Chemical Engineering Journal 262 (2015) 932–938

Contents lists available at ScienceDirect

Chemical Engineering Journal

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

Dewaterability of anaerobic digestate from food waste: Relationship with extracellular polymeric substances

Fan Lü [a,b], Qi Zhou [a], Duo Wu [a], Tianfeng Wang [a], Liming Shao [b,c], Pinjing He [b,c,*]

[a] State Key Laboratory of Pollution Control and Resource Reuse, Tongji University, Shanghai 200092, China
[b] Institute of Waste Treatment and Reclamation, Tongji University, Shanghai 200092, China
[c] 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 (MOHURD), Shanghai 200092, China

HIGHLIGHTS

- Food waste digestate's dewaterability strongly depended on EPS characteristics.
- Digestate dewaterability was affected more by digestion course than feedstock.
- Digestate dewaterability deteriorated during fast hydrolysis period.

ARTICLE INFO

Article history:
Received 30 July 2014
Received in revised form 7 October 2014
Accepted 15 October 2014
Available online 22 October 2014

Keywords:
Food waste
Anaerobic digestion
Anaerobic digestate
Dewaterability
Extracellular polymeric substances
Proteins

ABSTRACT

This study investigated the dewaterability and extracellular polymeric substances (EPS) characteristics of food waste digestates collected from different sources and after different anaerobic digestion times. The specific resistance to filtration, normalized capillary suction time and bound water indicated that the dewaterability of the digestates from restaurant food waste was inferior to those of household kitchen waste. However, the anaerobic digestion course was more vital to digestate dewaterability than the digested materials. The dewaterability significantly deteriorated and high amounts of EPS were extracted in the fast hydrolysis period, suggesting that the accumulated hydrolysates contributed to the low dewaterability. A long digestion time of over 30 days also led to low dewaterability. Correlation analysis and partial least square analysis indicated that EPS characteristics have an important influence on the dehydration of anaerobic digestates, with bound water being more influenced by polysaccharides and the other dewaterability indexes more affected by proteins.

1. Introduction

With the increasing biomass of solid waste and growing demand for renewable resources, anaerobic digestion has gradually gained wide application [1] owing to the advantages of mass and volume reduction [2], odor emission control by stabilization [3], and renewable energy recovery [4]. Moreover, the anaerobic digestate after post-treatment is suitable for land application as a valuable fertilizer and soil conditioner [5,6] and for pollutant absorption [7]. The widespread application of anaerobic digestion has led to large amounts of residual digestate that requires treatment.

Dewatering is necessary for digestate treatment. During dewatering, the liquor and fiber fraction of the digestate can be separated for the sake of storage, transportation, post-treatment and other purposes. Effective dewatering can significantly reduce the volume of digestate and reduce the cost of further processing. For example, separation of solid and liquid phases can reduce transportation requirements by up to 60%, and these can be reduced by an additional 25% after drying [8]. Therefore, it is necessary to clarify the factors influencing dewaterability and to optimize the dewatering operation. Although dewatering of sludge and its digestate have been thoroughly investigated [9,10], the dewaterability of anaerobic digestate from other organic waste is less known, although there are many engineering practices for

Abbreviations: ADs, anaerobic digestates; A^2O, anaeroxic–anoxic–oxic; BW, bound water; EPS, extracellular polymer substances; HKW, household kitchen waste; MGS, methanogenic granular sludge; NCST, normalized capillary suction; PN, proteins; PS, polysaccharides; RFW, restaurant food waste; SFW, a mixture of thermally pretreated sludge and restaurant food waste; SRF, specific resistance to filtration; TPS, thermally pretreated sludge; WAS, waste activated sludge.

* Corresponding author at: Institute of Waste Treatment and Reclamation, Tongji University, Shanghai 200092, China. Tel./fax: +86 21 65981383.
E-mail address: solidwaste@tongji.edu.cn (P. He).

http://dx.doi.org/10.1016/j.cej.2014.10.051
1385-8947/© 2014 Published by Elsevier B.V.

separating such wastes. As indicated in [11] and [12], the mean total solids (TS) in the fiber fraction of food waste digestate is highest after separation with a decanter centrifuge (22.3%), followed by a screw press (12.9%) and belt press (8.7%). These values are in the low range when compared with manure digestate (fiber TS 24.3%) [11] or sewage sludge digestate (cake TS 15–35%) [13] separated by centrifugal dewatering, indicating that the dewaterability of food waste digestate is inferior.

Numerous studies [14] have shown that the characteristics of extracellular polymeric substances (EPS) play an important role in sewage sludge dewaterability. EPS is the product of active secretion, cell surface material shedding, cell lysis, and sorption from the environment [15]. EPS is composed of a variety of organic substances including carbohydrates and proteins as the major constituents and humic substances, uronic acids and nucleic acids in smaller quantities [16]. However, the analysis of the influence of EPS on dewaterability of digestate was rare. In fact, anaerobic digestion with high loading is liable to cause the accumulation of soluble microbial products [17]. Additionally, there are abundant microbial residuals in organic waste digestate following digestion, resulting in the possibility of microbial EPS accumulation. Therefore, it is worth exploring whether microbial EPS affects the dewaterability of food waste digestate.

