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Short communication

Combination of different substrates to improve anaerobic digestion of sewage sludge in a wastewater treatment plant

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ABSTRACT

This study investigated the effects on methane production of combining diverse organic wastes as a method to improve the anaerobic digestion (AD) of sewage sludge in a wastewater treatment plant (WWTP). Evaluation of methane production from the AD of selected organic wastes showed the AD of food waste (FW) attained the highest methane production (522.9 mL CH_4/g VS), while the digestion of septage produced the lowest– (164.9 mL CH_4/g VS). Type of substrate determined the microbial community, possibly relating to differences in chemical properties of intermediates produced from the AD of wastes. Compared to the AD of primary sludge alone, co-digestion of primary sludge with FW achieved 72% higher methane production, while co-digestion with septage exhibited 20% lower production. Thus, the anaerobic co-digestion of sewage sludge with FW can provide a viable alternative to circumvent problems of separate digestion in WWTPs.

1. Introduction

The efficiency of AD in the stabilization of organic solid wastes such as sewage sludge, food waste and animal manure has led to its wide adoption (Berndes et al., 2003). Increasing attention to this process stems from the possibility of producing renewable energy in the form of biogas as well as recycling by-products such as valuable fertilizers or soil conditioners (Zheng et al., 2012). As technologies of AD have become well established, technical interest has been directed towards maximization of process yields—specifically methane generation from the digestion of organic wastes (Cesaro and Belgiorno, 2014). In wastewater treatment plants (WWTPs), methane production through the AD of sludge plays a vital role by offsetting energy consumption. However, only 40–50% of the organic fraction in sludge is converted to methane gas, resulting in low digestion efficiency and methane yield (Cao and Pawlowski, 2012). To improve AD yield, simultaneous digestion of different organic wastes in a single digester (co-digestion) offers an attractive option by adding both nutrients and organic contents that are currently missing from sewage sludge (Cesaro and Belgiorno, 2014). This process, known as anaerobic co-digestion, encourages biogas production by turning a waste into an energy source (Sosnowski et al., 2008).

For processing in co-digestion, a variety of wastes are available in an onsite anaerobic treatment process. Recently, the Korean government has strongly required the treatment of various organic wastes from landfill or ocean dumping be diverted into substrates of AD for renewable energy generation (Lee et al., 2013). Among various organic wastes, sewage sludge has a high moisture content, while septage produced from septic tanks treating human feces contains a low carbon to nitrogen ratio. Because of their characteristics, wastes such as sewage sludge and septage are difficult to be treated as a sole substrate but can be handled using proper proportions in an AD. Co-digestion of sewage sludge with other organic wastes might solve the limitations of digestion of a sole substrate, as well as the disposal of organic wastes. Accordingly, the objective of this study was to examine the anaerobic co-digestion of organic wastes to enhance methane production in the AD of sewage sludge generated from a WWTP.

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2. Materials and methods

2.1. Experimental set-up

Four different organic wastes were selected for this study. Primary sludge (PS) and waste activated sludge (WAS) were collected from a municipal wastewater treatment plant (WWTP) in Anyang City, Korea. Food waste (FW) and septage (ST) were sampled from a FW and ST treatment facility in Anyang, Korea. To investigate the individual digestibility of four selected organic wastes (PS, WAS, ST and FW), biochemical methane potential (BMP) tests were performed for 50 days in 160 mL serum bottles with a working volume of 100 mL. The bottles were initially inoculated with anaerobic sludge from an anaerobic digester treating PS in the WWTP. The inoculum and substrate were mixed at a ratio of 1:1 based on the concentration of volatile solids (VS) (Table S1). The second BMP tests were performed to compare methane production by digestion of PS alone to the co-digestion of PS with the three other wastes individually. In the anaerobic co-digestion, volume ratios of mixtures were determined reflecting the quantity of daily production of each waste generated from Anyang City, Korea: PS + WAS (38:62); PS + ST (67:33); PS + FW (53:47); PS + WAS + ST + FW (25:41:12:22). All BMP tests at 35 ± 1 °C and 120 rpm were performed in triplicate.

2.2. Chemical analysis

Biogas production was measured by gas chromatography (HP 5890, PA, USA) equipped with a thermal conductivity detector and helium as a carrier gas (Martín-González et al., 2010). The temperatures of oven, injector and detector were 70 °C, 150 °C and 180 °C, respectively. Total solids (TS), VS and chemical oxygen demand (COD) were analyzed according to standard methods (APHA, 2005).

2.3. Molecular microbial analysis

Total DNA from the sludge was extracted and purified using a Nucleo Spin® Soil kit (MACHEREY–NAGEL, Germany) according to the manufacturer's protocol. Bacterial and archaeal communities were analyzed via PCR–DGGE using the primer set BAC338F/805R and ARC787F/1059R, respectively, with a GC-clamp as previously described (Yu et al., 2005; Kim et al., 2013). Upon confirmation of the excision of single bands via a secondary DGGE run, the bands were re-amplified, purified with QIAEX II (Qiagen, CA), and sequenced (ABI3730XL DNA analyzer, Applied Biosystems, CA).

