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Bioresource Technology 97 (2006) 2091–2095
BIORESOURCE TECHNOLOGY

Effect of pre-composting on vermicomposting of kitchen waste

Jaya Nair *, Vanja Sekiozoic, Martin Anda

Environmental Technology Centre, Murdoch University, Perth, WA 6150, Australia

Received 1 March 2005; received in revised form 16 September 2005; accepted 20 September 2005
Available online 2 November 2005

Abstract

The aim of this work was to test combination of the thermocomposting and vermicomposting to improve the treatment efficiency and assess the optimum period required in each method to produce good quality compost. The results showed that pre-thermocomposting improved vermicomposting of kitchen waste. A 9-day thermocomposting prior to vermicomposting helped in mass reduction, moisture management and pathogen reduction.

Keywords: Compost; Kitchen waste; Pathogens; Thermocomposting; Vermicomposting

1. Introduction

Solid waste management is one of the biggest environmental challenges facing the world today due to the increasing population and urbanisation. A sustainable approach to handle this will be to treat and reprocess organic waste on-site, to produce useful products. Composting is the most economical and sustainable option for organic waste management as it is easy to operate and can be conducted in contained space provided it is managed properly to produce a good quality produce. Composting is a natural process of organic waste treatment which is currently practised with various modifications to the technology. Thermocomposting comprises a short period of high temperature treatment followed by a period of lower temperature, facilitating mass reduction, waste stabilisation and pathogen reduction. However the disadvantages are the long duration of the process, frequent aeration required, loss of nutrients (e.g. gassing off of nitrogen) and a heterogeneous end product. Composting using worms, known as vermicomposting gives a better end product (vermicastings) than composting due to the enzymatic and microbial activity that occur during the process (Bajsa et al., 2003). Many studies have shown that vermicomposting can achieve safe pathogen levels which may be facilitated by the microbial and enzymatic activity with an added advantage of converting the important plant nutrients into a more soluble state helping in plant utilisation.

The organic kitchen waste produced from restaurants and canteens form a major component of putrifying organic waste that end up in landfill sites or disposed off into roadsides and waterways in many developing countries. The main problems encountered with kitchen waste composting are its high moisture content, need of bulking substrate and constituents unacceptable for worms. Composting of raw waste therefore requires constant care with moisture management, constituents of the waste, the ratio of carbon and nitrogen that affect composting and the composting period. The aim of the experiment was to understand the effect of a pre-thermocomposting in managing those problems in vermicomposting of kitchen waste to reduce the period of composting and to improve the quality of the final compost.

2. Methods

2.1. Composting systems

The wastes used in this experiment were grass clippings (84 l), 35 l of shredded paper (newspaper and some office

* Corresponding author. Tel.: +61 8 93607322; fax: +61 8 93607311.
E-mail address: j.nair@murdoch.edu.au (J. Nair).

0960-8524/$ - see front matter
doi:10.1016/j.biortech.2005.09.020

paper) and 28 l of kitchen waste (lettuce, cabbage, oranges, tomatoes, mandarins, pears, apples and broccoli). These ingredients were selected based on their availability and production in an institution. Grass clippings and shredded paper was used as bulking materials and a source of carbon. Thermocomposting was conducted in tumbler composting bins and vermicomposting in Styrofoam boxes. Worm boxes were initially set up using vermicast collected from an established worm farm to a depth of 10–15 cm to start the process. Approximately 200 g of composting worms were added to each box comprising of a mixed species of 40:60 ratio of Red (*L. rubellus*) and Tiger (*E. fetida*).

The tumbler bins were tested daily to note the temperature, pH and moisture content. On days 6, 9, 12, and 15, 2 litres of partly composted waste was fed to separate worm farms for the completion of process. The composting and sampling schedule to study the optimum duration of thermocomposting and vermicomposting for kitchen waste treatment was as shown in Table 1. Vermicast from worm boxes were analysed for its physical and chemical quality at the end of 21 days. Microbial quality of compost was assessed based on the presence of *E. coli*, *E. faecalis*, and *Salmonella* spp. Microbial analyses were conducted at the end of 21 days composting and later monthly until the composts were found safe for handling. The kitchen waste was not expected to contain pathogens, however the lawn clippings may contain pathogens from pet faeces and other sources and therefore microbial analyses was considered essential to assess the safety of the product.

