Bioresource Technology 179 (2015) 398–406

Contents lists available at ScienceDirect

Bioresource Technology

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

Evolution of process control parameters during extended co-composting of green waste and solid fraction of cattle slurry to obtain growing media

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HIGHLIGHTS

- Green waste and cattle slurry were composted to produce growing media.
- Different evolution of process parameters and compost features have been found.
- New parameter has been proposed (degree hour per day-DH).
- DH enables to quantify the decomposing material exposure to high temperatures.
- Nitrification during composting led to a trend change in compost alkalinity.

ARTICLE INFO

Article history:
Received 4 November 2014
Received in revised form 12 December 2014
Accepted 13 December 2014
Available online 18 December 2014

Keywords:
Separated cattle slurry
Green waste
Degree-hour
Growing medium
Physico-chemical properties

ABSTRACT

This study aimed to monitor process parameters when two by-products (green waste – GW, and the solid fraction of cattle slurry – SFCS) were composted to obtain growing media. Using compost in growing medium mixtures involves prolonged composting processes that can last at least half a year. It is therefore crucial to study the parameters that affect compost stability as measured in the field in order to shorten the composting process at composting facilities. Two mixtures were prepared: GW25 (25% GW and 75% SFCS, v/v) and GW75 (75% GW and 25% SFCS, v/v). The different raw mixtures resulted in the production of two different growing media, and the evolution of process management parameters was different. A new parameter has been proposed to deal with attaining the thermophilic temperature range and maintaining it during composting, not only it would be useful to optimize composting processes, but also to assess the hygienization degree.

1. Introduction

Composting is increasingly becoming a popular universal option as an environmentally sustainable means of recycling agricultural and municipal organic by-products (Rao et al., 2007). The benefits of composting go beyond simply reducing the volume of waste. They also include a new approach to waste, in that it is perceived as a potentially valuable material (Benito et al., 2009). In Catalonia, commercial composting technology has been developed and applied to convert large volumes of waste, but it is necessary to produce high-quality end products (compost) to increase farmers' interest in using these products.

Due to legal constraints on peat use and the low market availability of raw materials for formulating substrates, it is necessary to seek alternative renewable materials. In earlier studies, it was reported the feasibility of composting the solid fraction of cattle slurries (SFCS) to obtain a high-quality product that can be used as a growing medium (Cáceres et al., 2006). For example, it has been shown that promoting the nitrification process by using static methods can reduce the pH of the final compost. Fertility diagnosis tools should also be implemented to properly monitor the fertilization status of compost-based substrates (Cáceres and Marfà, 2013).

The amount of green waste (GW), i.e. park and garden litter and trimmings generated in cities, has increased dramatically with the rapid development of urban green spaces in Spain and other countries (Zhang and Sun, 2014). In light of new municipal policies, a great deal of urban GW is now collected separately (López et al., 2010). In addition, Spain's highly active livestock industry generates large quantities of slurries. GW and SFCS have both been described as potential raw materials for composting to produce growing media (Benito et al., 2005; Raviv et al., 2005). These by-products have complementary characteristics. When combined with SFCS, GW can balance the normally high N content, absorb

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http://dx.doi.org/10.1016/j.biortech.2014.12.051
0960-8524/

extra water, improve the structure and enhance aeration (López et al., 2010). The addition of GW to SFCS also reduces ammonia and N_2O emissions during composting (de Guardia et al., 2010b). Other recent research on green waste composting have demonstrated the feasibility to obtain different and quality products, going in depth with microbial aspects and other important issues (two-stage composting procedure) (Zhang and Sun, 2014). However, no studies have been performed to describe the effects of using the static method to compost very different proportions of these materials.

Although composting is a widely used process, there are still gaps in our understanding of it due to the high variety of feedstock materials and composting conditions (Himanen and Hänninen, 2011). In addition, it has been indicated that suitable composting management is necessary to obtain a quality product (Bernal et al., 2009). Moreover, the use of compost as a growing medium in soilless cultures in horticulture requires long composting processes to ensure the material is stable. Microbial activity produces gradual changes in the physical, chemical and biological parameters that reveal the progress of the composting process (Zeng et al., 2011). Therefore, more knowledge on composting development and control is needed to ensure that this transformation process effectively occurs, and that composting facilities are efficiently designed and operated (Ekinci et al., 2004).

The degree-hour (DH) concept has been used in several disciplines such as agronomy and climate control in buildings. In this study, the concept was applied to the composting process. The temperature of the material in decomposition is the most important indicator of process efficiency and, among other factors, it is dependent on the oxygen available to microorganisms and, thus, on the aerobic nature of the composting process (Imbeah, 1998). Therefore, controlling the compost temperature is important not only for pathogen destruction, but also for optimizing respiration rates and stabilizing the compost. In order to achieve maximum biodegradation rates, it is crucial to attain high temperatures and maintain them throughout the decomposition phase. This can considerably shorten the entire process (Sidelko et al., 2010). However, in most cases, only daily temperatures are recorded and analyzed (Nolan et al., 2011). The present study, therefore, applies the degree-hour concept to composting to generate a new parameter that can help quantify the exposure of feedstock to high and intermediate temperatures during certain periods of time or throughout the entire process.

