Waste Management 32 (2012) 400–403

Contents lists available at SciVerse ScienceDirect

Waste Management

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

Effect of leachate recirculation on mesophilic anaerobic digestion of food waste

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ARTICLE INFO

Article history:
Received 6 June 2011
Accepted 18 October 2011
Available online 15 November 2011

Keywords:
Anaerobic digestion
BMP
Organic waste
Leachate recycling
Water reuse

ABSTRACT

The effects of using untreated leachate for supplemental water addition and liquid recirculation on anaerobic digestion of food waste was evaluated by combining cyclic water recycle operations with batch mesophilic biochemical methane potential (BMP) assays. Cyclic BMP assays indicated that using an appropriate fraction of recycled leachate and fresh make up water can stimulate methanogenic activity and enhance biogas production. Conversely increasing the percentage of recycled leachate in the make up water eventually causes methanogenic inhibition and decrease in the rate of food waste stabilization. The decrease in activity is exacerbated as the number cycles increases. Inhibition is possibly attributed to accumulation and elevated concentrations of ammonia as well as other waste by products in the recycled leachate that inhibit methanogenesis.

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1. Introduction

Anaerobic digestion (AD) of organic waste for solids reduction and biogas production has become a reliable technology in recent years with a number of processes available. Variations in organic waste digestion are often characterized by the level of moisture used in the process. In general three categories of moisture and solid content exist: (a) low-solids or "wet" process with total solids (TS) less than 20%, (b) high-solids or "dry" process with TS greater than 20%, and (c) "semi-dry" process with TS of about 20%.

One of the main advantages claimed for the dry fermentation of organic waste is high volumetric organic loading rates. However there are a number of disadvantages: complete mixing of the waste is extremely difficult and in practice is not possible; accordingly the optimal performance and interactions of the various microbial consortia in the AD process is believed not to be achieved. Moreover, expensive pumps or augers with high maintenance requirements are needed to move the denser material caused by the higher TS concentration in the reactors (Nichols, 2004).

Wet digestion of organic waste can be performed in conventional reactor systems by incorporating organic waste dilution either by addition of fresh water and/or recycled leachate (De Laclos et al., 1997; Hamzavi et al., 1999) or by co-digestion with a more liquid waste if available (Bujoczek et al., 2002; Agdag and Sponza, 2007). In some cases tap water (Pavan et al., 2000) and in other cases (such as BTA) fresh make up water is mixed with untreated leachate. Using fresh water for dilution is not a sustainable or feasible option both environmentally and/or economically. Recycling of leachate is a good solution but there are restrictions and limits for water reuse. Accumulation of microbial waste products, recalcitrant components from treated organic waste as well as intermediate breakdown components such as ammonia in the leachate with its reuse can eventually produce environmental conditions that inhibit the microbial consortia responsible for digestion. Unfortunately information in the literature pertaining to water reuse for digestion of organic waste is very limited. Nordberg et al. (1992) reported on the use of water and leachate to dilute alfalfa silage to 6% TS for subsequent AD. While limited in its scope they reported that AD could not be sustained if 100% leachate was used for dilution. They indicated that the process failed due to the accumulation of inhibitory concentrations of ammonium in the system. Unfortunately they did not provide any information on water/leachate mixtures or potential operational scenarios to reduce fresh water consumption.

The objective of this study is to provide insight into the use of leachate for process make up water and investigate the impact of leachate/fresh water mixtures on the biogas production and stabilization of a wet food waste treatment process. The study uses batch biochemical methane potential (BMP) assays various water/leachate mixtures and multiple cycles to evaluate the impact on the digestion of food waste.

2. Methods

Initial base line BMP assays referred to as cycle 0 were performed at 35 ± 1 °C in 250 mL (150 ml working volume) Kimax bottles sealed with 45 mm screw caps and butyl rubber stoppers.

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doi:10.1016/j.wasman.2011.10.022

In order to determine variation in anaerobic biodegradability, each BMP assay contained 120 ml of chemical oxygen demand (COD) standardized sample and 30 ml of acclimated anaerobic biomass acclimated to organic waste over a period of 1 year. The biomass has characterized by Shahriari et al. (2011a), total COD (TCOD) and volatile solids (VS) were 10 and 12 g/L, respectively. Model food waste was first diluted with fresh water to TCOD concentrations of ~7 g/L (Shahriari et al., 2011a). Food waste contained cooked rice (18 wt%), cooked pasta (18 wt%), cabbage (11 wt%), carrot (11 wt%), apple (11 wt%), banana (11 wt%), corned ground beef (10 wt%) and dog food (10 wt%). An initial M/F ratio of approximately 0.75 g VS inoculum/g VS of food waste was used with equal parts of $NaHCO_3$ and $KHCO_3$ for an alkalinity of 4000–6000 mg/L as $CaCO_3$ to minimize pH effects. BMP bottles were placed on a rotary shaker (PhycroTherm, New Brunswick Scientific Co. Inc., NB, Canada) at 100 rpm and biogas production was monitored daily. After 15 days bottles were allowed to stand for 24 h which resulted in a relatively clarified leachate. Concentrations of VS and COD in the leachate recovered from the bottles for the next BMP assay were considered in all subsequent calculations. The biomass was then mixed with fresh food waste diluted with different combinations of leachate and fresh water: 0%, 30%, 60% and 100%. This procedure was repeated and BMP assay bottles were run through five sequential assay cycles designated C_1, C_2, C_3, C_4, and C_5, respectively. Reactors R_0, R_{30}, R_{60} and R_{100} refer to 0%, 30%, 60% and 100% recycled leachate, respectively.

Biogas production, pH, volatile fatty acids (VFA), COD and ammonium concentration were monitored to establish the number of times leachate can be recycled without decreasing the efficiency of the system. Analytical methods are the same as Shahriari et al. (2011b).

