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ScienceDirect

Bioresource Technology 99 (2008) 6994–7002

BIORESOURCE TECHNOLOGY

Influence of total solid and inoculum contents on performance of anaerobic reactors treating food waste

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Received 7 November 2007; received in revised form 7 January 2008; accepted 9 January 2008
Available online 4 March 2008

Abstract

The aim of this paper was to analyze the biomethanization process of food waste (FW) from a university campus restaurant in six reactors with three different total solid percentages (20%, 25% and 30% TS) and two different inoculum percentages (20–30% of mesophilic sludge). The experimental procedure was programmed to select the initial performance parameters (total solid and inoculum contents) in a lab-reactor with V: 1100 mL and, later, to validate the optimal parameters in a lab-scale batch reactor with V: 5000 mL. The best performance for food waste biodegradation and methane generation was the reactor with 20% of total solid and 30% of inoculum: give rise to an acclimation stage with acidogenic/acetogenic activity between 20 and 60 days and methane yield of 0.49 L CH4/g VS. Also, lab-scale batch reactor (V: 5000 mL) exhibit the classical waste decomposition pattern and the process was completed with high values of methane yield (0.22 L CH_4/g VS). Finally, a protocol was proposed to enhance the start-up phase for dry thermophilic anaerobic digestion of food waste.

Keywords: Food waste; Thermophilic digestion; Dry conditions; Inoculum source; Methane

1. Introduction

Questions related to the final disposal and treatment of municipal solid waste (MSW) constitutes one of the most serious problems of contemporary societies. The volume of waste has increased very quickly (approximately 24 millions of metric ton of MSW has been generated in Spain last year, with 40–45% of organic fraction (OFMSW) (INE, 2006). The need for processes in the field of conservation of resources has become more than clear in recent years.

Biological treatment already demonstrated that is one of the most advantageous methods for maximizing recycle and recovering its components. Anaerobic digestion of sorted organic fraction of municipal solid wastes, especially food wastes, is the utmost attractive alternative and the most cost-effective technology (Bouallagui et al., 2004; Chynoweth et al., 2002; Mata-Alvarez et al., 1992; Rao and Singh, 2004; Forster-Carneiro et al., 2004,2006; Bolzonella et al., 2003; Bonzonella et al., 2005). Generally, the overall anaerobic organic solid digestion stages can be roughly classified into hydrolysis, acidogenesis, acetogenesis and methanogenesis (Chynoweth et al., 2002), each metabolic stage is functioned by a series of microorganisms. From these four stages, hydrolysis, which includes various enzyme functions involving carbon, nitrogen and phosphorus cycles, is the most rates limiting stage (Christ et al., 2000).

One of the most important factors affecting anaerobic digestion of organic solid waste is temperature (Ahring, 1992). Generally, anaerobic digestion process is operated under mesophilic or thermophilic condition, in which thermophilic digestion is reported to be the more efficient method (De Baere, 2000; De la Rubia et al., 2005). In

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doi:10.1016/j.biortech.2008.01.018

addition, it is usually difficult to maintain an appropriate circumstance to each microorganism and the problems caused by imbalance of production and consumption of intermediary products often occur in practical anaerobic process, especially during the start-up period. However, the anaerobic digestion process can restore its efficiency from imbalance circumstances, such as the lower pH condition owning to the accumulation of volatile fatty acids (VFAs) and the consumption of alkalinity.

Conventional anaerobic digesters require feed material with total solids content below 10%. Modern systems can deal with >20% total solids content in the feed. Anaerobic digestion in semi-dry (Pavan et al., 1994) (total solids content of 10–20%) and dry conditions is considered capable of producing an inert bio-solid product with higher methane productivity (Mata-Alvarez et al., 2000; De Baere, 2000). Compared with wet anaerobic digestion, dry anaerobic digestion has several advantages, such as compact digester with high organic loading rate and energetically effective performance (Pavan et al., 2000). This process also results in a lower production of leachate and easier handle of digested residues that can be further treated by composting process or be used as fertilizer (Ten Brummeler, 2000).

