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Short Communication

Using feature objects aided strategy to evaluate the biomethane production of food waste and corn stalk anaerobic co-digestion

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HIGHLIGHTS

- Feature object aided strategy was used to investigate real waste co-digestion.
- Food waste and corn stalk were co-digested compared with mono-digestion at 35 °C.
- The kinetic of feature objects and real waste anaerobic digestions were evaluated.
- The biomethane production and reaction rate were improved by mixing substrates.
- 22.48–41.55% enhancement was achieved in food waste and corn stalk co-digestion.

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ABSTRACT

Feature objects aided strategy was used to predict and evaluate the biomethane production of food waste and corn stalk anaerobic co-digestion. The kinetics of co-digestion and mono-digestion of food waste and/or corn stalk was also analyzed. The results indicated that the compositions of food waste and corn stalk were significantly different. The anaerobic digestion of three feature objects at different mixing ratios showed the different biomethane yields and kinetic constants. Food waste and corn stalk co-digestion enhanced the digestion rate and achieved 22.48% and 41.55% higher biomethane production than those of food waste and corn stalk mono-digestion, respectively.

1. Introduction

Corn stalk and food waste are typical organic wastes in China. Traditional organic waste disposals like incineration and landfill were not best choice due to the potential second-time environmental pollution associated. Anaerobic digestion (AD) has been proven to be an efficient green treatment, waste reduction, and energy recycling included (MacLellan et al., 2013). Large amount of corn stalk and food waste has high methane potential (Zhang et al., 2011). Both of them are attractive feedstocks for biomethane production through anaerobic digestion. However, food waste is facing the problem of ammonia nitrogen inhibition (Chen et al., 2008). On the other hand, corn stalk will result in acidification in the reactor, leading to lower buffering capacity, due to its high C/N ratio at high organic loadings. Besides, feedstock supplement is not stable when the corn stalk is used as only feedstock source for anaerobic digestion because of seasonal influence.

Anaerobic co-digestion is a process, which could treat two or more organic wastes at the same time (Ganesh et al., 2013). Biomethane production and biodegradability could be enhanced by optimum complementary relation between the multiple feedstocks. Anaerobic co-digestion of food waste and corn stalk is a good attempt to mitigate the unstable supplement of single feedstock, meanwhile, provide more balanced nutrients. Though there are a few reports about anaerobic co-digestion of various wastes (Yue et al., 2013; Zhang et al., 2013), very limited references are available for the co-digestion of Chinese food waste and corn stalk.

Food waste is significantly different from corn stalk in components. The content of total reducing sugar and protein was approximately 43.5–85.2% in food waste, while 73.3–82.3% of lignocellulose was found in the corn stalk (Yan et al., 2011; Song et al., 2014; Tianxue et al., 2014). Therefore, it is necessary to investigate the effects on biogas production and reaction rate of different ingredients when food waste and corn stalk were co-digested.

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This study was to evaluate and predict the biomethane production from food waste and corn stalk anaerobic co-digestion by using feature objects (FOs) aided strategy. FOs used included glucose, peptone, and microcrystalline cellulose (MC). The reaction rates for the wastes were also determined with first-order kinetic model.

2. Methods

2.1. Characteristics of feedstocks and inoculum

Food waste for anaerobic digestion was collected from the dining room in Beijing University of Chemical Technology. The indigestible materials in food waste such as bones, egg shells, and plastic bags were removed before it was homogenized into slurry by a food waste homogenizer (SS2600, Meijiamada Co., Zhenjiang, China). Corn stalk was collected from rural area in Shunyi District, Beijing, China. After chopping into 3–4 cm in length, the corn stalk was ground into a desired size of 5–10 mm by a hammer mill (FE130, Staida, Co., Tianjin, China). The slurry of food waste was stored at −20 °C for later AD tests.

The inoculum was the activated sludge which was collected from an AD plant for swine manure treatment in Shunyi District, Beijing, China. The total solid (TS) and volatile solid (VS) were 11.13% and 5.36%, respectively. The inoculum was stored at 4 °C after collection and was incubated at 35 °C for a week before it was inoculated for AD. The characteristics of feedstocks and inoculum are listed in Table 1.

