors. The aeration for 15 min/hour at the rate of 50 L air/min provided sufficient quantity of O_2 for aerobic conditions in the composting mixtures. The compost mixtures with sunflower husks maintained longer thermophilic phase with higher average daily temperatures in comparison to the other two bulking agents.

Keywords: Cattle manure, composting, bulking agents, sawdust, rice pods, sunflower husks.

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I. Introduction

One of the main methods for processing the cattle manure into pathogen free and environmentally safe product is composting. The composting is aerobic process of stabilization of the organic matter, facilitated by different microbial species and various number of non-vertebral organisms.

The degradation of organic matter produces heat and the overall process is facilitated by the rise of the temperature. Due to the aerobic nature of the process, the organic matter loses some of its carbon content in the form of CO_2, but that improves the physicochemical properties of the final product and the rest of the carbon is immobilized in the form of stable soil fertilizer.

Composting is the biological conversion of organic waste under aerobic conditions in which bacteria, fungi and other micro-organisms break down the initial organic materials to produce stable organic substances, or compost. Compost can be used to improve soil properties. This is also an effective and safe way for reduction of the manure's mass and volume, destruction of pathogens and stabilization of nutrients and organic matter.

The key parameters influencing the efficacy of the process are C/N ratio, moisture content, airflow rate, particle size and temperature. Successful optimization of these parameters may shorten the duration of the process and result in quality product i.e. stable and mature compost (Guo et al., 2012).

Cattle manure is beneficial for composting (including a high degradation rate of organic matter), as well as a high nutrient concentration in the system, characteristics that are both environmentally and economically favorable (Orrico Junior et al., 2012).

The chemical composition and structure of the various types of bulking materials used for composting are important indicators for the degradation of organic waste (Dell'Abate et al., 2002). Sawdust is a side product of cutting, grinding or other wood processing. Bhamidimarri and Pandey (1996) reported that sawdust is an ideal composting filler because it has ability to adsorb moisture and provide good porosity to the structure. Sawdust is used as a bulking agent, since it absorbs the water that fills the free air space between the solid particles of raw compost mixture and improves aeration. However, the link between the final product quality and the initial low C/N ratio is not yet well understood (Huang et al., 2004).

Straw is a residual raw material, a secondary product derived from wheat, barley, rice, rye and legumes after removal of the grain. As a common agricultural by-product, wheat straw is the second largest biomass feedstock in the world and is of great potential feedstock for the rapid composting (Talebnia et al., 2010).

According to Zhang et al., (2016), wheat straw is only partly degraded at the end of the composting process, leading to the formation of a relatively low temperature environment (<60 °C). Rice straw has limited use as an animal feed because of its high silica content (Van Soest, 2006) and ordinary composting of rice straw is a too slow process for farmers, and may require at least 90 days to allow transformation of the residue into stable and mature compost (Goyal and Sindhu, 2011). This is actually because microbial access to cellulose (a major biodegradable component of crop residue), is known to be inhibited by hemicellulose–lignin association during the decomposition process.

Sunflower husks compared to other biomass sources, are of high calorific value and resistance to biodegradation that results from high lignin content (Raclavska et al., 2011).

The aim of the study was to determine the influence of the aeration rate and the type of different carbon sources addition as bulking agents to cattle manure on performance characteristics of composting process.

II. Materials And Methods

2.1 Composting Materials

Fresh cattle manure, sawdust, rice pods and sunflower husks were used as experimental materials and were collected in polyethylene bags. The input materials were analyzed, immediately after transportation to the laboratory (Table 1) and three compost mixtures were prepared for filling the composting reactors.

The cattle manure and three carbon sources were manually mixed in plastic boxes to achieve better homogenization of the mix. Three different mixtures (for composting reactors 1, 2 and 3) in a volume ratio of 3:1 were prepared in combination as follows: cattle manure and sawdust (reactor 1), cattle manure and rice pods (reactor 2), and cattle manure and sunflower husks (reactor 3).

Table 1: Characteristics of raw composting materials (values represent a mean followed by the standard error of three replicates).