2.2. Sample analyses

The samples were tested for pH, moisture, compaction rate and carbon:nitrogen ratio. The temperature was measured at inside the tumbler and air temperature outside the tumbler. The pH and moisture content of the samples was measured as described by Morais and Queda (2003) and Wu and Ma (2001). Total carbon was tested using high temperature non-dispersive infrared gas analyser and total nitrogen as per APHA (1995) from which carbon:nitrogen ratio (C:N) was calculated.

For the microbial analysis, 1 g of compost was weighed out and added to 9 ml of distilled water, shaken vigorously and then mixed with a rotating mixer on high speed for 10 min. One ml of the mixture was then added to 10 ml of distilled water and again mixed in the same manner. The samples were analysed for the concentration of *E. coli* and *E. faecalis* using the most probable number (MPN) method (Standards Australia, 1995a,b), respectively. All tests were carried out in duplicates. For *E. faecalis* and *S. typhimurium* the initial dilution was made to 1:100 whereas for *S. typhimurium*, the MPN method developed for compost by Sidhu et al. (2001) was followed. The biochemical confirmation of *E. coli*, *E. faecalis* and *S. typhimurium* was carried out as described in the Standards Australia (1995a,b,c), respectively.

3. Results and discussion

Food wastes high in organic and moisture content are not only difficult for collection, transport and storage but also cause serious environmental pollution if not treated before disposal. In small systems to treat kitchen waste due to the varying nature of constituents of food waste and the bulking agent, the operation performance may vary from one system to another compared to windrow composting. In the present study considerable reduction in the volume of waste, 85% and 79% was noted in both tumblers without considering the waste taken out for feeding worm farms in 3 weeks (Fig. 1). The reduction in volume of waste that occurred during thermocomposting reduced the area of worm bed required and reduced the time required for vermicomposting.

The temperature in both tumblers reached a peak at above 55 °C by the second day and was found to stabilise at around 25 °C after day 10. No relationship between the outside air temperature and the temperature inside the tumblers was observed (Fig. 2). The pH of the substrates varied

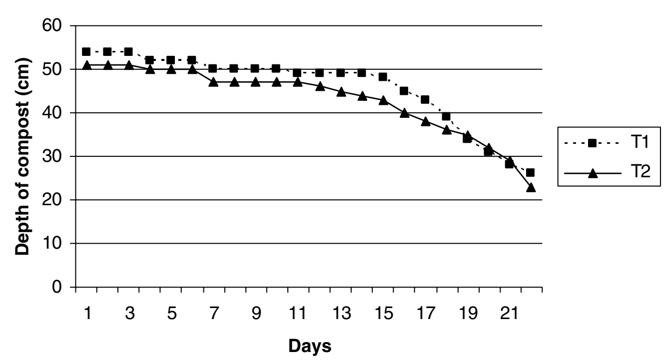

Fig. 1. The depth of compost from the bottom of the barrel over the period of composting.

Table 1
Pathogen content in terms of *E. coli* and *E. faecalis* over the composting period

Sample	Composting schedule	*E. coli* (MPN/g)		*E. faecalis* (MPN/g)	
		2 months	3 months	2 months	3 months
Thermocompost	21 days	>110	110	>110	46
Vermicompost	21 days	110	7.5	110	4.3
Thermo. + vermi.	6DT and 15DV	24	21	46	2.3
Thermo. + vermi.	9DT and 12DV	46	15	46	9.3
Thermo. + vermi.	12DT and 9DV	110	15	46	4.3
Thermo. + vermi.	15DT and 6DV	>110	4.3	24	2.3

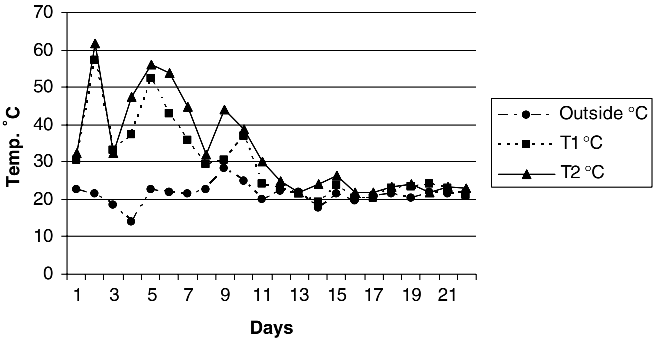

Fig. 2. The tumbler and outside temperatures during the experiment period.