This study investigated the dewaterability of digestate obtained from the anaerobic digestion of food waste, sludge or their mixture, and from different periods of food waste digestion. The characteristics of their corresponding EPS were evaluated with the goal of exploring the relationship between EPS and dewaterability of food waste digestate. The extracted EPS was tested for their proteins, carbohydrates and nucleic acids contents. The dewaterability was assessed using three types of common dewatering indicators, specific resistance to filtration (SRF), normalized capillary suction time (NCST), and bound water content (BW). Finally, the effectiveness of these three indicators for representing the digestate dewaterability are discussed.

2. Materials and methods

2.1. Digestate from the anaerobic digestion of different feedstocks

The first series of digestates were obtained from eight anaerobic digestion batch experiments with different feedstocks, including restaurant food waste (RFW) from catering businesses, household kitchen waste (HKW), thermally pretreated sludge (TPS), waste activated sludge (WAS) and a mixture of TPS and RFW (called SFW, mixture ratio = 6:4 in volatile solids (VS) basis). The RFW and HKW were broken into particle sizes of about 3 cm. The WAS was collected from the clarifier of a local domestic wastewater treatment plant in Shanghai, China, with an anaerobic–anoxic–oxic (A^2O) process. The TPS sludge was WAS sludge that had been thermally pretreated at 158 °C and 0.6 MPa for 30 min.

Two types of inocula were used, anaerobic digestates (ADs) collected from a 21-m^3 mesophilic (35 °C) anaerobic digester fed with a mixture of TPS and RFW for a hydraulic retention time of 20 days with f TPS and RFW feed loadings of 1 $m^3\,d^{-1}$ and 140 kg d^{-1}, respectively. The other inoculum was a methanogenic granular sludge (MGS) that was collected from an upflow anaerobic sludge bed reactor with liquid internal recirculation as described in our previous research [18]. The feedstock materials and inocula were combined into eight treatments, each in triplicate (Table 1). The ratio of inoculum to substrate was 4:1 on a VS basis, according to the optimized results of our preliminary assessment. The batch mesophilic anaerobic experiments were conducted in 500-mL bottles of the Automatic Methane Potential Test System (AMPTS II, GAIA Solutions, LLC, Sweden) with a retention time of 22 days at 35 ± 1 °C. The AMPTS system could be used for real-time online monitoring of methane yield and to control the stirring. The total VS in each bottle was identical and water was added to a total mass of 320 g.

The second series of digestate were collected frequently during the anaerobic digestion process of the two experiments, which were conducted in duplicate at 35 ± 1 °C in 25-L sealed barrels. The operational conditions were the same as those for the first Series-C using RFW and first Series-D using HKW, except for the total mass in each barrel, which was 20 kg. The two treatments were marked as second Series-C and second Series-D, respectively. The set-up of all treatments is listed in Table 1 with 28 batch experiments (24 in 1st series and 4 in 2nd series) in total, and the physicochemical characteristics of the feedstock materials and inocula are listed in Table 2.

2.2. Digestate dewaterability analysis

Three indicators were tested to represent digestate dewaterability, SRF, NCST and BW. SRF is a composite dewatering indicator that presents the vacuum filtration performance of the tested material. NCST is modified from the capillary suction time (CST), which is the ratio of CST to the concentration of the tested material required to eliminate the influence of solid particles [19]. BW was determined by the ratio of moisture content to total solid content when achieving a vacuum filtration equilibrium [20]. The filtration dehydration performance became poor as SRF and NCST increased. Additionally, mechanical dehydration is difficult when the BW

Table 1
Fitting of Gompertz model parameters to cumulative methane production data.

Experiment	Ultimate methane yield, P (mL g^{-1} VS_{added})	Maximum methane production rate, R_{max} (mL g^{-1} VS_{added} d^{-1})	Lag phase λ (d)	R^2
1st series				
A: ADs + SFW	176.2 ± 1.64	37.0 ± 2.3	2.19 ± 0.16	0.993
B: ADs + TPS	118.2 ± 1.1	21.4 ± 1.2	1.77 ± 0.17	0.993
C: ADs + RFW	378.3 ± 2.0	96.1 ± 3.9	2.82 ± 0.09	0.998
D: ADS + HKW	316.2 ± 1.4	42.4 ± 0.9	1.34 ± 0.08	0.999
E: ADS + WAS	63.6 ± 1.9	4.5 ± 0.3	0.00 ± 0.42	0.983
F: ADs + ADs	12.2 ± 0.3	1.1 ± 0.1	0.00 ± 0.38	0.981
G: MGS + SFW	157.5 ± 0.8	34.0 ± 1.3	1.97 ± 0.09	0.998
H: MGS + ADs	39.2 ± 0.4	4.5 ± 0.2	2.93 ± 0.15	0.997
2nd series				
C: ADs + RFW	371.5 ± 11.3	21.8 ± 1.6	0.00 ± 0.53	0.985
D: ADs + HKW	250.7 ± 10.9	15.0 ± 1.6	0.00 ± 0.76	0.965

Note: the parameter value is given in mean ± standard deviation.