Parameters	Cattle manure	Sawdust	Rice pods	Sunflower husks
Dry matter, %ww	17.64 ± 0.43	95.62 ± 0.59	75.95 ± 4.09	92.70 ± 0.24
Organic matter, % dw	89.85 ± 0.07	99.31 ± 0.02	92.34 ± 0.08	95.81 ± 0.06
Total organic carbon, % dw	46.39 ± 0.49	55.13 ± 0.01	49.21 ± 0.03	53.34 ± 0.07
Total nitrogen, % dw	1.50 ± 0.06	3.18 ± 0.02	1.22 ± 0.05	1.96 ± 0.14
C/N	30.93	17.34	40.34	27.21

2.2 Experimental Setup and Procedure

A laboratory-scale composting system as shown in Fig. 1 was used for the aim of this study. The investigation was conducted using three identical metal reactors with volume of 125 L. The reactors had insulation layer of polyurethane foam (5 cm of thickness). Each reactor could spin around its horizontal axis, which was sufficient for the complete mixing of the composting mix.

Two modes of filling of the composting reactors were tested:

- gradually filling - daily addition of compost mixture;
- single filling of the composting reactor.

Two types of duration of aeration to the experimental mixture were tested:

-once every **two hours** for 15 minutes (0.242 L/min per kilogram of dry matter (DM) or 0.256 L/min per kilogram of organic matter (OM));

-once every **one hour** for 15 minutes (0.483 L/min per kilogram of (DM) or 0.513 L/min per kilogram of (OM)).

The reactors were equipped with an aeration system that supplied 50 L of fresh air per minute.

Each reactor had six 12-bit digital temperature sensors (DS18B20, Maxim Integrated Products, Inc.), installed inside of the reactor's chamber, to monitor the temperature of the composting materials at 1-min intervals. The acquisition module (digital controller - SoC - © Raspberry Pi Foundation 2016) was used to record the temperature data from inside of the reactors and the ambient temperature. The advantages of this model of sensors are - easy maintenance, high accuracy, resolution in the range of -55° C to + 125° C and the ability to operate in humid environment (Statham et al., 2015; Czekala et al. 2016; Willen et al., 2016).

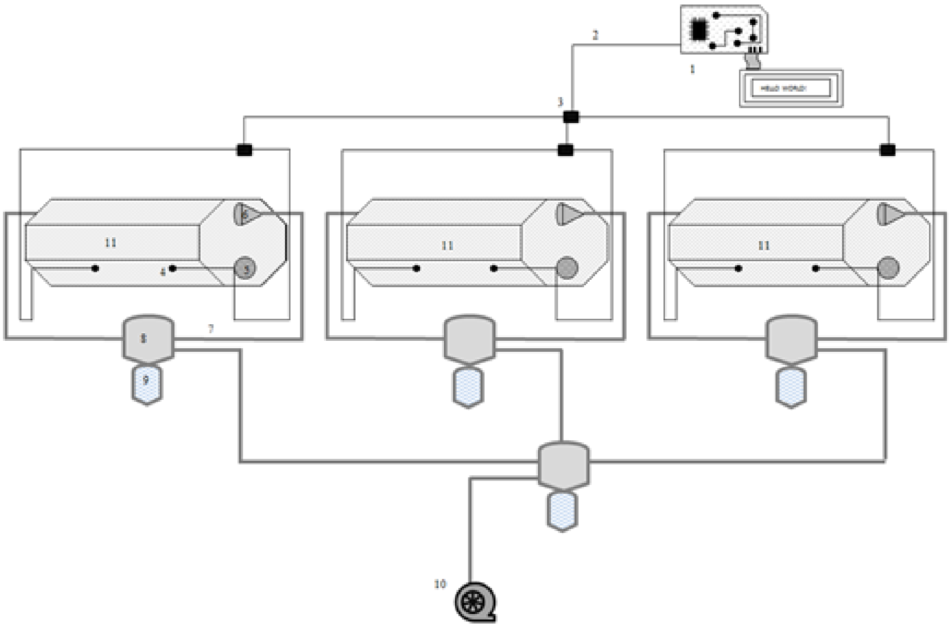

Fig. 1. Schematic diagram of reactor system for composting process: (1) controller with display, (2) data cable, (3) rosette, (4) thermal sensor, (5) fresh air valve, (6) exhaust valve, (7) air duct, (8) condenser, (9) water collector, (10) vacuum pump, (11) composter.

