Chemical Engineering Journal 259 (2015) 795–805

Contents lists available at ScienceDirect

Chemical Engineering Journal

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

# Anaerobic co-digestion of food waste with MSW incineration plant fresh leachate: process performance and synergistic effects

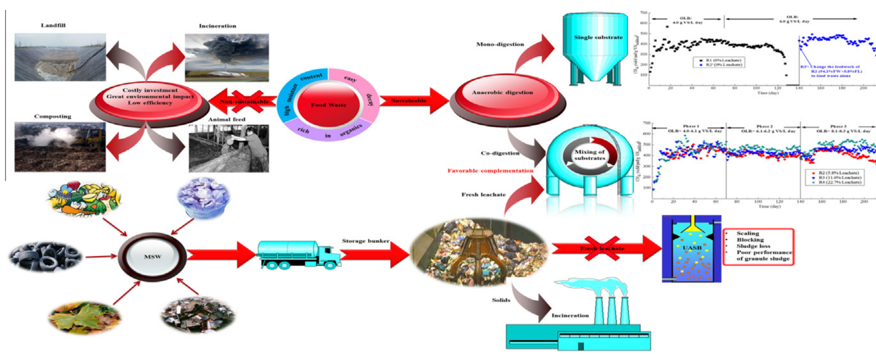
Wanli Zhang, Lei Zhang *, Aimin Li *

*Key Laboratory of Industrial Ecology and Environmental Engineering (Ministry of Education), School of Environmental Science and Technology, Dalian University of Technology, Linggong Road 2, Dalian 116024, PR China*

## HIGHLIGHTS

- Anaerobic mono-digestion of food waste exhibited poor performance and stability.
- The deficiency of essential metal elements of food waste was the limiting factor.
- Propionate inhibition was eliminated by supplementing metal elements.
- Anaerobic digestion of food waste was improved by co-digesting with fresh leachate.
- A feasible approach to co-treat food waste and fresh leachate was provided.

## GRAPHICAL ABSTRACT




## ARTICLE INFO

*Article history:*
Received 7 June 2014
Received in revised form 5 August 2014
Accepted 13 August 2014
Available online 20 August 2014

*Keywords:*
Anaerobic co-digestion
Food waste
Fresh leachate
Trace metal element
VFA accumulation

## ABSTRACT

The objectives of this study were to examine the feasibility of improving biogas production and process stability of anaerobic mono-digestion of food waste by co-digesting with MSW incineration plant fresh leachate, and to identify the key factors governing performance and stability of anaerobic digestion. For this purpose, a series of semi-continuous experiments were carried out. During a long-term operation period, contrary to the failure of mono-digestion of food waste, anaerobic co-digestion with fresh leachate exhibited a much better performance and stability in terms of high $CH_4$ yields (375.9–506.3 mL/g $VS_{added}$), high VS removals (66.9–81.7%), no VFA inhibition, and stable pH (7.2–7.8). The unstable mono-digestion of food waste was recovered from process imbalance by supplementing trace metal elements (Fe, Co, Mo, Ni), as indicated by the increased $CH_4$ yields (from 384.1 to 456.5 mL/g $VS_{added}$), the decreased propionate concentration (from 899.0 to 10.0 mg/L), and the increased pH (from 6.9 to 7.4). These results were in line with our analytical results that the food waste was deficient in trace metal elements, and fresh leachate was rich in them. Co-digestion strategy provided abundant trace elements for anaerobic process. Our results clearly demonstrated that the deficiency of metal elements was the reason causing the unstable performance of anaerobic mono-digestion of food waste, which was corrected by co-digesting with fresh leachate. This research provides a more technically and economically feasible approach to co-treating and co-utilizing food waste and fresh leachate from MSW incineration plant.


* Corresponding authors. Tel.: +86 411 84707448; fax: +86 411 84706679.
*E-mail addresses:* shdlhjzwl@163.com (W. Zhang), zhanglei78@dlut.edu.cn (L. Zhang), leeam@dlut.edu.cn (A. Li).

http://dx.doi.org/10.1016/j.cej.2014.08.039
1385-8947/

## 1. Introduction

In 2012, around 171 million tons of municipal solid waste (MSW) were generated in China [1], 50–60% (by weight) of which was food waste [2]. With the explosive growth of food waste production, the management strategies for food waste have raised a lot of environmental concerns. Due to the features of high moisture content, low calorific value, and easy decay of food waste, current management practices of food waste such as landfill, incineration, composting, and animal feed are less satisfactory in terms of unsustainable resource recycle, great environmental impact, and costly investment [3]. It is a challenge to develop an environmentally-friendly, efficient, and cost-effective strategy for food waste treatment.

Anaerobic digestion is considered to be a desirable disposal method for organic wastes owing to valuable products, low emission of secondary pollutants, and high economic feasibility [4-6]. Recent researches indicated that food waste was an easily biodegradable substrate for anaerobic digestion with high carbohydrate, lipid, protein, and moderate moisture content. Browne and Murphy [7] reported that the biochemical methane potential (BMP) of food waste (467–529 mL $CH_4$/g $VS_{added}$) was high. Nonetheless, the poor stability has been often reported as the main problem for anaerobic digestion of food waste. First, high-calorie food waste was easily acidified into volatile fatty acid (VFA) by fermentative bacteria, and VFA accumulation led to the decreased pH and the inhibition of methanogenic system [3]. Furthermore, high protein content of food waste typically gave a high nitrogen content by hydrolysis and led to the elevated ammonia concentration in digester [8]. In addition, the deficiency of essential trace elements of food waste limited $CH_4$ production and led to the failure of anaerobic digestion process [9]. Thus, it is an urgent task to solve the problem of instability of anaerobic digestion of food waste.

