ARTICLE IN PRESS

Waste Management xxx (2018) xxx–xxx

Contents lists available at ScienceDirect

Waste Management

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

Review

Co-biodrying of sewage sludge and organic fraction of municipal solid waste: Role of mixing proportions

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ARTICLE INFO

Article history:
Received 8 January 2018
Revised 10 March 2018
Accepted 13 April 2018
Available online xxxx

Keywords:
Sewage sludge
Municipal solid waste
Co-biodrying
Water removal
Energy utilization

ABSTRACT

This study investigated the performance of co-biodrying sewage sludge and organic fraction of municipal solid waste (OFMSW) at different proportions. Cornstalk was added at 15% (of total wet weight) as the bulking agent. Results show that increasing OFMSW percentage promoted the biodegradation of organic matter, thus enhancing the temperature integration value and water removal to above 75% during sludge and OFMSW co-biodrying. In particular, adding more OFMSW accelerated the biodegradation of soluble carbohydrates, lignins, lipids, and amylums, resulting in more organic loss and thus lower biodrying index (3.3–3.7 for 55–85% OFMSW). Water balance calculation indicated that evaporation was the main mechanism for water removal. Heat used for water evaporation was 37.7–48.6% of total heat consumption during co-biodrying. Our results suggest that sludge and OFMSW should be mixed equally for their efficient co-biodrying.

Contents

1. Introduction

Waste to energy is an important guideline for management of solid wastes (Papageorgiou et al., 2009; Brunner et al., 2015; Ngusale et al., 2017). Energy recovery from solid wastes can be achieved by either direct combustion or production of combustible fuels, for example, in the form of methane, hydrogen (Cheng and Hu, 2010), refuse derived fuel (RDF) and (Ragazzi and Rada, 2012; Ouda et al., 2016), and other solid recovered fuels (SRF) (Ragazzi and Rada, 2012; Passamani et al., 2016). In general, incineration is the most common process to convert solid wastes to

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https://doi.org/10.1016/j.wasman.2018.04.016
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Please cite this article in press as: Zhang, D., et al. Co-biodrying of sewage sludge and organic fraction of municipal solid waste: Role of mixing proportions. Waste Management (2018), https://doi.org/10.1016/j.wasman.2018.04.016

energy and has been practiced globally. However, the high moisture content of most solid wastes hinders the efficiency of energy recovery (Hamidian et al., 2016; Tom et al., 2016; Yuan et al., 2017). Incineration without prior moisture reduction increases energy input for heating, resulting in high outlay and indirect emissions of greenhouse gases (Liu et al., 2017).

A variation of composting, namely biodrying, has been developed to remove water in materials, particularly organic solids, with high moisture by forced ventilation and heat generated from the biodegradation of organic substances (Sugni et al., 2005; Velis et al., 2009; Rada et al., 2012; Somsai et al., 2017). Independent from fossil or extremal heating sources, water elimination during biodrying can be achieved by water evaporation, air convection, and molecular diffusion (Frei et al., 2004). With minimum consumption of organic matter, biodrying can maximally preserve the energy potential of waste matrix. Therefore, solid wastes after biodrying can be used as a source of high quality and renewable solid fuels (e.g., RDF or SRF) as alternatives to fossil fuel (Papageorgiou et al., 2009; Colomer-Mendoza et al., 2013; Bilgin and Tulun, 2015; Ouda et al., 2016; Passamani et al., 2016).

Biodrying has also been commonly applied for the pretreatment of wastes with high initial moisture, such as municipal solid waste (MSW) and sewage sludge (Rada et al., 2009; Song et al., 2015; Ma et al., 2016). Indeed, biodrying is a preferable option to dry and partially stabilize MSW prior to landfill or combustion (Adani et al., 2002; Yuan et al., 2017). Both volume and weight of MSW can be reduced considerably after biodrying for better short-term storage and transportation (Bilgin and Tulun, 2015). Zhang et al. (2009) showed that biodrying could effectively reduce the moisture and thus enhance the sorting efficiency of MSW by 36%, which is favourable to mechanical separation for resource recovery. Moreover, the low moisture of biodried MSW mitigates their secondary pollution, such as leachate, in subsequent treatment (Tambone et al., 2011). It has also been reported that biodrying can potentially convert wasted sludge from wastewater treatment facilities to an attractive brown coal replacement (Navaee-Ardeh et al., 2006). Compared to other drying methods, such as thermal drying, sludge biodrying requires less electric consumption and preserves more energy potential in final product (i.e. biodried sludge) (Winkler et al., 2013). In addition, Liu et al. (2017) demonstrated that sludge biodrying could reduce 50% greenhouse gas emissions from mono-incineration.