2.3 Sampling and Analysis

The composting material was mixed for 15 min once a day. Average samples (from the top, middle, and bottom of the composting chambers) of the compost mix (about 50 g) were taken daily, immediately after mixing. The analyses of the fresh samples were performed immediately after taking them out of the reactor.

Electrical conductivity and pH were measured according to the requirements of EN 13038:2012 and EN 15933:2012. The dry matter content was determined, according to the requirements of EN 15934:2012. The determination of Kjeldahl Nitrogen was performed according to EN 16169:2012. The carbon content (%C) was calculated according to Haug, R. (1993). Each analysis was done in triplicate with calculation of the mean value. And also all data were analyzed statistically, using statistical package (STATMOST, 1995).

III. Results And Discussions

The temperature profiles inside the chambers of the reactors filled with mixture of cattle manure and sawdust are illustrated in Fig. 2 and Fig.3.

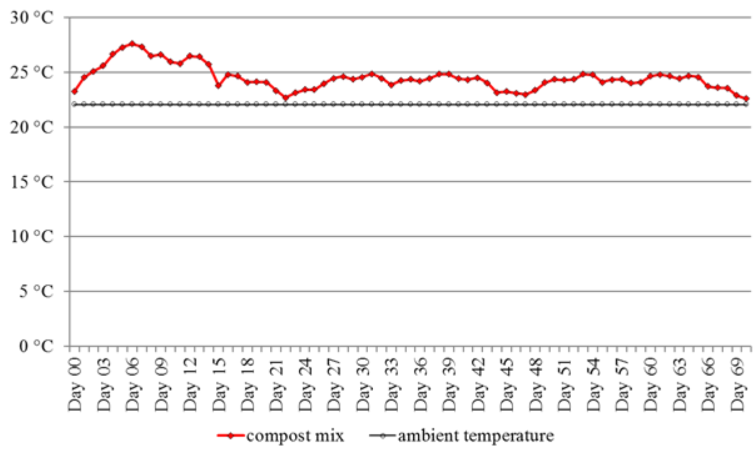

Fig. 2. Change of average daily temperatures using sawdust, gradually filling and duration of aeration 15 minutes for every 2 hours.

In the experiment with gradual filling of the reactor, using sawdust as bulking agent and duration of aeration 15 minutes every 2 hours, the temperature did not exceed 27 ° C for a period of 70 days.

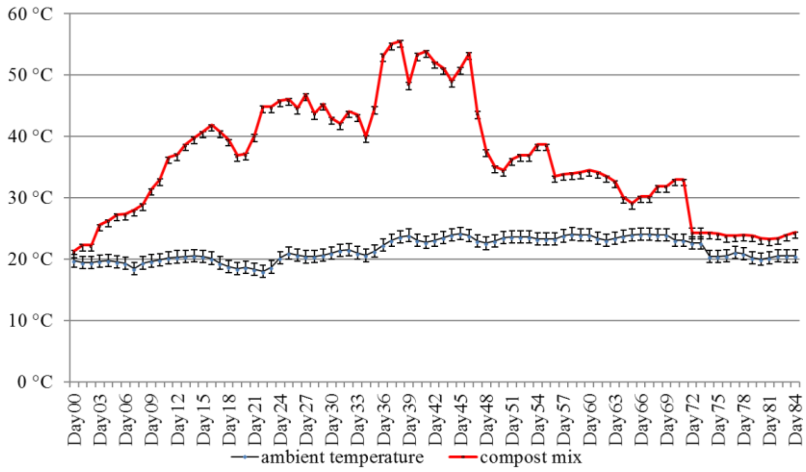

Fig. 3. Change of average daily temperatures using sawdust, gradually fill and duration of aeration 15 minutes for every 1 hour.

In the scenario of gradual filling of the composter with increased aeration (15 min/hour), a fast rise of temperature was observed soon after the reactor was full (day 38). After several hours the temperature in the composting mass reached the maximum daily average temperature of 55.54 °C. After 48 days, the temperature dropped sharply to 34.49 ° C, and to the end of the experiment, (84 days) remained unchanged.

