Available online at www.sciencedirect.com

ScienceDirect

www.elsevier.com/locate/jes

JES JOURNAL OF ENVIRONMENTAL SCIENCES www.jesc.ac.cn

Importance of storage time in mesophilic anaerobic digestion of food waste

Fan Lü[1], *Xian Xu*[1], *Liming Shao*[2,3], *Pinjing He*[2,3,*]

1. *State Key Laboratory of Pollution Control and Resource Reuses, Tongji University, Shanghai 200092, China. E-mail: lufan.rhodea@tongji.edu.cn*
2. *Institute of Waste Treatment and Reclamation, Tongji University, Shanghai 200092, China*
3. *Centre for the Technology Research and Training on Household Waste in Small Towns & Rural Area, Ministry of Housing and Urban–Rural Development of PR China, Shanghai 200092, China*

ARTICLE INFO

Article history:
Received 16 August 2015
Revised 23 October 2015
Accepted 2 November 2015
Available online 16 January 2016

Keywords:
Food waste
Bio-pretreatment
Storage
Fermentation
Biochemical methane potential
Hydrolysates

ABSTRACT

Storage was used as a pretreatment to enhance the methanization performance of mesophilic anaerobic digestion of food waste. Food wastes were separately stored for 0, 1, 2, 3, 4, 5, 7, and 12 days, and then fed into a methanogenic reactor for a biochemical methane potential (BMP) test lasting up to 60 days. Relative to the methane production of food waste stored for 0–1 day (285–308 mL/g-added volatile solids (VS_{added})), that after 2–4 days and after 5–12 days of storage increased to 418–530 and 618–696 mL/g-VS_{added}, respectively. The efficiency of hydrolysis and acidification of pre-stored food waste in the methanization reactors increased with storage time. The characteristics of stored waste suggest that methane production was not correlated with the total hydrolysis efficiency of organics in pre-stored food waste but was positively correlated with the storage time and acidification level of the waste. From the results, we recommend 5–7 days of storage of food waste in anaerobic digestion treatment plants.

Introduction

Production of urban food waste on a global scale is predicted to increase by 44% from 2005 to 2025 (Adhikari et al., 2006). Because of its high moisture content, as well as organic- and nutrient-rich composition, food waste is considered as a valuable biomass resource for biomethane recovery using anaerobic digestion (AD) (Kiran et al., 2014; Komemoto et al., 2009; Wang et al., 2015b). AD is a widely used but complicated technology for the treatment of food waste, in which organic matter is converted to methane and carbon dioxide under an oxygen-free environment (Jiang et al., 2013). AD of food waste can be generally divided into two steps, i.e., fermentation and methanization.

Hydrolysates, which are fermentation products, significantly affect the performance of methanization reactors. Therefore, optimum environmental and operational parameters influencing acid-phase digestion of food waste, including pH (Jiang et al., 2013; Lim et al., 2008; Wang et al., 2014), temperature (Jiang et al., 2013; Komemoto et al., 2009; Lim et al., 2008; Vanwonterghem et al., 2015), hydraulic retention time (HRT) (Lim et al., 2008; Wang et al., 2015a), inoculum-to-substrate ratio (Forster-Carneiro et al., 2008; Xu et al., 2012), and organic loading rate (Jiang et al., 2013; Lim et al., 2008), have been intensively investigated. Some studies have focused on the physical or chemical pretreatment of food waste in order to enhance the hydrolysis or to alter the properties of food waste and thus to facilitate subsequent methanization through

* *Corresponding author*. E-mail: solidwaste@tongji.edu.cn (Pinjing He).

http://dx.doi.org/10.1016/j.jes.2015.11.019
1001-0742/

processes such as microwave treatment (Marin et al., 2010; Shahriari et al., 2013), ultrasonication (Cho et al., 2013; Elbeshbishy and Nakhla 2011), mechanical grinding (Izumi et al., 2010), alkali treatment (Lin et al., 2013), thermal treatment (Li and Li and Jin, 2015; Wang et al., 2006), ozonation (Ariunbaatar et al., 2014), and enzyme treatment (Kim et al., 2006).

