Bioresource Technology 236 (2017) 11–19

Contents lists available at ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

Spectroscopic, thermogravimetric and structural characterization analyses for comparing Municipal Solid Waste composts and vermicomposts stability and maturity

Nuhaa Soobhany [a], Sanjana Gunasee [a,b], Yogeshwari Pooja Rago [a], Hashita Joyram [a], Pravesh Raghoo [a], Romeela Mohee [c], Vinod Kumar Garg [d,*]

[a] Department of Chemical & Environmental Engineering, Faculty of Engineering, University of Mauritius, Réduit, 80837, Mauritius
[b] Department of Process Engineering, Stellenbosch University, Matieland, 7602, South Africa
[c] University of Mauritius, Réduit, 80837, Mauritius
[d] Centre for Environmental Sciences and Technology, Central University of Punjab, Bathinda 151001, Punjab, India

HIGHLIGHTS

- Extensive comparison of maturity indexes among compost and vermicompost is assessed.
- Difference in intensity of peaks by FT-IR spectra between compost and vermicompost.
- Vermicompost TG curve had lower mass loss than compost, indicating higher stability.
- Low-temperature peak in vermicompost DSC curve proved greater maturity than control.
- SEM micrographs of vermicompost showed strong disaggregation compared to compost.

ARTICLE INFO

Article history:
Received 21 February 2017
Received in revised form 22 March 2017
Accepted 28 March 2017
Available online 29 March 2017

Keywords:
Municipal Solid Waste
Vermicompost
FT-IR
Scanning electron microscope
Thermogravimetric analysis
Differential scanning calorimetry

ABSTRACT

This is the first-ever study of its kind for an extensive assessment and comparison of maturity indexes between compost and vermicompost that have been derived from Municipal Solid Waste (MSW). The spectroscopic (Fourier transform infrared spectroscopy: FT-IR), thermogravimetric analysis (TG), differential scanning calorimetry (DSC) and structural characterization (scanning electron microscope: SEM) were recorded. FT-IR spectra showed an increase in conversion of polysaccharides species and aliphatic methylene groups in vermicompost compared to compost as depicted from the variation of the intensity of the peaks. TG curves of final vermicompost showed a much lower mass loss when compared to compost, indicating higher stability in feedstock. SEM micrographs of the vermicompost reflected strong fragmentation of material than composts which revealed the extent of intra-structural degradation of MSW. These findings elucidate on a clear comparison between composts and vermicomposts in terms of maturity indexes for soil enhancement and in agriculture as organic fertilizer.

1. Introduction

With the rapid expansion in urbanization, modern life style, consumption pattern and the imposition of stricter environmental laws, the production of Municipal Solid Waste (MSW) has been increasing dramatically in yesteryears. Due to the putrescible characteristics in posing serious threat to ecosystem functioning and continuous increase in MSW generation, solid waste management (SWM) has become an issue of growing global environmental concern. In the reckoning of a few authors and in most cases, the common SWM practice which is adopted for MSW by several countries around the world is sanitary land filling (Norbu et al., 2005) and open dumping. From an ecological point of view, these waste disposal methods are unsustainable owing to the production of certain toxic substances and gases from MSW which may have potential adverse effects on the environment, health and biodiversity. Also, it was found that the total contribution of methane emission worldwide from landfills is about 3–19% (Gupta and Garg, 2009). In this context, the need for sustainable and cost-effective methods with promises of reducing the organic load on landfills and environmental impacts of improper SWM is greatly urged.

* Corresponding author.
E-mail address: vinodkgarg@yahoo.com (V.K. Garg).

http://dx.doi.org/10.1016/j.biortech.2017.03.161

Over the last two decades, composting emerges as an appropriate technology to alleviate SWM and it has been brought up to date to handle organic waste of different origins, including MSW (Castaldi et al., 2005; Petric et al., 2012; Gutierrez et al., 2015). Composting is an extensively recognized technology which involves the recycling of nutrients for plant growth and their reuse as an organic amendment for the enhancement of soil physical properties (Huang et al., 2005) owing to moisture reduction, pathogen inactivation and low processing cost (Aggelides and Londra, 2000). Recently, Soobhany et al. (2015a) found that vermicomposting considerably improved the decomposition and stabilization of organic fraction of MSW into an organic fertilizer. In contrast to normal composting, vermitechnology involves microorganisms which are in charge for the biochemical break down of organic substances and earthworms for promoting aeration states, organic materials fragmentation and consequently augment the organic matter mineralization rate (Hanc and Vasak, 2015). In addition, the vermicompost is much richer in plant-friendly minerals, hormones/enzymes and biochemically enhanced over conventional compost owing to greater humification rate during vermistabilization (Hussain et al., 2016). It is known from previous research that vermicomposts derived from organic waste usually contain higher bioavailability of nutrients content (Soobhany et al., 2015b) with an increased level in humic acid as compared to their parent materials (Edwards et al., 2011). Additionally, sanitization of organic solid waste (Ndegwa and Thompson, 2001) and elimination of toxic heavy metals are enabled by an integrated composting-vermicomposting system (Soobhany et al., 2015a; He et al., 2016). But no past attempt concerning a broad assessment and comparison of stability and maturity indexes between MSW compost and vermicompost has been researched. Moreover, the physicochemical properties such as temperature, particle size, pH, electrical conductivity, bulk density, volatile solids, nutrient contents and organic carbon in composting employed to treat organic waste have been broadly researched (Nolan et al., 2011; Petric et al., 2012).