In the experiment with single filling of the reactor, using sawdust, a fast increase in temperature in the first 24 hours – 49.27 °C was observed, indicating a marked microbial activity – Fig.4.

During the next 48 hours the temperature increased to 55.30 ° C, but this maximum temperature was maintained very shortly (only 48 hours). Until the end of the experiment (42 days) the temperature is kept below 40 ° C.

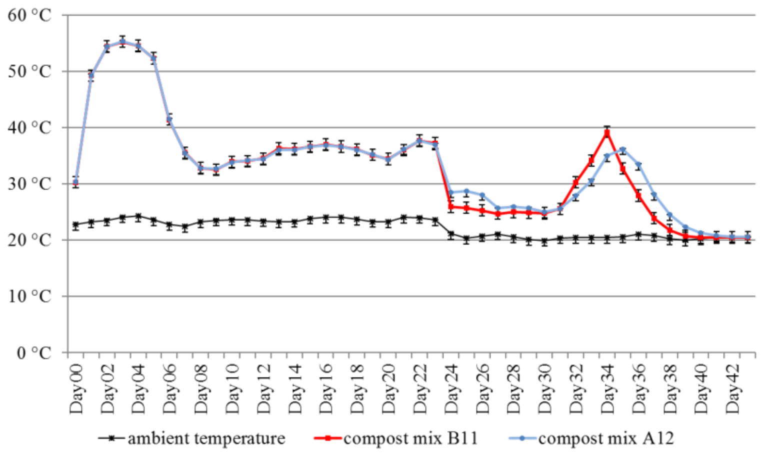

Fig. 4. Change of average daily temperatures using sawdust, single fill and duration of aeration 15 minutes for every 1 hour.

The results from the experiments with sawdust showed, that after the initial temperature peak (55.54 °C) there was no significant temperature change even after a new mixing of the compost mixture. That could be explained by the fact that the easily digested compounds are degraded and the mass has reached a stable state. This was confirmed by Farrell and Jones, (2009).

The aeration rate 0.242 L/min and 0.483 L/min per kilogram of DM, were similar to that used by Yuan et al. (2016). Best results were obtained with higher aeration rate (0.483L/min). That might be due to the cyclic air supply and the formation of a temporary reserve of O_2 in the mix. The rapid reach of thermophilic conditions showed that the system had sufficient oxygen.

The temperature profile of the reactor with rice pods is illustrated in Fig. 5. The maximum daily average temperature was reached on the 9th day of the experiment (47.79 °C).

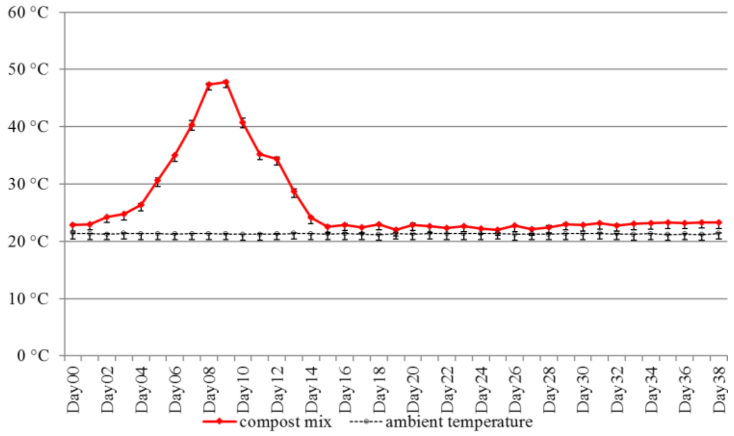

Fig. 5. Change of average daily temperatures using rice pods, single fill and duration of aeration 15 minutes for every 1 hour.

The temperature profile of the reactor with sunflower husks is illustrated in Fig. 6. And after the initial fill of the reactor, a fast increase in temperature was observed in the first 24 hours – 46.04 °C, indicating a marked microbial activity – Fig.6. The highest average daily temperature was reached on the 5th day – 69.19 °C.