Nevertheless, the aforementioned pretreatment methods are costly and decrease the efficiency of extracting energy from food waste. By contrast, simple storage can be used as an alternative pretreatment step. Xu et al. (2011) reported that anaerobic storage of dewatered sludge improves its biodegradability, increasing the soluble organic acid content from 90 to 2400 mg/L and increasing the soluble organic carbon content from 220 to 1650 mg/L. However, there are few studies on the effect of storage on food waste digestion. Although food storage in many industrial practices lasts from 0 h to tens of days, operators only consider transportation or loading requirements. Compared with sludge and other solid waste, food waste has low microbial load because of sanitation and cooking processes. There are studies focusing on the fermentation time of food waste in a fermentation reactor using an inoculum. For example, Wang et al. (2015a) used retention times of 1, 3, 5 days for an acidogenic reactor for food waste using mesophilic two-phase AD. They used a 1:1 inoculum-to-substrate ratio on total solids (TS) basis. The highest acidification effect was achieved with 5 days of fermentation. Lim et al. (2008) studied the effect of different HRT (4, 8, 12 days) on the production of volatile fatty acids (VFAs) in food waste inoculated with digested sludge and found that total VFAs produced by 8 and 12 days of fermentation were much more than those formed after 4 days. However, to the best knowledge of the authors, there are no studies on the storage pretreatment of uninoculated food waste to obtain optimal hydrolysates for subsequent methane production.

Therefore, the objective of this work was to investigate the effects of storage time on the properties of the hydrolysates from food waste and on the performance of the subsequent methanization. A further aim was to determine the optimal storage time for AD treatment plants for food waste.

1. Methods and materials

1.1. Substrates and inoculant

Food waste used in the study was collected from the canteen of Tongji University, Shanghai, China. It consisted of cooked rice, vegetables, fish, eggs, etc. After bones and inert materials were removed, the waste was homogenized in a shredding machine. Anaerobic sludge obtained from an up-flow anaerobic digester of a paper mill was used as inoculant. The food waste and sludge had a TS content of 24.1 wt.% and 11.8 wt.%, respectively, and volatile solid (VS) content of 88.2% dry weight (dw) and 60.8% dw, respectively.

1.2. Experimental set-up

The prepared waste was first fed into fermentation reactors and incubated in an oscillating cultivation box (SPX-250-Z-S, Yuejin, China) at 35 ± 2°C for 0, 1, 2, 3, 4, 5, 7, and 12 days, respectively. Polystyrene centrifuge tubes of 50 mL without lids served as the storage reactors, covered by Parafilm (WI54956, Bemis, USA) which was pricked to enable the escape of biogas produced during fermentation, so as to simulate the anoxic conditions of storage. Four parallel experiments were performed for each fermentation retention time. In one parallel experiment, the waste was immediately stored at 4°C in a refrigerator for property characterization. In the other three, waste was used as feed stock for a methanization reactor and stored at –20°C before use.

Methanization of the pre-fermented waste was carried out in an automatic methane potential test system (AMPTS II, Bioprocess Ltd., Sweden) under mesophilic conditions (35 ± 1°C) maintained by a thermostatic water-bath incubator. Serum bottles (1 L) were hermetically sealed with rubber stoppers having two metal tubes to enable separate sampling of liquids and gas flow. The biogas produced first flowed into a bottle with 3 mol/L NaOH to absorb CO_2, and the remaining gas volume was measured by the principle of water-displacement and buoyancy. Tests were carried out in triplicate. Two blank reactors were used to measure the quantity of methane produced by the inoculum. The reported methane production of food waste was after deducting the background value of the inoculated sludge. The flow chart of the storage and methanization experiments is shown in Fig. 1. Mechanical stirring was neither employed in storage nor in AMPTS operation, but the liquid in methanization reactors was homogenized by hand-shaking before sampling.

The recipe for methanization included food waste that had been subjected to various times of fermentation, inoculant, nutrient solutions, and distilled water. The mixture had a TS content of 105 g/L and a VS content of 72 g/L. The inoculant-to-substrate ratio on a VS basis was 2:1. The preparation of nutrient solutions was based on documented methods (ISO, 1998). The initial pH was adjusted to 6.8–7.2 by using 1 mol/L HCl and 1 mol/L NaOH solutions. Reactors were purged from the bottom with nitrogen gas for 5 min. Liquid samples were collected every 2 days within the first 24 days of digestion.

1.3. Analytical methods

The pH, TS, VS, VFAs, and total organic carbon (TOC) were measured to evaluate the characteristics of hydrolysates at various fermentation times. The pH, TOC, and VFAs of each liquid sample in the methanogenic reactor were analyzed to study the degradation of organic matter in the reactor. Methane production was automatically recorded by the AMPTS system.

The TS and VS content were analyzed by using standard methods (APHA et al., 2012). The pH and VFA content were measured with a pH meter (6230M, Jenco, USA) and high-performance liquid chromatography system (LC-20AD, Shimadzu, Japan) respectively. TOC values were obtained from the difference between total carbon (TC) and inorganic carbon, both of which were analyzed with a TOC analyzer (TOC-V_{CPN}, Shimadzu, Japan). The total nitrogen (TN) value can also be obtained from the TOC analyzer. Prior to the analysis of VFAs