Besides these parameters, compost and vermicompost maturity can be evaluated by employing spectroscopic characteristics (Fourier transform infrared spectroscopy: FT-IR) (Ouatmane et al., 2000), thermogravimetric analysis (TG) (Smidt and Lechner, 2005; Zbytniewski and Buszewski, 2005), differential scanning calorimetry analysis (DSC) and structural characterization (scanning electron microscope: SEM) (Hussain et al., 2016). Thus, these spectroscopic, thermal and structural analyses could be used effectively to obtain comparative, complementary information and description on MSW composts and vermicomposts maturity. FT-IR analysis is a crucial qualitative technique for distinguishing the functional groups of organic substances and is usually utilized in the examination of soil organic matter, organic wastes and their compost (Amir et al., 2010). Thermal analysis (TG and DSC) are effective tools for exemplifying the end product in providing chemical characteristics of samples since they are straightforward, fairly cheap and steadfast methods (Zbytniewski and Buszewski, 2005; Wu et al., 2011). SEM analysis serves as a microscopic tool on various organic waste and composts where the surface morphology is clearly elucidated (Wan Razali et al., 2012). Generally, the application of these various maturity analyses will further give a comprehensive depiction and nature of the vermicompost as compared to compost (control) derived from MSW, in which case there is a lack of information regarding compost against vermicompost characterization using high-end equipments. Still, regardless of numerous studies on composting, no information has hitherto been found on these analyses for an extensive assessment and comparison of stability and maturity indexes between vermicompost and compost. The few studies that are available on vermicomposting maturity entailed spectroscopic analysis of vermicompost compared to initial wastes. The search for an effective use of MSW vermicomposts as compared to composts in terms of best compost stability and maturity criteria is still under way. It should however be noted that this study was confined to the characteristics of the final composting and vermicomposting products. Therefore, in line with the actual situation and to enhance a reliable and easily manageable method for the determination of compost stability and maturity, the present study reports extensive investigations supported by FT-IR, TG, DSC and SEM analyses to identify the difference in MSW vermicomposts compared to its respective composts (control).

2. Materials and methods

2.1. Feedstock materials collection

The detailed method to generate the best compost and vermicompost from organic MSW was described by Soobhany et al. (2015a). In regards to appropriateness for vermicomposting, the organic waste from the Municipal Solid Waste (MSW) that were chosen were food waste, grass clippings, dry leaves and small branches, market waste, office shredded paper and newspaper, and cow dung. The organic waste was collected from the waste collecting trucks which consisted of mixed MSW such as kitchen waste, yard waste, paper waste, plastics, textiles, metal cans, glasses and others. To obtain the organic fraction of waste materials, the mixed MSW wastes were sorted manually. The finished compost which was employed for the research was compost from MSW which comprised of kitchen and yard wastes. The cow dung was provided by the agricultural farm of the University of Mauritius in Réduit. Cow dung was not the MSW fraction and it was added to the scenarios to balance the C/N ratio. Moreover, another purpose was that cow dung could aid as a bedding material for the earthworms. Three different compositions with dissimilar components of the organic fraction of MSW were opted and computed with the purpose of achieving a C to N ratio of 30 and moisture content of 55–60%.

2.2. Collection and culturing of earthworm biomass

Stock earthworms *Eudrilus eugeniae* (African Nightcrawlers) which were of different age groups were acquired from a vermicomposting building block of a local cowshed by disinterring into the composted cow dung. These earthworms were nurtured on partially decomposed cow dung mixed with leaf litter of *Litchi chinensis* in the laboratory which has a controlled temperature facility system. Perspex bin of sizes $450 \times 300 \times 450$ mm were constructed for growing the cultures. Hatchlings were obtained from the incubation of fresh cocoons of stock earthworms *Eudrilus eugeniae* at 25 °C in laboratory. For the purpose of avoiding any contamination, the second generation of earthworms was utilized for the vermicomposting experiments. For the aim of this study, acclimatized juvenile and adult earthworms were unsystematically picked from the separately conserved cultures and used for the vermicomposting scenarios.

2.3. Experimental design

2.3.1. Mix calculation and preparation

The mix calculation and preparation of the mixtures was followed as per the procedure explained in Soobhany et al. (2015a). A total of six scenarios were set up wherein three experimentations were for composting symbolized as S1 for food waste mix (ratio of 5:0.5:1 of food waste, dry leaves and paper), S2 for paper waste mix (ratio of 4:5:1 of market waste, cow dung and paper)