3. Results and discussion

3.1. Methane production of selected organic wastes

Fig. 1a shows cumulative methane yields through the AD of the four selected organic wastes. Among the sole substrates used in anaerobic digesters, AD of FW provided maximum methane production of 522.9 mL-CH_4/g-VS with a VS reduction of 67%. Next in descending order, the AD of PS and WAS produced similar cumulative methane of 227.1 and 192.2 mL-CH_4/g-VS, respectively. The lowest methane production of 164.9 mL-CH_4/g-VS was generated from the AD of ST substrate, exhibiting a methane yield of less than one-third the methane yield of that of FW. Given a theoretical methane a potential based on proposed equation (Boyle, 1976), both the AD of ST ($C_{12.3}H_{46.6}O_{5.9}N$) and FW ($C_{17.6}H_{74.2}O_{7.8}N$) were expected to generate high methane productions of 646.8 and 661.7 mL-CH_4/g-VS, respectively (Fig. 2). Contrary to the experimental achievement of 79% of theoretical methane production

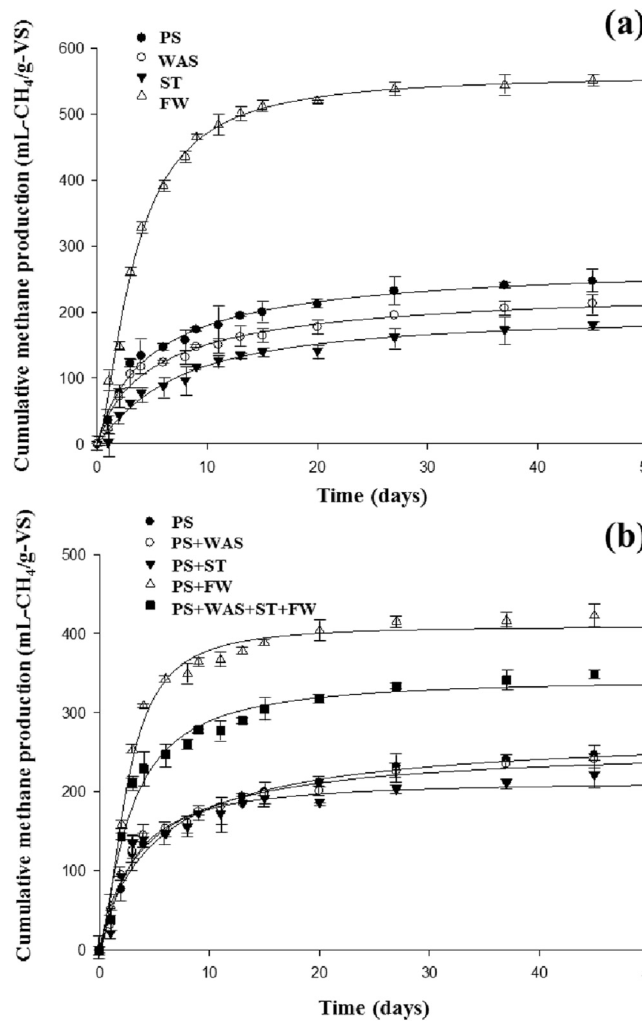

Fig. 1. Cumulative methane production (a) from anaerobic digestion of four selected wastes; (b) from anaerobic co-digestion of primary sludge and different wastes (PS, primary sludge; WAS, waste activated sludge; ST, septage; FW, food waste).

from FW, the experimental methane production of ST actually achieved less than 25.5% of the theoretical methane potential. This reflects the very low utilizable organic content in ST which contains a much lower percentage of VS than does FW, thus confirming the observation that a high VS content assures easily biodegradable

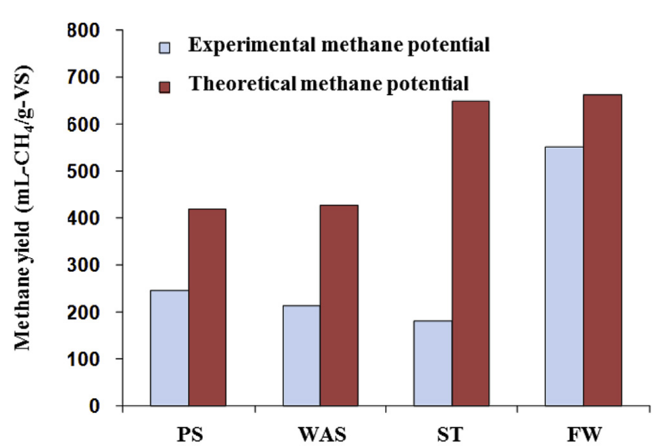

Fig. 2. Comparison of the experimental and theoretical methane production.