Fresh leachate from MSW incineration plant (MSWIP) is another major organic waste stream. Recently, MSW incineration has been developing rapidly in China due to the excellent efficiency of waste reduction. However, the high moisture content and low calorific value of MSW due to the large proportion of food waste (50–60% by weight) both suggested that it could not be incinerated effectively without fuel addition or meticulous separation [2]. In practice, MSW was stored in storage bunkers for 3–7 days before incineration. By this way, the moisture content was reduced, and the calorific value was increased [10]. During the storage period, a large amount of fresh leachate (10–20% of MSW (by weight)) was generated. This is different from some developed countries, where less fresh leachate was produced from source-sorted MSW [11]. Thus, fresh leachate from storage bunkers of MSWIP may be a specific waste stream for developing countries. The fresh leachate was rich in organic matters, VFA, ammonia-N, and metal elements [12]. In conventional completely stirring tank reactor (CSTR), a high organic load rate (OLR) could not be achieved by reducing the hydraulic retention time (HRT) due to the relative low organic strength. In some cases, the up-flow anaerobic sludge blanket (UASB) reactor and expanded granular sludge bed (EGSB) were employed to treat the fresh leachate of MSWIP [10,13]. However, due to the features of fresh leachate rich in calcium ion and ammonia-N, UASB and EGSB may encounter the problems of scaling, blocking, poor performance of granule sludge, and sludge loss. Therefore, it is still a challenging task to treat MSWIP fresh leachate in a more effective manner.

Recently, anaerobic co-digestion attracted more attentions due to the sharing facility and complementary features of substrates [14,15]. Anaerobic co-digestion of food waste with other components have been studied, including sewage sludge, cattle manure, piggery wastewater, and other components [16]. With regard to the fresh leachate, its high alkalinity could improve the buffering ability of anaerobic digestion system. Moreover, fresh leachate rich in trace elements due to the diverse sources could increase the enzymatic activity of anaerobes. Besides, the abundant VFA of fresh leachate could be used by acetogens and methanogens without hydrolysis and acidogenesis, which might accelerate the start-up of anaerobic digestion process. Considering complementary features of food waste and fresh leachate, it seemed to be feasible to co-digest food waste with fresh leachate. So far, there is no report about anaerobic co-digestion of food waste and MSWIP fresh leachate. This was the reason to initiate the present study, where the influence of MSWIP fresh leachate addition on performance and stability of anaerobic digestion of food waste was examined. The co-digestion process was evaluated under varying OLR and HRT conditions, VFA profiles, $CH_4$ yields, and organic removals in semi-continuous mode. Moreover, the food waste, fresh leachate, and digestate were characterized, and special focus was put on metal elements. In addition, the effect of trace elements (Fe, Co, Mo, Ni) supplementation on the recovery of unstable anaerobic mono-digestion of food waste was tested to explore the role of metal elements of fresh leachate in maintaining good performance and stability of co-digestion process.

## 2. Materials and methods

### 2.1. Materials and sample preparation procedures

The food waste (FW) containing mainly rice, vegetable, and meat was obtained from a campus restaurant of Dalian University of Technology, China. The impurities, such as bones, napkins, plastic bags, etc., were picked out by hand. The food waste was homogenized using an electrical kitchen blender, and then screened through a 14-meshes screen. The food waste sample was frozen at −18 °C and thawed for 12 h at 5 °C before use.

The fresh leachate (FL) was obtained from a waste storage bunker of a MSW incineration plant, Dalian, China. The incineration plant had a daily handling capacity of 1500 t MSW, and about 175 t/day fresh leachate was generated. The preparation and storage methods of fresh leachate sample were the same as those for food waste.

The seed sludge was obtained from the anaerobic digester of one municipal sewage sludge treatment plant, Dalian, China. The volatile suspended solid (VSS) of seed sludge was 29.3 ± 0.6 g/L.

### 2.2. Experimental procedures

In order to evaluate the biodegradability of the food waste and fresh leachate, BMP tests were carried out in triplicate in 500-mL Schott Duran bottles with silica gel stoppers. The working volume of each bottle was 300 mL, which was filled with 200 mL of seed sludge and 100 mL of substrate. The OLR of each reactor was 10 g VS/L. The control was filled with 200 mL of seed sludge and 100 mL of distilled water for background $CH_4$ production. Nitrogen gas was injected into the bottles for 5 min to remove the air. Then, the reactors were incubated in a shaking incubator at 150 rpm, 37 °C. The batch experiments lasted for 30 days.

The semi-continuous anaerobic digestion experiments were also carried out in 500-mL Schott Duran bottles. The method of nitrogen gas injection and the operating conditions of the shaking incubator were the same as BMP tests. The initial working volume of each bottle was 300 mL and was fed and discharged regularly once a day. The proportions of fresh leachate (by VS) in the feedstock of R1, R2, R3, and R4 were 0%, 5.8%, 11.6%, and 22.7%, respectively. The VS contents were kept at 8.0–9.3%.

The experimental period was divided into three phases. In Phase 1, R1–R4 were operated at a relative low OLRs (4–4.1 g VS/