Sewage sludge is not appropriate for aerobic biodegradation due to its high water content, small void spaces, and low organic matter (Lu et al., 2009; Zhao et al., 2010). Thus, sewage sludge is commonly co-biodried with other substrates, such as bulking agents and food waste (Zhao et al., 2011; Song et al., 2015; Ma et al., 2016). Bulking agents, such as cornstalks and sawdust, can be used to improve waste properties (e.g. moisture and carbon/nitrogen (C/N) to facilitate the biodrying process (Yang et al., 2013; Song et al., 2015). Indeed, Song et al. (2015) demonstrated that cornstalks could be used as the bulking agent to improve the co-biodrying of dewatered sludge and food waste. Ma et al. (2016) subsequently evidenced a synergistic enhancement in co-biodrying of dewatered sludge and food waste with corncob as the bulking agent by observing a stable temperature profile and long thermophilic period. By comparing these two similar studies, it appears that cornstalks could be a better bulking agent than corncob, possibly due to its sponge-like and flexible structure. In a recent study, Yuan et al. (2017) reported that cornstalk addition could increase the matrix temperature and moisture removal during biodrying of organic fraction of MSW (OFMSW), which is featured with high water content. Nevertheless, little is known about the performance of co-biodrying sewage sludge and OFMSW, particularly with appropriate bulking agents.

This study aimed to evaluate the performance of co-biodrying sewage sludge and OFMSW at different proportions. Cornstalks were used as the bulking agent to facilitate their co-biodrying. Water loss and organic degradation during biodrying were evaluated. In addition, water and heat balances during co-biodrying were also determined. Results from this study determine the optimal mixing range for co-biodrying sewage sludge and OFMSW, thereby providing important insights for their simultaneous management in practice.

2. Materials and methods

2.1. Biodrying materials and their pretreatment

Sewage sludge wasted from a membrane bioreactor system from a local Municipal Wastewater Treatment Plant (Beijing, China) was used. The sewage sludge was dehydrated onsite by centrifugation. Fresh MSW was collected from a local Waste Transfer Station (Beijing, China). The collected MSW was screened to 0–80 mm. OFMSW was used by manually removing non-biodegradable substances, such as metals, glasses, and papers. The OFMSW comprised 57.9% vegetables, 12.7% peels, 13.7% staple food, 4.2% meat, 6.3% eggshells, bones and shells, and 5.3% nutshells and cores (on the wet weight basis). Cornstalk was collected from a local farmland (Beijing, China) and cut to 3–5 cm after air-dried. In this study, cornstalk was used as the bulking agent to adjust matrix moisture and provide structural support for co-biodrying of OFMSW and sewage sludge under aerobic conditions. Key physiochemical properties of these raw materials were characterized based on the analytical methods detailed in Section 2.3 and are presented in Table 1.

2.2. Experimental design and methods

In this study, seven treatments (i.e. T1–T7) were designed with different proportions of sewage sludge and OFMSW based on the total weight of all biodrying materials (Table 2). In these treatments, 15% (of total wet weight) cornstalks was added as the bulking agent. It has been reported that adding 15% cornstalks could effectively control leachate production and gaseous emissions during the composting of OFMSW (Zhang et al., 2011) and sewage sludge (Yuan et al., 2016), respectively. It is noteworthy that sewage sludge had high water content (Table 1), resulting in the initial matrix moisture at approximately 70% when mixed with OFMSW at higher proportions (i.e. the T1–T2 treatments). Thus, certain

Table 1

Key physicochemical properties of raw biodrying materials (average value ± standard deviation from triplicate measurements).

Parameters	Sewage sludge	OFMSW[a]	Cornstalk
Moisture content (%)	83.1 ± 1.4	66.5 ± 0.8	8.5 ± 0.6
Volatile solid[b] (%)	52.1 ± 0.7	70.1 ± 1.5	96.2 ± 1.3
Bulk density (kg·m^{-3})	948.4 ± 18.6	523.2 ± 27.8	112.1 ± 12.2
Total carbon[b] (%)	25.2 ± 0.9	35.1 ± 0.5	43.9 ± 0.1
Total nitrogen[b] (%)	4.0 ± 0.1	2.2 ± 0.1	0.8 ± 0.1
Carbon/nitrogen ratio	6.4 ± 0.1	16.0 ± 0.1	52.9 ± 0.1
Amylums[b] (%)	1.6 ± 0.0	7.0 ± 0.1	3.4 ± 0.0
Proteins[b] (%)	26.7 ± 0.3	14.4 ± 0.3	7.2 ± 0.1
Lipids[b] (%)	7.3 ± 0.1	12.2 ± 0.2	10.9 ± 0.3
Soluble carbohydrates[b] (%)	0.5 ± 0.0	4.4 ± 0.0	2.6 ± 0.0
Celluloses[b] (%)	1.2 ± 0.0	11.48 ± 0.2	30.6 ± 1.3
Hemicelluloses[b] (%)	3.8 ± 0.2	4.8 ± 0.0	20.2 ± 0.4
Lignins[b] (%)	11.3 ± 0.6	8.5 ± 0.1	19.4 ± 0.2

[a] OFMSW = organic fraction of municipal solid waste.

[b] On the dry weight basis.

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