Waste Management xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Waste Management

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

A systematic approach to evaluate parameter consistency in the inlet stream of source separated biowaste composting facilities: A case study in Colombia

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ARTICLE INFO

Article history:
Received 1 November 2016
Revised 24 January 2017
Accepted 6 February 2017
Available online xxxx

Keywords:
Biowaste
Source separated organics
Composting
Substrate quality
Variability

ABSTRACT

Biowaste is commonly the largest fraction of municipal solid waste (MSW) in developing countries. Although composting is an effective method to treat source separated biowaste (SSB), there are certain limitations in terms of operation, partly due to insufficient control to the variability of SSB quality, which affects process kinetics and product quality. This study assesses the variability of the SSB physicochemical quality in a composting facility located in a small town of Colombia, in which SSB collection was performed twice a week. Likewise, the influence of the SSB physicochemical variability on the variability of compost parameters was assessed. Parametric and non-parametric tests (i.e. Student's *t*-test and the Mann-Whitney test) showed no significant differences in the quality parameters of SSB among collection days, and therefore, it was unnecessary to establish specific operation and maintenance regulations for each collection day. Significant variability was found in eight of the twelve quality parameters analyzed in the inlet stream, with corresponding coefficients of variation (CV) higher than 23%. The CVs for the eight parameters analyzed in the final compost (i.e. pH, moisture, total organic carbon, total nitrogen, C/N ratio, total phosphorus, total potassium and ash) ranged from 9.6% to 49.4%, with significant variations in five of those parameters (CV > 20%). The above indicate that variability in the inlet stream can affect the variability of the end-product. Results suggest the need to consider variability of the inlet stream in the performance of composting facilities to achieve a compost of consistent quality.

1. Introduction

Biowaste commonly constitutes the largest fraction of municipal solid waste (MSW) in developing countries, reaching up to 70% (wet base) of the MSW stream (Hoornweg and Bhada-Tata, 2012). The disposal of biowaste in landfills contributes to the emission of leachate and greenhouse gases that cause adverse sanitary and environmental impacts. Composting is considered an effective technology to manage source separated biowaste (SSB) which is relatively simple to carry out, and requires small investments when compared with other options (Li et al., 2013; Sundberg and Navia, 2014).

The physicochemical quality of substrates is a key factor for both the composting process and the product quality (Hargreaves et al., 2008). SSB physicochemical characteristics are variable due to aspects such as food consumption habits, the socioeconomic profile of the population, climatic conditions, and waste handling practices (Ward et al., 2004; Hansen et al., 2007; Neves et al., 2009).

Several authors have reported on the influence of the physicochemical characteristics of substrates during SSB composting (Forster-Carneiro et al., 2008); Hanc et al., 2011; Tosun et al., 2008; López et al., 2010; Huerta-Pujol et al., 2011). However, only a few studies have reported on the variability of SSB characteristics (Ward et al., 2004) and its effect on the composting process (Chang and Hsu, 2008). This variability in substrate characteristics determines the decomposition rate during the composting process and, therefore affects product quality (Zhang et al., 2007; Iacovidou et al., 2012).

Studying the variability in the physicochemical quality of SSB facilitates to identify the necessary operation activities

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http://dx.doi.org/10.1016/j.wasman.2017.02.010
0956-053X/

(e.g. addition of bulking or amendment materials, augmenting the control of the process) that can aid to obtain a compost of a quality that both fulfils national regulations (Cesaro et al., 2015) and meets user requirements (Adhikari et al., 2008).

In developing countries, such as Colombia, the design practice of small SSB composting facilities does not involve in detail the physicochemical characteristics of the inlet SSB. In addition, the variability of the inlet quality has not been studied so that to be incorporated as a key factor in process control (Oviedo-Ocaña, 2015). This gap in knowledge could be a possible reason for the low effectiveness of the composting technology in such countries.

To the authors' knowledge, the scientific literature lacks information on a systematic monitoring of the variability of the parameters measured in the inlet material of typical SSB composting facilities.

The general aim of this study is to investigate the influence of SSB composition on the quality of the compost. This objective is addressed by analyzing several physicochemical characteristics of both the inlet SSB and the produced compost over 15 months of operation. The study attempts to determine the effect of the variability of the inlet material (herein referred simply as inlet) on the variability of the end-product (compost quality). This study was conducted at a SSB composting facility located in a typical small town of Colombia (i.e. manual operation without mechanization) that was considered as a case study typical of a developing country. The results are expected to increase the knowledge on the variability of SSB characteristics, providing information that contributes to a more efficient control process in composting facilities in developing countries. It is noted that several solid waste management initiatives introduced in developing countries have been successful and have achieved to introduce paradigms in solid waste management innovation for several low to medium income countries (Guerrero et al., 2013). Therefore, the work presented here is not intended to be a mere case study, but rather attempts to introduce certain issues that need to be taken into account in all SSB composting facilities.