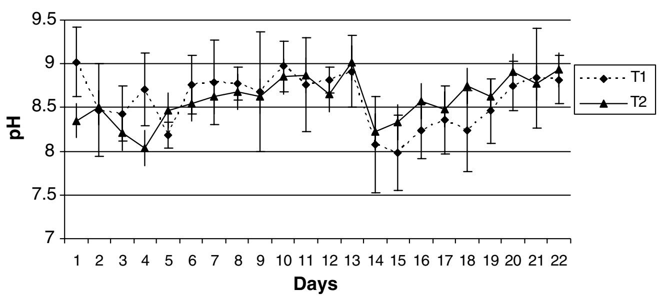

Fig. 3. The changes in pH of the substrates in tumblers during the experiment period.

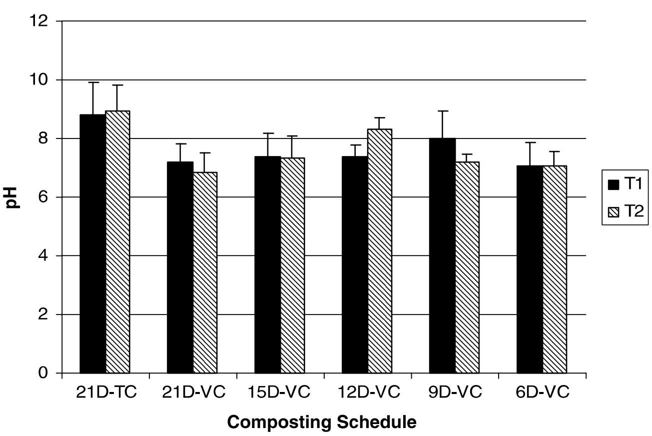

Fig. 4. The pH of compost after various composting schedule (TC—thermocomposting; VC—vermicomposting).

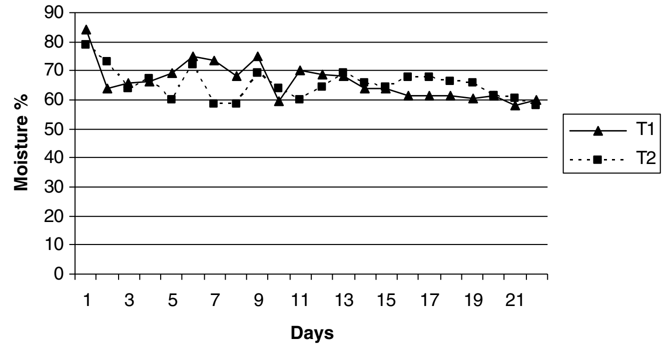

Fig. 5. The moisture content of the substrates during the experiment period.

during the sampling period between 8 and 9.2 in the tumblers as shown in Fig. 3. However, vermcomposting followed by thermocomposting neutralised the pH in all trials (Fig. 4). The moisture content of the substrate during thermocomposting was between 60% and 75% throughout the experiment (Fig. 5) although the initial sample had moisture level of 80–85%, which was not ideal for vermicomposting.

According to Wu and Smith (1999) for efficient composting and pathogen reduction, a temperature of 55 °C must be maintained for 15 consecutive days. It has been reported that food waste when combined with sawdust and mulch, was composted successfully in 14 days after which needed to be cured in windrows (Donahue et al., 1998). In the present trial, the temperature higher than 55 °C was achieved on the second day, which dropped below 40 °C the next day and then regained the thermophilic phase for 3 days after day 6. The large-scale systems are generally able to maintain thermophilic condition for longer period as against small tumbler bins which are more prone to temperature fluctuation. This may be due to the less volume of waste and high surface area for heat loss in small systems.

The moisture level required for effective thermo-composting is between 55% and 65% whereas kitchen waste usually has higher moisture content and, therefore, adding bulking agents such as saw dust, or shredded paper would help to reduce the moisture level and to develop the thermophilic condition. The heat generated during the degrading process also helps in reducing the moisture content. This seems to benefit the vermicomposting process that followed thermocomposting as too much moisture in worm boxes could result in putrification of waste (Kristiana et al., 2005).

Although organic matter could be composted at a wide range of pH between 3 and 11, pH was found to increase from 4 to 8 during composting of food waste with cow manure and hay mulch (Cekmecelioglu et al., 2005). Worms do not normally like citrus and acidic waste and, therefore, these wastes are normally excluded from vermicomposting systems. The results showed that a prior thermo-composting would enable worm farms to handle citrus and acidic waste to a certain extent. By 21 days both tumblers and worm farms attained a closer to neutral pH. Therefore, if the waste is thermo-composted prior to vermicomposting separation of acidic waste and onion peels may not be required as pre-composting would stabilise the pH.

