



Performance and kinetic study of semi-dry thermophilic anaerobic digestion of organic fraction of municipal solid waste



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ABSTRACT

Anaerobic digestion (AD) of the organic fraction of municipal solid waste (OFMSW) is promoted as an energy source and waste disposal. In this study semi dry anaerobic digestion of organic solid wastes was conducted for 45 days in a lab-scale batch experiment for total solid concentration of 100 g/L for investigating the start-up performances under thermophilic condition (50 °C). The performance of the reactor was evaluated by measuring the daily biogas production and calculating the degradation of total solids and the total volatile solids. The biogas yield at the end of the digestion was 52.9 L/kg VS (volatile solid) for the total solid (TS) concentration of 100 g/L. About 66.7% of the volatile solid degradation was obtained during the digestion. A first order model based on the availability of substrate as the limiting factor was used to perform the kinetic studies of batch anaerobic digestion system. The value of reaction rate constant, k , obtained was 0.0249 day^{-1} .

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1. Introduction

Municipal solid waste (MSW) generation is significantly increasing in Indian urban areas and started creating enormous waste disposal problems in the recent past (Rao and Singh, 2004). In India, MSW management is the duty of the local municipalities. More than 90% of the municipal solid waste generated in India is dumped in an unsatisfactory way, what creates environmental hazards to water, air and land. In general the organic fraction of MSW in India is about 40–60% (Sharholly et al., 2008). In Kerala, around 70% of the waste is compostable organics enabling high level of recycling in the form of manure or fuel (Ajayakumar Varma, 2013a,b). The anaerobic digestion is an attractive option for energy generation from the putrescible fraction of MSW as well as for reducing the disposal problem. It has reduced environmental impact, especially with respect to the greenhouse effect and global warming (De Baere, 2000a).

Anaerobic digestion is a biological process wherein diverse group of microorganism convert the complex organic matter into a simple and stable end products in the absence of oxygen (de Baere, 2000b). AD of organic fraction of municipal solid waste is used in different regions worldwide to reduce the amount of material being landfilled, stabilize organic material before disposal in

order to reduce future environmental impacts from air and water emissions and recover energy (De Baere, 2006). Several research groups have developed anaerobic digestion processes using different organic substrates (Mata-Alvarez et al., 1992; Prema Viswanath et al., 1992; Forster-Carneiro et al., 2007; Gallert et al., 2003). The amenability of substrate for biogasification, gas yield–organic loading relationships, bioprocess conversion efficiency and process inhibitory parameters vary from substrate to substrate, and for different environmental and operating conditions such as pH, temperature, type and quality of substrate, mixing, and retention time. In this view, anaerobic digestion of solid waste is a process that is rapidly gaining to new advances especially in the area of dry anaerobic fermentation and has become a major focus of interest in waste management throughout the world.

One of the most important factors affecting anaerobic digestion of organic solid wastes is temperature (Hansen et al., 2008). Generally, anaerobic digestion process is operated under mesophilic or thermophilic condition, in which thermophilic digestion is reported more efficient method (Ahring, 1994; Mackie et al., 1998). Thermophilic digestion processes potentially allow higher loadings with reduced hydraulic retention times, higher conversion efficiencies and pathogen disinfection. Mesophilic anaerobic digestion on the other hand may be more stable and less at risk from ammonia nitrogen toxicity and requires less process heat. A wide variety of systems have been developed to anaerobically treat

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MSW (dry and wet digestion, continuous and batch process, mesophilic and thermophilic digestion and single stage and multi-stage digestion). The dry anaerobic digestion process has been regarded as an innovative waste recycling approach to treat high-solid-content bio-wastes (>15%) in its produced form (De Baere, 2000a; Gunaseelan, 1997; Pavan et al., 2000). According to Tchobanoglous low solids systems contain less than 10% TS, medium solids contain about 10–15%, and high solids system contain greater than 15% (Tchobanoglous et al., 1993). However, there is no established standard for the cut-off point. When compared with wet anaerobic digestion, dry anaerobic digestion is beneficial to its compact digester with high organic loading rate and its energetically effective performance (Pavan et al., 2000). This process also results in a lower outcome of leachate and easy handle of digested residues that can be further treated by composting process or be used as fertilizer (Brummeler, 2000). The purpose of this paper was to analyze the biomethanization process of OFMSW from nearby market of Thrissur, Kerala, India with a substrate concentration of 100 g/L (TS-11.2%); hence it is a medium solid or semidry system. The objectives of the present study were to investigate the performance of semi-dry anaerobic digestion of OFMSW in a single stage batch anaerobic reactor operated at thermophilic condition (50 °C) and to study the kinetics.