3. Results

Cycle 0 was run for 20 days and at the end all BMP assay bottles produced very similar amounts of biogas. Cycle 0 results suggests that all assays had a healthy anaerobic microbial consortia able to stabilize the food waste and subsequent assays could be compared to each other to evaluate the impact of leachate recycle. Cycle 0 results were also used to estimate the maximum biogas yield and set a practical assay time (15 days) for subsequent cycles that would tend to maximize biogas production from the food waste while minimizing biogas production carryover. While some biogas carryover does occur it was considered in all calculations and discussion. The cumulative biogas productions (CBPs) for cycles 1, 3, 4 and 5 are shown in Fig. 1a–d, respectively.

Fig. 1a shows that all four C_1 reactors were acclimated to the waste and there was no evidence of a lag phase indicating little advantage or disadvantage for any of the recycled water combinations. Around day 4, CBPs differences between R_0 and R_{100} was 30%, but by day 12 the difference decreased to 6% and by the end of the assay there was no statistical difference in the biogas production between any of the bottles. It is possible that with the higher proportion of leachate used for dilution in R_{60} and R_{100} resulted in a greater carryover of anaerobic biomass that stimulated biogas production early in the assay. It was also noted that use of leachate for dilution increased alkalinity of R_{30}, R_{60} and R_{100} proportionally (Table 1), which resulted in a proportional increase in the sample pH. The percentage of TCOD and soluble COD (SCOD) removal was not significantly different at the conclusion of the first run (Table 2), but concentrations of SCOD and VS in bottles with a higher proportion of recycled leachate were higher than the control (R_0)

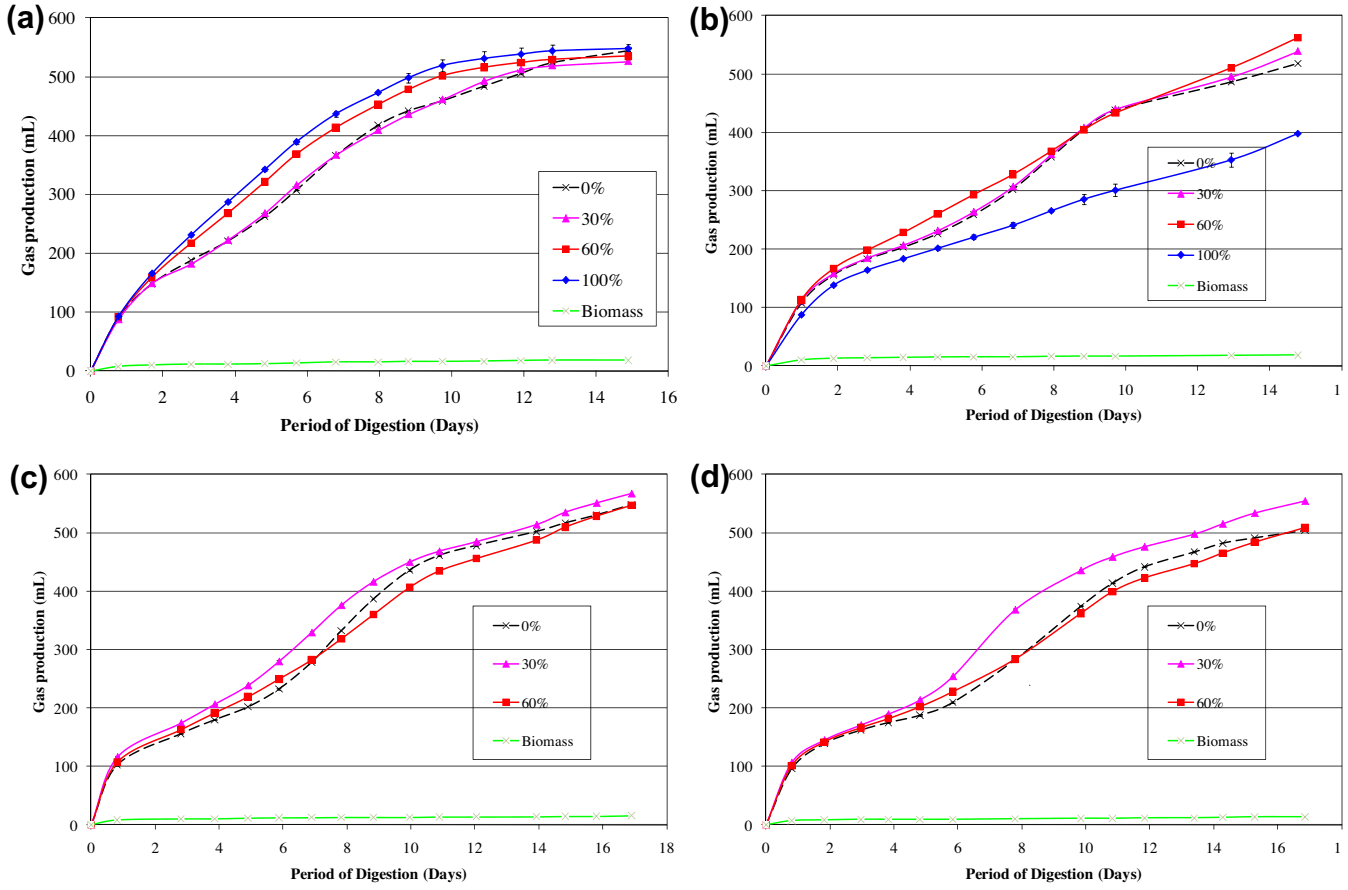

Fig. 1. CBP for (a) cycle 1, (b) cycle 3, (c) cycle 4, (d) cycle 5.

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