The parameter traditionally considered to determine the degree of maturity of compost and to define its agronomic quality is the C:N ratio. It is believed that a C:N ratio below 20 is indicative of acceptable maturity, while a ratio of 15 or lower being preferable (Morais and Queda, 2003). High C:N ratio indicated by high carbon decreased biological activity, resulting in slow degradation (Haug, 1993). Wong et al. (2003) observed that the C:N ratio decreased

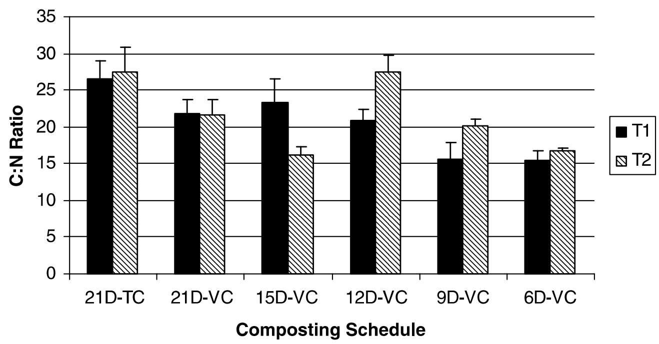

Fig. 6. C:N ratio of end product at various composting schedule (TC—thermocomposting; VC—vermicomposting).

rapidly to below 20 by day 21 and then remained at similar level to 56 days of composting. The 21 days trial conducted in the present study showed that C:N ratio was reduced to below 20 in pre composted vermicompost as against the 21 days of just thermocomposting (Fig. 6). Tripathi and Bhardwaj (2004) explained that the changes in C:N ratio in thermocomposting normally occurred by the loss of carbon as carbon dioxide while in vermicomposting, in addition to loss of carbon the increase in nitrogen content of the substrate due to microbial and enzymatic activity also influence the reduction of C:N ratio.

Although it was noticed that 21 days of a combination of thermocomposting and vermicomposting produced compost with acceptable C:N ratio and good homogenous consistency of a fertiliser, the pathogen level was very high. The initial samples were found to have a high numbers of *E. coli*, *E. faecalis* (>110 MPN/g), while *S. typhimurium* was undetectable and therefore not tested further. Table 1 showed that the *E. coli* and *E. faecalis* levels were high after two months of composting which was reduced to within the guideline limits by three months, except in fully thermocomposted samples. The samples that were only thermocomposted, retained high level of pathogens even after three months. After two months, it could be observed that greater the period of vermicomposting better was the *E. coli* reduction. However, after three months not much difference was noticed between all vermicomposted samples. The optimum period to obtain pathogen safety was 9 days thermocomposting, followed by 2.5 months of vermicomposting. This result showed that if thermocomposting process did not reach high enough temperature, it was possible that not only inactivation of pathogens will not occur but they might even grow, as high counts of faecal coliforms and *E. faecalis* were noticed after 21 days of thermocomposting. In the present study, the origin of pathogenic bacteria could be from the lawn clippings that were used. Thermocomposting alone did not inactivate the pathogens which could be due the non-achievement of temperature >55 °C for 3 consecutive days as per ARMCANZ (1995) requirement. However subsequent vermicomposting was effective in pathogen inactivation where the best pathogen die-off was achieved in worm boxes which had 9 days of thermocomposting followed by 75 days of vermicomposting. The results showed that although compost of good homogenous consistency was achieved in 21 days in the thermo-vermicomposting process, the substrate needed to be left in vermicomposting system for at least three months to ensure microbial safety of the product. Ndegwa and Thompson (2001) observed that by combining the processes of composting and vermicomposting in biosolids treatment improved the product quality, met pathogen level requirement and shortened the stabilisation time. They also obtained a more stable and homogenous product that had less impact on environment.

4. Conclusion

Thermocomposting prior to vermicomposting was helpful in waste stabilisation, pH and moisture stabilisation as well as for mass reduction. Vermicomposting after thermocomposting was effective in inactivating the pathogens. This study revealed that while treating kitchen waste, thermo-composting for 9 days followed by 2.5 months of vermicomposting produced pathogen safe compost.

Acknowledgements

We thank St John of God Health Care Centre, Murdoch, Western Australia and National Lifestyle Villages Pty Ltd. for the support provided to conduct this research.

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