Also, it is crucial the selection of waste/inoculum ratio as well as the assessment of anaerobic biodegradability of solid wastes (Lopes et al., 2004). The percentage of inoculation for acidogenic fermentation of organic urban wastes is approximately 30% weight/weight (w/w) (Sans et al., 1995). In case of the anaerobic biodegradability of solid waste, the use of a highly active anaerobic inoculum or animal inoculum waste will reduce significantly the experimental time, or reduce the amount of inoculum required in full scale batch digesters, and consequently, the corresponding digester volume (Obaja et al., 2003). In dry-thermophilic digestion, the inoculum source and the total solid percentage selected are responsible to accomplish rapid onset of a balanced microbial population. Also, the start up phase is considered the most critical step in the operation of anaerobic digesters.

So far, few reports can be found on the study of dry anaerobic digestion of food wastes, and the explanation of solid wastes anaerobic digestion performance in the start-up period from the point of view of the total solids content and proportion of the inoculum used is not extensively investigated yet.

Hence, the aims of this study were to investigate the start-up performance of dry anaerobic digestion of food waste and sewage sludge under thermophilic conditions in six completely mixed one phase anaerobic digester in a lab-scale experimental process. Hence, the experimental procedure is programming to study: (a) the influence of initial total solid contents in the digester, (b) the influence of the inoculum percentages in the treatment process of fermentable food waste and (c) to propose a protocol to enhance the start-up phase for dry-thermophilic anaerobic digestion of food waste.

2. Methods

2.1. Reactors used

2.1.1. Batch reactors

The system was conformed by six reactors. The assays were carried out in batch reactors with an internal diameter of 10.45 cm and a total height of 32.15 cm. The total volume capacity was 1.1 L (laboratory scale) with net volume of 0.7 L. Each reactor had independent agitation system and electric control. The main axis contained 14 horizontal and cylindrical crosses willing to different heights, and it rotated in alternate senses by means of a cylindrical temporize, capable to maintain uniform moisture content and to redistribute soluble substrate and bacteria. The operational temperature was 55 °C, controlled and monitored by means of thermostatic bath model SELECT CORP.

The conditions selected were: dry anaerobic digestion (with 20%, 25% and 30% TS), and two different proportions between FW/inoculum loaded in the reactors (80/20 and 70/30) at single phase thermophilic (55 °C) condition.

2.1.2. Lab-scale stirred tank reactor (STR20-30)

The assays were carried on batch laboratory scale reactor with total capacity of 5.0 L (STR20-30). The cover of each reactor incorporated three separate ports for different functions: pH control; mechanical agitation system; measurement of the biogas composition and production (use of the Tedlar bag, 40 L); a temperature control by means of recirculation of the internal liquid; taking liquid samples. This configuration allowed the systems to operate under high-solids conditions without any hindrance to the leachate circulation and without the need for maintenance of mechanical devices. It is a continuous flow reactor based on the fundamental of attainment a good contact between the biomass and the effluent for the development of a balanced process and with some appropriate yields. The experiments were performed under thermophilic conditions (55 °C) and dry (20% total solid) conditions, with 30% of inoculation.

2.2. Characteristic of food waste and inoculum

The study is programmed to evaluate the thermophilic anaerobic digestion of FW at three different initial concentrations of total solids in the process, 20% TS, 25% TS and 30% TS and two different initial inoculum percentages (20% and 30%).

Table 1 resumes the characteristics and composition of each reactor: (R20-20) 20%TS_20%SLUDGE; (R20-30) 20%TS_30%SLUDGE; (R25-20) 25%TS_20%SLUDGE; (R25-30) 25%TS_30%SLUDGE; (R30-20) 30%TS_20%SLUDGE; (R30-30) 30%TS_30%SLUDGE.

The unsorted and fresh organic fraction of municipal solid waste and inoculum source selected for use in discontinuous reactor were as follows: