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Effect of different livestock dungs as inoculum on food waste anaerobic digestion and its kinetics

Kondusamy Dhamodharan *, Vikas Kumar, Ajay S. Kalamdhad

Department of Civil Engineering, Indian Institute of Technology Guwahati, Guwahati 781039, India

HIGHLIGHTS

- Different livestock dung as inoculum for methane production from food waste digestion.
- Cow dung followed by piggery dung added reactors produced higher methane production.
- Kinetic studies showed the higher R^2 and M value for cow dung added reactor.
- Highest volatile solids degradation was observed in cow dung added reactor.

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ABSTRACT

The aim of this study was to evaluate the effect of different livestock inoculums on the anaerobic digestion of food waste (FW). Five different livestock dungs i.e., poultry dung (PD), goat dung (GD), cow dung (CD), piggery dung (PGD) and rhinoceros dung (RD) were utilized as inoculums and their effects were valued in various food to microorganism (F/M) ratios in batch reactors. Different livestock dungs achieved higher methane production and volatile solids (VS) reduction in different F/M ratios such as PD, GD, CD, PGD and RD achieved at F/M ratio maintained at 1.5, 2, 2, 1.5 and 1.5, respectively. The results indicated that CD and PGD inoculum were more suitable for the anaerobic digestion of FW than other livestock dungs. Reactors inoculated with CD achieved higher methane production (227 mL g^{-1} VS degraded) and volatile solids degradation (54.58%) at F/M ratio maintained at 2.

1. Introduction

Food waste (FW) contains high percentage of degradable organic and moisture content that need to be treated distinctly from municipal solid waste (MSW). According to FAOUN (2011), one third of the food cultivated for consumption is wasted by human activities and storage problems and it's about 1.3 billion tons per year. FW has been used for various purposes such as cattle's feed, composting, anaerobic digestion (AD) (Chen et al., 2010) and landfilling (Zhang et al., 2007). FW used as a feed in anaerobic digestion might satisfy large amount of energy requirement. AD carried out with semisolids, proteins and lipids containing byproducts such as slaughterhouses, pharmaceutical, food, beverage industries, distilleries and municipal bio-wastes achieved the higher gas production from 0.3 to 1.3 L g^{-1} volatile solids (VS) added (Braun et al., 2003).

The FW characteristics has been varied from place to place, it has moisture content of 74–90%, volatile solids to total solids ratio (VS/TS) of 80–97% and carbon to nitrogen ratio (C/N) of 14.7–36.4 (Zhang et al., 2007). Because of its high moisture content, FW is more adoptable for anaerobic digestion when compared to conventional technologies, such as combustion, gasification and landfilling (Zhang et al., 2007). FW is one of the best substrate for AD because of its methane producing potentiality (Zhang et al., 2011). The utilization of FW with high VS content for anaerobic production can improve the quantity and quality of biogas.

The biochemical methane potential (BMP) assay is the best technique to find out the type of substrate, its concentration with inoculum and finally its bio-methane potential (Labatut, 2012). Batch digesters are easy for fabrication, maintenance and operation. It can be applicable for both industrial scale batch reactors and laboratory scale BMP's. Addition of inoculum is necessary in the batch reactors with the substrate to start reactions (Liu et al., 2009). The food to micro-organism (F/M) ratio is a prominent feature in all batch anaerobic digestion processes and also in the degradation of VS of the organic solid particles (Liu et al., 2009).

* Corresponding author. Tel.: +91 361 2582431; fax: +91 361 2582440.
E-mail address: Krishna.120187@gmail.com (K. Dhamodharan).

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Every anaerobe has its own capacity to degrade substrate for that optimum condition that has to be maintained by its buffering capacity which can only be maintained in specific F/M ratio.

Inoculums should contain active microbial communities, which are needed for anaerobic digestion. It varies according to the substrate, due to its amount of volatile fatty acids (VFA) and the ammonium produced during the hydrolysis of carbohydrates and proteins respectively to buffer the medium (Neves et al., 2004). The major process in a one-stage batch reactor is to prevent volatile fatty acids accumulation inside the "seed" particles beyond their assimilative methanogenic capacity. This accumulation can be prevented by increasing the amount of seed sludge, in order to overcome irreversible acidification during start-up (Veeken and Hamelers, 1999) (Kalyuzhnyi et al., 2000).

Another important parameter is the waste to inoculum ratio in high solid anaerobic digestion process carried out in batch mode. The use of a large inoculum amount in a batch process allows a successful digestion without pH adjustment, being a value of 1 (VS basis) used in the assessment of the BMP (Gunaseelan, 1997). However, in the case of more recalcitrant wastes, the rate of methane production in BMP assays was optimized by decreasing the waste to inoculum ratio to 0.5 g VS g^{-1} VS (Chynoweth et al., 1993). FW can be easily hydrolyzed, thus extra methane-producing bacteria are needed to utilize the VFA present at high concentration. Mostly inoculum is preferred in a small amount because of the endogenous biogas production possibility to affect the target results (Lesteur et al., 2010).

Studies were done on the basis of F/M ratio of different waste composition and different inoculums to attain the maximum gas production. The trials were done to find the proper F/M ratio for its higher growth (Braun et al., 2003; Gerardi, 2003; Lesteur et al., 2010). A suitable inoculum can increase the degradation rate, enhance biogas production, shorten the starting time, and more stable digestion process (Lettinga et al., 1996). Gu et al. (2014) has tried various inoculum sources for the anaerobic digestion of rice straw and reported that digested manure produced the highest biogas amount compared to all other manures. Therefore, main objective of this study is to find the best livestock inoculum to attain higher methane yield from the FW at different F/M ratio of five different livestock inoculum such as poultry dung (PD), goat dung (GD), cow dung (CD), piggery dung (PGD) and rhinoceros dung (RD).

2. Methods

2.1. Inoculum and substrate

In the present study five different livestock dung has been utilized as an inoculum such as PD, GD, CD, PGD and RD. Inoculum was obtained from different places near Amingoan locality, Guwahati, Assam, India. The FW was collected from hostels of Indian Institute of Technology Guwahati, Assam, India. The characteristics of FW varied daily according to hostel mess menu system. Therefore, the FW was segregated and mixed. The collected FW was ground using a wet grinder of 15 L capacity and the particle size was checked by passing through a 3 mm sieve.

2.2. Characterization of food waste

20 g of fresh FW was taken in a conical flask with 100 mL of Millipore water and mixed for 2 h at 150 rpm in a horizontal shaker and it was used to measure the pH. Moisture content (MC), total solids (TS), VS and soluble chemical oxygen demand (COD) were analyzed for the FW using standard protocols according to APHA (2005). The FW was dried at 105 °C in hot air oven until all the moisture is removed, then powdered and sieved in 0.2 mm sieve. The sieved powder was used for the total Kjeldahl nitrogen (TKN) analysis. TKN was measured after Kjeldahl nitrogen digestion using a digestion mixture of H_2SO_4, K_2SO_4, and $CuSO_4$ (Behera, 2006). VFA was analyzed using DiLalo and Albertson pH titration method (1961).

2.3. Inoculum activity test

The VS content of the inoculum was determined and its activity test was done. The anaerobic inoculum was taken in serum bottles such that there was 1.0 g VS content and acetic acid with mineral media added as the substrate. Acetic acid was fed at 0, 42 and 84 h and the experiment was conducted for 120 h. The organic loading rate was 1.0 g COD g^{-1} VS_{added}. The bottles were filled up to 500 mL using distilled water and purged with nitrogen gas to remove oxygen. The reactors were connected to aspirator bottles filled with 1.5 N NaOH. The quantification of methane produced is measured by volume of displaced NaOH from bottle filled with NaOH solution as shown in Fig. 1 (Esposito et al., 2012) and the gas production was continuously monitored for every 6 h.

2.4. Anaerobic batch setup

The batch reactor was prepared using 1 L reagent glass bottles with rubber corks for closing the bottles. In each inoculum study, 15 batch reactors were used, 12 reactors were fed with different amount of FW with essential macro and micro nutrients in addition of 100 g of inoculum. Rest of the 3 was used as a control with only 100 g of inoculum, macro and micro nutrients. Finally all the 15 reactors were made up to 500 mL using distilled water. The batch set up was shown in Fig. 1. The reactors were maintained at 30 °C. The amount of different livestock Inoculum and FW taken was based on optimization studies of F/M ratio. Four F/M ratio's 1.0, 1.5, 2.0, 2.5 based on VS basis was studied. On the basis of gas production and VS reduction, F/M 2.0 was observed as best at 30 °C. All the parameters were monitored properly such as temperature, pH, stirring intensity, physical and chemical characteristics of substrates, F/M ratio that affects BMP test (Browne and

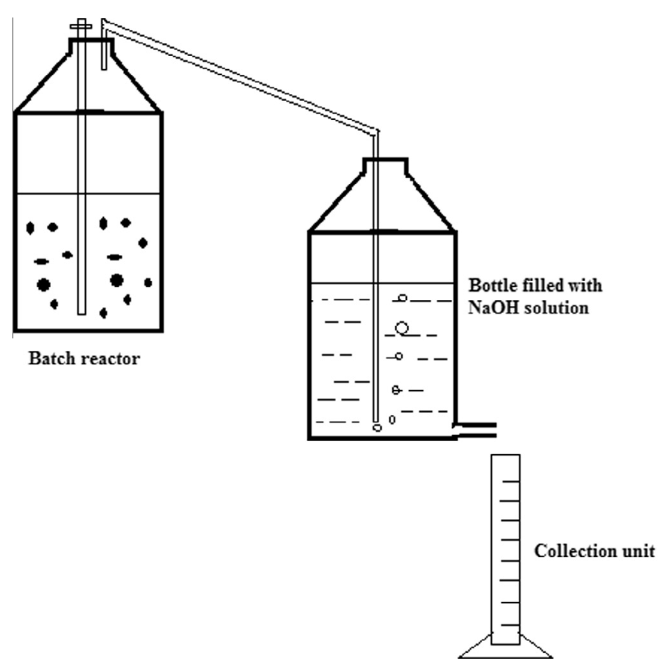

Fig. 1. Experimental setup for anaerobic batch studies.