The objectives of this study were:

(a) To assess the effects of using different ratios of the two by-products (GW and SFCS) on composting progress in terms of process control parameters and compost characteristics.
(b) To verify the feasibility of the degree-hour parameter for defining the progress of the composting process and monitoring long-term composting processes.

2. Methods

The experiment lasted for 27 weeks (approximately 6 months). A long-term composting process is required when the desired end product is high-value compost that can be used as a peat substitute (Cáceres et al., 2006).

2.1. Materials

Shredded green waste feedstock (GW) was obtained from a composting plant in Cabrils (Barcelona, Catalonia-Spain). It consisted mainly of green leaves, woody trimmings and garden debris. The solid fraction of cattle slurry (SFCS) was obtained from a livestock farm in Sant Joan les Fonts (Girona, Catalonia-Spain). Due to its compactness and high water content, SFCS should be composted with another organic material that is rich in lignin components to provide the structural support to create inter-particle voids (Doublet et al., 2011). Mixtures with 25% of each feedstock were tested, resulting in two composting piles: GW25 (25% GW and 75% SFCS, v/v) and GW75 (75% GW and 25% SFCS, v/v).

2.2. Laboratory methods

2.2.1. Physico-chemical, physical and chemical parameters

The physicochemical, chemical and physical parameters of the raw materials and the mixtures were measured at the beginning of the composting process. At the end of the composting process, three samples were also taken from different locations in each pile (the right, center and left).

Electrical conductivity (EC) and pH were measured in aqueous extract using a conductivity cell (model 52 92 plugged to the meter GLP 31, Crison Instruments S.A., Barcelona, Spain) and a pH electrode (Ross Ultra® Triode of pH/ATC, Thermo Scientific Orion, Nijkert, Netherlands) plugged to a Expandible Ion Analyzer (Orion Dual Star pH/ISE Bechtop, Thermo Scientific Orion, Nijkert, Netherlands), respectively. This aqueous extract was obtained by mechanically shaking the samples with water at a solid to distilled water ratio of 1:5, w/w (Cáceres et al., 2006). Water-extractable ammonium-N was measured in the extract using a specific ion electrode (ORION Ammonia Electrode, model 95–12) plugged to the mentioned Expandible Ion Analyzer. The organic fraction of the samples was analyzed in dry and ground samples. Organic matter was measured by weight loss on ignition by incineration at 470 °C in a muffle furnace for five hours. Organic N (Norg) was measured using the mentioned ammonia electrode after a Kjeldahl digestion. The C/Norg ratio was calculated using Eq. (1) (Jolanun and Towparyoon, 2010). At the end of the process, the composts were also analyzed with regard to the same parameters.

$$\frac{C}{Norg} = \frac{0.58 \times MO}{Norg} \quad (1)$$

A volumetric sample (approximately 200 g fresh sample) was collected to determine the moisture content in gravimetric and volumetric terms (Mg and Mv, respectively). The compost moisture content was determined by oven drying the samples at 105 °C for 48 h. The bulk density (BD) was also calculated. The samples' air-filled porosity was theoretically calculated based on easily measured parameters, including wet bulk density and dry matter, and well-known parameters such as the density of water, organic matter and ash (Malińska and Richard, 2006; Malińska and Zabochnicka-Świątek, 2013).

$$\varepsilon_a = 1 - \rho_{wb} \cdot \left[\frac{1 - DM}{\rho_W} + \frac{DM \cdot OM}{\rho_{om}} + \frac{DM \cdot (1 - OM)}{\rho_{ash}}\right] \quad (2)$$

The rate of organic matter loss was worked out as an indicator of the overall composting rate (Eq. (3)) (Haug, 1993; Petric et al., 2012).

$$k = \frac{[OM_m\ (\%) - OM_p\ (\%)] \cdot 100}{OM_m\ (\%) \cdot [100 - OM_p\ (\%)]} \cdot 100 \quad (3)$$

where OM_m is the OM content at the beginning of the process and OM_p is the OM content at the end of the process.

2.2.2. Germination bioassay

Fresh samples of the obtained composts were tested for phytotoxicity using a lettuce (*Lactuca sativa* L.) germination test, following the procedure carried out by Jodice (1989). Ten millilitres of water extract (1/10 compost/water ratio (v/v), diluted with distilled water: 0%, 25%, 50% and 100%) were placed on Petri dishes, adding 10 lettuce seeds in each. Then, the mentioned dishes were