2. Methods

2.1. Experimental reactor

The experiments were carried on batch laboratory scale reactor with total capacity of 1 L. The reactor was made of borosilicate glass. The bottles were closed by rubber stoppers equipped with glass tubes for gas removal and for adjusting the pH. Schematic diagram of the experimental set up is shown in Fig. 1. The glass tube was dipped inside the slurry to avoid gas loss during the pH adjustments. The effective volume of the reactor was maintained at 800 ml. Biogas production from the reactors was monitored daily by water displacement method. The volume of water displaced from the bottle was equivalent to the volume of gas generated. The reactor was mixed manually by means of shaking and

swirling once in a day. The reactors was operated at thermophilic condition (50 °C) using a constant temperature water bath.

2.2. Inoculum

The inoculum used in this study was fresh cattle dung which contains all the required microbes essential for anaerobic digestion process. The pH, total solid and volatile solid of the inoculum were 6.5%, 25.2% and 85.9% respectively. The percentage of inoculum for acidogenic fermentation of the organic waste is approximately 30% of the working volume. The inoculum was collected from nearby farm and kept at 4 °C until used.

2.3. Feed stock preparation

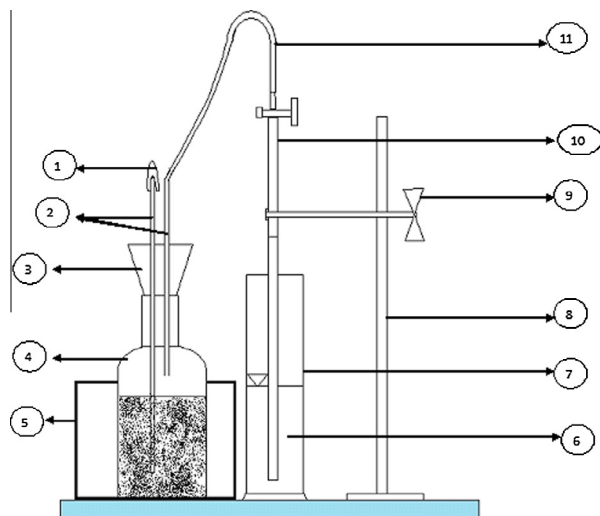
Fresh organic fractions of MSW and inoculum were used as feed to the bioreactor. Organic fraction of MSW consists of food waste, fruit waste, vegetable waste from nearby vegetable market and house hold. Composition of substrate were as follows vegetable waste (35%), fruits (25%), food waste (37%) and paper (3%) (Zeshan, 2012). The wastes were sorted and shredded, then mixed several times in laboratory and kept at 4 °C until used. The reactor was loaded with raw feed stock and inoculated with fresh cattle dung. Water was added to obtain the desired total solid concentration.

The characteristics of the substrate and feed were shown in the Table 1.

2.4. Experimental procedure

The study is programmed to evaluate the thermophilic digestion of OFMSW at the substrate concentrations of 100 g/L. As per the previous study of the author (Sajeena Beevi et al., 2014), the optimum substrate concentration obtained was 100 g/L. The substrate concentration was expressed as weight of solids/total volume of solids plus water, assuming that the density of the solids is approximately equal to the density of water. The substrate was mixed well with inoculums before loading to the reactor to initiate the digestion process. Separate inoculum acclimatization was not conducted. However, the reactor's temperature was started-up in mesophilic (34 °C) and then the temperature was gradually increased by 2 °C/day until the optimum thermophilic (50 °C) was reached (Chea Eliyan et al., 2007). This is used as a strategy to avoid the temperature shock load to microorganisms.

The reactor was fed with municipal garbage, tap water and cattle dung slurry (inoculum), used as the starter in the reactor. Liquid sample was drawn from each reactor periodically and analyzed for pH, volatile fatty acids (VFA), alkalinity, chemical oxygen demand (COD) and ammonia nitrogen (NH₄-N). The pH was measured every 2 days and it was maintained in the range of 6.5–7.5 using 6N sodium hydroxide solution as which is the optimum range for methanogens growth (Banks et al., 2008). Volatile fatty acids, alkalinity, chemical oxygen demand and ammonia nitrogen were analyzed every 5 days. Daily biogas production was measured by



1. Sealing Clip, 2. Glass tubes, 3. Rubber stopper, 4. Anaerobic digester, 5. Constant temperature water bath, 6. Saturated NaCl solution, 7. Graduated cylinder, 8. Stand, 9. Clamp, 10. Graduated burette, 11. Rubber hose

Fig. 1. Schematic diagram of experimental set up.

Table 1
Characteristics of the substrate and feed.

Parameter	OFMSW	Feed
pH	6.20	6.61
TS (%)	18.7	11.2
VS (%)	90.6	87.8
VFA (meq/L)	10.85	10.57
COD (mg/L)	36,936	38,018
TKN (g/L)	1.04	1.06
TOC (g/L)	20.49	22.5

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