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Evaluating Methane Potential and Kinetics of Anaerobic Co-digestion with feces and food waste

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ABSTRACT

Feces and food waste from households are generally discharged in centralized treatment systems. With community-on-site treatment, the need and costs for transportation and subsequent emissions can be minimized. Feces and food waste can be treated anaerobically. Anaerobic digestion is a biochemical technology for the treatment of organic wastes and the production of biogas.BMP test was conducted for three different substrates, such as a mixture of feces and food waste, feces, and food waste. According to the 70 days of observation results, co-digestion case showed the highest methane production and kinetic constant among three tested cases. The observed methane production and kinetic constant of co-digestion were much higher than single digestion results and the synergic effect of co-digestion was partially proved.

1. Introduction

In traditional sanitation, the domestic wastewater is considered only as a contaminant, where valuable resources in wastewater (water, organic matter and nutrients) are discharged in centralized sewage systems. On the other hand, the domestic wastewater in sustainable sanitation is considered not only as a pollutant, but also as a resource for closing water and nutrient cycles (Li 2009, Elmitwalli 2011). In a sustainable sanitation, separated treatment of feces and urine is mainly applied, which can lead to the appropriate utilization of resources in the wastewater and proper control and removal of macro and micro pollutants.

Food waste from households requires treatment to reduce its uncontrolled degradation on disposal sites, odor, and nutrient emissions. In urban areas, FW can be collected and transported to centralized treatment, but in rural areas such activity is not supportable in terms of sustainability or cost-efficiency. However, with community-on-site treatment, the need for transportation and subsequent emissions can be minimized. FW is rich in nutrients and organic material, and easily biodegraded (Rajagopal 2013).

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While composting is often used, it can also be treated anaerobically.

Anaerobic digestion is a biochemical technology, which removes and converts the organic matter in the wastewater to the production of biogas. Consequently, it is beneficial to apply anaerobic digestion within sustainable sanitation (El-Mashad 2010, Elmitwalli 2011). However, single digestion of organic wastes may not meet the required nutrient levels and results in problems. Co-digestion can be an alternative method because it can establish positive synergism and the added nutrients can support microbial growth.

The objective of this study was to assess feasibility and synergy effect of co-digestion with feces and food waste and to evaluate a simulation model to predict biogas production rates. In addition, biogas production rates were simulated via first order reaction equation and the modified Gompertz equation.

2. Materials and methods

2.1 Substrates

A mixture of feces and food waste (co-digestion), feces, and food waste. Feces for BMP test samples were collected from public toilet to represent usual feces. For the batch experiments, the feces were taken and used at once. The sample prepared by homogeneous mixing, drying at 105℃, and grinding. Food waste was prepared by standard methods of food waste products, which proposed by Korea Environmental Industry and Technology Institute, also to have the same reason as feces sample, and it follows the identical procedure for the rest of the preparation. Components of food waste are in Table 1.

Table 1. Composition of standard food waste, suggested by Korea Environmental Industry and Technology Institute

Components		Composition (wet-wt. %)
Grain	Rice	16
Vegetables	Cabbage	9
	Potato	20
	Onion	20
	Radish	2
Fruits	Apple	7
	Orange	7
The others	Meat	4
	Fish	12
	Egg shell	3
Total		100

2.2 Biochemical Methane Potential (BMP) test

BMP test was conducted for three different substrates, such as a mixture of feces and food waste, feces, and food waste. A feeding mixture ratio was set according to statistical Korean values. Feces and food waste generated amount of feces and food waste was 150 g and 250 g per one person a day, respectively. (Korea Ministry of

Environment, MOE)

BMP tests performed in 250-ml bottles at 35°C and 150 RPM for 70 days. Each sample setup triplicated to avoid error. Gas production and gas composition were analyzed to assess the efficiency of the anaerobic digestion of the BMP test by Gas Chromatography everyday (GC, Younglin ACME 6100, Korea).

3. Results

3.1. Biogas production

The results of the BMP tests are in Fig. 1.

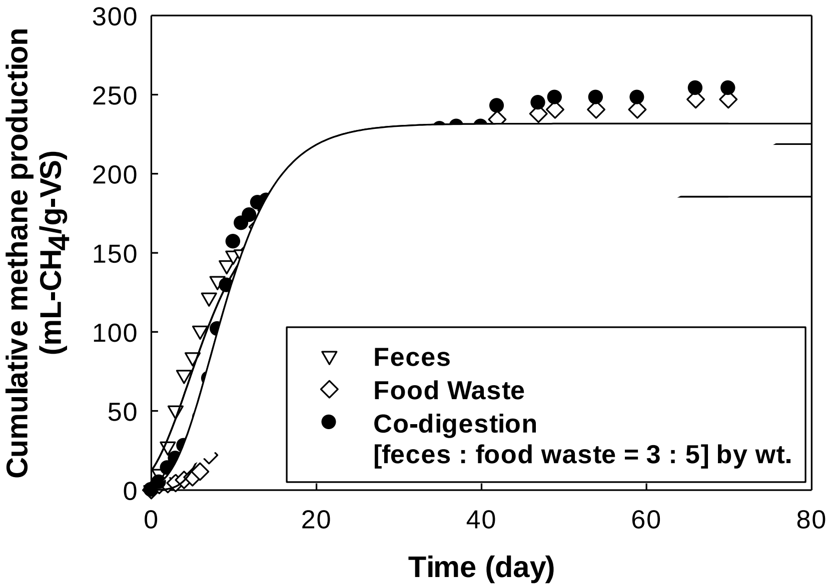

Fig. 1 Cumulative methane production

The modified Gompertz equation Eq. (1) used for fitting the observed cumulative methane yield to determine the maximum methane production potential in this study.