As SSB in this paper, we define the organic household (kitchen/food and yard) waste that is collected via a door to door collection system using plastic bags. In the case study described here, SSB mainly constituted of food/kitchen waste, with yard waste being present in much lower percentages.

2. Materials and methods

This section firstly outlines the study area in which the analysis is situated. Secondly, it describes the determination of substrate quality to the inlet material of a SSB composting facility. Thirdly, the criteria to evaluate the influence of the physicochemical variability in the inlet material and in the end-product are described. In addition, the methods used for substrate sampling, physicochemical characterisation and data processing are presented.

2.1. Study area

The study was developed in Versalles (Valle del Cauca), a town in Colombia with a population of 3276 inhabitants. The average temperature in the location was 18 °C, and the average precipitation was 1500 mm/year (Oviedo-Ocaña, 2015). Based on a survey developed by Marmolejo et al. (2010) as well as on reports from the waste management company, it was estimated that approximately 80% of the population in Versalles practiced source separation of solid waste, whilst 94% used plastic bags for storing SSB. The collection service included selective collection two times per week (Mondays and Thursdays). Therefore, the biowaste were stored either three (i.e. Mondays to Thursdays) or four (i.e. Thursdays to Mondays) days within the households. No bins were provided for the separate SSB collection, since a door to door collection system is implemented in Versalles and SSB is placed by the residents in simple plastic bags. Since the typical four annual seasons do not exist in Colombia, no significant seasonal variations are expected to affect waste composition. SSB was transported in dump trucks to the composting facility in which residual non-biodegradable materials were manually separated. Taking into account the SSB production in the city used here (0.28 kg/cap/day according to Marmolejo et al., 2010) and the storage periods mentioned above, composting piles were prepared 24 h after the SSB arrived with weights of 3.8 tonnes (for SSB collected on Monday) or 2.8 tonnes (for SSB collected on Thursday). During pile formation, the SSB from each sampling date (Monday or Thursday) was manually homogenized and sieved, using a 10 cm square mesh. The piles had a conical shape and an average height of 1.1 m and were placed on an impermeable base and covered by a temporary roof. The piles were manually operated (e.g. turned and moisturized). No bulking agent was used in the preparation of the piles. The composting facility used here (Versalles) had the characteristics of a typical facility from Valle del Cauca (Colombia) (see Table 1), where manual operation and limited monitoring of the inlet and product quality occur. The characteristics of the five monitored biowaste composting facilities in Valle del Cauca are presented in Table 1.

2.2. Quality of the inlet to the SSB composting facility

2.2.1. Inlet sampling, physical composition, and physicochemical characterisation

The physical composition and physicochemical characterisation of the inlet (SSB) were based on samples made of sub-samples obtained after the formation of the composting piles. The sampling procedure was as follows: (i) each pile was previously mixed to obtain the maximum homogenisation possible; (ii) from each pile, 50 kg were obtained through a random quartering technique from several parts of the pile; (iii) the 50 kg of sample were then mixed and subsequently, 2 kg (sub-sample) were obtained randomly for use during the physicochemical characterisation; (iv) the remaining 48 kg were used to determine physical composition. We note that although the quartering technique is widely used for the sampling of solid wastes (Dahlén and Lagerkvist, 2008), it can induce fundamental sampling errors, as has been demonstrated by Edjabou et al. (2015), for physical waste composition, and Esbensen et al. (2007) and Petersen (2004) for chemical waste composition. To reduce the experimental error, sampling activities were performed throughout the study by the same operator, who had been previously trained. Sampling and preservation techniques were conducted according to Sullivan and Miller (2001). This characterisation process was developed during 15 months, in which a total of 39 samples were obtained; from those 39, 20 samples had been obtained from piles consisting of substrates that were stored for four days (sampling on Tuesday) and 19 samples from the substrates stored for three days (sampling Friday). We assumed no differences in the waste composition among seasons due to the lack of the classic four seasons in Colombia (only a wet and a dry season exists).

The physical composition was determined after weighing and classifying the remaining material (48 kg) into nine categories (see Table 2). Categories 1–5 corresponded to unprocessed food types, whilst Category 6 was the processed food. These categories were proposed after taking into account the studies of Parfitt et al. (2010) and Gustavsson et al. (2011). For example, Parfitt et al. (2010) had presented food wastes that comprised of 8 categories, whilst Gustavsson et al. (2011) had included a breakdown of materials that integrated categories such as cereals, roots and

Please cite this article in press as: Oviedo-Ocaña, E.R., et al. A systematic approach to evaluate parameter consistency in the inlet stream of source separated biowaste composting facilities: A case study in Colombia. Waste Management (2017), http://dx.doi.org/10.1016/j.wasman.2017.02.010