2.2. FOs selection

Food waste and corn stalk presented different biodegradability and biochemical methane production (BMP) (Labatut et al., 2011; Zhang et al., 2007). This was mainly attributed to the easily-biodegradable compositions of sugar, protein, starch and fat in food waste compared to the hard-biodegradable ingredients of cellulose, hemi-cellulose and lignin (Wang et al., 2007). Table 1 shows the characteristics of food waste and corn stalk. The concentrations of reducing sugar, protein and cellulose in food waste are 38.63%, 15.32% and 9.68%, respectively, and the content of cellulose in the corn stalk is 42.97%. In order to describe the biogas production performances of food waste and corn stalk more precisely, glucose, peptone and microcrystalline cellulose were selected as FOs to simulate the food waste and corn stalk anaerobic co-digestion.

Table 1
Characteristics of feedstocks and inoculum.

Items	Food waste	Corn stalk	Inoculum
pH [a]	5.02	–	7.44
TS (%)	22.71	94.48	11.13
VS (%)	20.72	86.76	5.36
TC (%)[b]	48.30	49.77	19.09
TN (%)[c]	2.56	0.78	2.14
C/N	18.9	63.5	8.9
Reducing sugar (%)[d]	38.63	–	–
Protein (%)[e]	15.32	–	–
Cellulose (%)[f]	9.68	42.97	5.09

[a] The pH value was measured by pH meter (CHN868, Thermo Orion, America).
[b] TC was determined by an elemental analyzer (Vario EL/micro cube elemental analyzer, Germany).
[c] TN was determined by the total Kjeldahl nitrogen analyzer (Model KDN-2C, Shanghai).
[d] The content of reducing sugar was determined by DNS method with ultraviolet spectrophotometer (UV-2012C, UNICO, America).
[e] The content of protein was determined by Kjeldahl Determination (Model KDN-2C, Shanghai).
[f] The content of cellulose was measured by the extraction unit according to the procedures proposed by Van Soest et al. (1991).

2.3. Anaerobic digestion batch tests

Anaerobic digestion batch tests were carried out on 500 mL serum bottles with the working volume of 300 mL. The bottles were sealed by rubber plugs and parafilm after the substrates and inoculum were loaded in the bottles. Afterwards, the bottles were incubated at 35 °C and shaken in a frequency of 120 rpm for 5 min every hour. The daily biogas production and methane content were monitored every day to evaluate the biomethane production performances.

2.4. Experimental procedure

Four levels of organic loadings (OLs), 15–45 g-VS/L, were set in the first period of the experiments. In each level of OLs, glucose, peptone, and MC were loaded in a proportion of real food waste and corn stalk, respectively. In the second part of the experiments, glucose, peptone, and MC were mixed at different ratios to evaluate the biomethane production performances. At last, food waste and corn stalk were anaerobically digested in mono-way and co-way.

2.5. Analysis methods

AD batch tests were measured by water displacement method. Methane content of the biogas was determined by gas chromatography (SP-2100, China) equipped with a molecular sieve packed stainless-steel column with the length and diameter of 2.0 m × 3.0 mm (TDX-01) and a thermal conductivity detector (TCD). The standard gas with 5.0% N_2, 60.1% CH_4, and 34.9% CO_2 was used for the standard calibration for the determination. The biomethane production was calculated based on the methane content and biogas production (Li et al., 2009).

3. Results and discussion

3.1. Biomethane production of FOs at different OL levels

Fig. 1 presents the total methane production (TMP) and kinetic constants of glucose, peptone, and MC. MC achieved the highest TMP at all levels of OLs, as compared with glucose and peptone. The TMP of MC was increased from 1349.4 to 2659.7 mL when OL was raised from 15 to 45 g-VS/L. Similar trends were observed for other two FOs. Assuming that biomethane production is a function of bacterial growth, the cumulative methane yield data was fitted to the modified Gompertz equation (Eq. (1)) (Nopharatana et al., 2007).

$$M = P \times \exp\left\{-\exp\left[\frac{R_m \times e}{P}(\lambda - t) + 1\right]\right\} \quad (1)$$

where M is the biomethane yield at t time, mL/(g-VS d), P is the final biomethane yield, mL/g-VS, R_m is the maximum daily biomethane yield, mL/(g-VS d), λ is the lag phase, d.

Subsequently, the anaerobic digestion rate can be described as a first-order kinetic model with respect to methane production (Eq. (2)) (Group, 2002).

$$d[(B_0 - B)/B_0]/dt = -k[(B_0 - B)/B_0] \quad (2)$$

where k is the first order kinetic constant, d^{-1}, t is the digestion time, d, B_0 is the ultimate methane production at the end of the experiment corresponding to the initial substrate concentration,