$$\mathrm{M} = \mathrm{P}\exp\left[-\exp\left\{\frac{\mathrm{R_e} \cdot e}{\mathrm{P}}(\lambda - \mathrm{t}) + 1\right\}\right] \tag{1}$$

where M represents the cumulative methane production (mL·CH_4/g·VS), t means the time over the period (day), P is the methane production potential (mL·CH_4/g·VS), Re represents the maximum methane production rate (mL·CH_4/g·VS·day), λ means the lag phase time (day) and e is equal to 2.718282. The regression models were completed by SigmaPlot 12 version.

Experimental data of biogas production from a mixture of feces and food waste, food waste, and feces can be found in Fig. 1. As Fig. 1 shows, co-digestion case in the BMP test through the 70 days has highest methane gas production potential. The methane gas production potential of co-digestion, food waste, and feces was 231.69, 218.76, and 185.56 mL·CH_4/g·VS, respectively. The cumulative methane production was found to be co-digestion (254.02 mL CH_4/g VS) > food waste (247.04 mL CH_4/g VS) > feces (220.01 mL CH_4/g VS).

Meanwhile, food waste was shown high methane production from single substrate among the other, co-digestion was shown the highest methane production potential from BMP test. It is suggested that co-digestion offset the lack of nutrients and dilute harmful substances and promotes methane gas production.

3.2 kinetic constants

Table 2 and Fig. 2 showed the experimental data, simulation results of kinetic constants. First-order kinetics can only be applied when the rate limiting factor is the surface of the particulate substrate, and bioavailability or biodegradability related phenomena do not interfere (Sanders 2003).

$$\frac{\mathrm{dS}}{\mathrm{dt}} = -kS \qquad (2)$$

Where, k is kinetic constant, S is substrate concentration.

Eq (2) integral expresses the expression Eq (3).

$$\ln\left(\frac{S}{S_0}\right) = -kt \qquad (3)$$

The concentration of biodegradable VS inside the reactor generated directly biogas was related as follows Eq (4).

$$\left(\frac{S}{S_0}\right) = \left(\frac{B_0 - B}{B_0}\right) \qquad (4)$$

The combination of the above Eq (2) and Eq (4);

$$\left(\frac{B_0 - B}{B_0}\right) = \exp\,(-kt) \qquad (5)$$

where, B_0 is the maximum methane production, B is the cumulative methane production

Table 2 indicated that the first order kinetic constants followed the first order equation well. The correlation coefficient was feces (0.9694), food waste (0.9638), and co-digestion (0.9503).

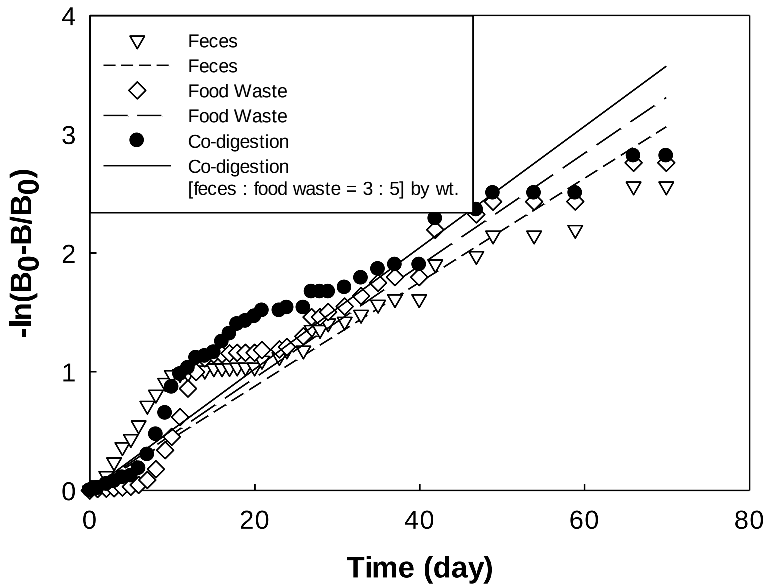

Fig. 2 kinetic constant (k) according to three different substrates

Table 2 summarizes the ultimate methane production and kinetic coefficients for three different substrates. A range of values of the first-order rate coefficient can be seen for the correlation coefficient. This range of values can be explained by different experimental conditions.

Table 2 kinetic constant (k) and ultimate methane production

	Correlation coefficient	k (d^{-1})	Ultimate methane production (mL CH_4/g VS)
Feces	0.9694	0.0438	220.01
Food waste	0.9638	0.0474	247.04
Co-digestion	0.9503	0.0511	254.02

4. Conclusion

This study demonstrated that anaerobic co-digestion of feces and food waste proved to be a potential substrate for biogas production. Anaerobic co-digestion showed higher methane production than feces and food waste in single substrate conditions. The highest methane production and rate found at co-digestion compare to single digestion. The first order kinetics fitted experimental value well. The first order kinetics had a high correlation for simulating cumulative methane production and higher kinetics constants than the others. Thus, co-digestion is expected to be more favorable for methane gas production.

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