During the next 96 hours, the temperature was kept above 60 ° C, after that period the temperature decreased sharply and no extreme temperatures were reached to the end of the experiment. The temperature in this reactor was maintained above 60 °C about 4 days, which should be sufficient to destroy pathogens and maximize the sanitation of the manure. A secondary temperature peak started on the 21st day and continued until 28th day, although the values of the temperature did not exceed 50 °C

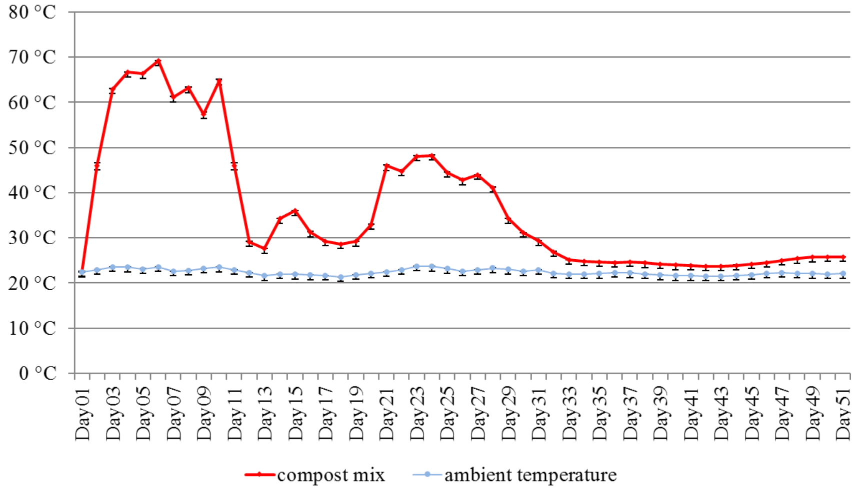

Fig. 6. Change of average daily temperatures using sunflower husks, single fill and duration of aeration 15 minutes for every 1 hour.

The secondary temperature peak that occurred in the reactor was a possible result of delayed microbial growth in the lower portions of composting mixtures or indication of degradation of cellulose after readily degradable matter was consumed.

At the end of the process the composting mixture cooled down and the temperature of the decomposed material became comparable to the ambient temperature. The characteristics of compost mixture (cattle manure and sunflower husks), ready for use in composter reactors are presented in Table 2.

Table 2: Characteristics of compost mixture composed of cattle manure and sunflower husks (values represent a mean followed by the standard error of three replicates).

Index	Value
Dry matter, % ww	40.66 ± 0.35
pH	7.91 ± 0.01
Organic matter, % dw	94.26 ± 0.20
Electrical conductivity, mS/cm	2.89 ± 0.066

Total organic carbon, % dw	57.07 ± 0.21
Total nitrogen, % dw	1.74 ± 0.04
C/N	32.80

The sunflower husks showed to be more appropriate bulking agent for fast and efficient composting in comparison to sawdust and rice pods. The size of the individual particles of the sunflower husk were between 0.1 and 0.5 cm that contributed to an extremely large total surface area of all particles used in the compost mixture. This fact could also explains the high moisture-retaining ability of sunflower husks.

On the other hand, sunflower husks have a relative strength due to the high fiber content. This allows maintaining high structural porosity and aerobic conditions in the compost mixture.

Sunflower husks also contain some crushed material from the sunflower seeds. This residue is rich in protein, carbohydrates and fats that are available sources of energy and nitrogen for the microorganisms during the composting process.

The aeration system could be a tool that controls the temperature of composting reactors. This substantially reduces the risk of overheating and microbial inhibition. The inhibition starts when the temperature reaches 65 °C. If the temperature in composting reactor becomes greater than 65 °C, the majority of bacteria, actinomycetes and fungi are inactived and only spore-forming bacteria can develop.

IV. Conclusions And Final Remark

Based on the present study, one can get following outcomes:

The physical and chemical parameters of the bulking agents influence the dynamics of the composting process.

Single filling the composting reactor leads to faster reaching of the thermophilic conditions.

Aeration rate of 50L air/minute with duration for 15 minutes per hour maintains aerobic condition in composting system with volume of 125L.

The sunflower husks are potentially better bulking agent in comparison to sawdust and rice pods.

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