Bioresource Technology 182 (2015) 239–244

Contents lists available at ScienceDirect

Bioresource Technology

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

Multi-phased anaerobic baffled reactor treating food waste

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HIGHLIGHTS

- Study on isolation of different phases of an anaerobic digestion process.
- First reference for biogas yield from food waste using anaerobic baffled reactor.
- Effluent quality shows this as an efficient treatment for food waste.

ARTICLE INFO

Article history:
Received 12 November 2014
Received in revised form 26 January 2015
Accepted 28 January 2015
Available online 4 February 2015

Keywords:
Food waste
Anaerobic baffled reactor
Phase separation
Biogas
Anaerobic digestion

ABSTRACT

This study was conducted to identify the performance of a multi-phased anaerobic baffled reactor (MP-ABR) with food waste (FW) as the substrate for biogas production and thereby to promote an efficient energy recovery and treatment method for the wastes with high organic solid content through phase separation. A four-chambered ABR was operated at an HRT of 30 days with an OLR of 0.5–1.0 g-VS/L d for a period of 175 days at 35 ± 1 °C. Consistent overall removal efficiencies of 85.3% (COD_t), 94.5% (COD_s), 89.6% (VFA) and 86.4% (VS) were observed throughout the experiment displaying a great potential to treat FW. Biogas generated was 215.57 mL/g-$VS_{removed}$ d. Phase separation was observed and supported by the COD and VFA trends, and an efficient recovery of bioenergy from FW was achieved.

1. Introduction

Approximately one third of the food produced in the world for human consumption every year, which is approximately 1.3 billion tonnes, gets wasted globally. The wastage of food can be attributed into loss of resources in food production, and the unnecessary production of greenhouse gas emissions (FAO, 2013). In a world with depleting energy resources, the amount of food waste (FW) generated everyday needs an utmost use to move towards sustainable development. FW, rich in organic acids, constitutes an ideal source for bioenergy recovery. On the other hand, FW disposal has been a growing problem in highly populated cities such as Singapore comprising 21.1% of the municipal solid waste that is disposed (NEA, 2013). Wang et al. (2003) reported that FW has been main source of odour and leachate in collection and transportation of municipal solid waste due to their high volatile components and moisture content, and has been causing significant environmental impact.

Anaerobic digestion (AD), a biological conversion of organic matter into methane, carbon dioxide, inorganic nutrients and humus-like matter, appears to be the most promising method for FW treatment (Liu et al., 2008). As compared to the aerobic method, the use of anaerobic processes for the waste streams provides greater economic and environmental benefits and advantages (Mohan and Bindhu, 2008). AD technology is a well known method for waste utilization, and various configurations of the reactor type have been developed thus far. The most prominent and simple design is the single stage process and it has been widely used in various applications. However, its low efficiency has been highlighted (Ke et al., 2005). Besides single stage system, two-phase reactors have gained attraction and relevant research works has been reviewed by Ke et al. (2005). The two-phase

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http://dx.doi.org/10.1016/j.biortech.2015.01.117
0960-8524/

system attempts to separate the acidogenic and methanogenic phases of AD process. The goal is to improve the performance of the reactor by allowing enough buffering capacity and space for respective microbial communities to flourish under suitable conditions. Adding on to this, a two-phase hybrid anaerobic solid–liquid system (HASL) by Wang et al. (2002, 2003) and Liu et al. (2008), was studied in detail for FW digestion and has shown promising results. Apart from these reactor types, an up-flow anaerobic sludge blanket process elaborately reviewed by Chong et al. (2012) is extensively applied for wastewater treatment with relatively high removal efficiency at short hydraulic retention times (HRTs), but is also considered not suitable for wastes with high solid content such as municipal FW (Tawfik et al., 2011b).

Improving the soluble component removal efficiency, longer biomass retention, enhanced bacterial activity and high rate of contact between the cells and the substrate are important attributes for an efficient anaerobic digestion system (Grobicki and Stuckey, 1991). The multi-phased anaerobic baffled reactor (MP-ABR) possess a great potential in improving the afore mentioned criterion, and also provides better resilience to hydraulic and organic shock loadings (Barber and Stuckey, 1999). The reactor design allows adequate space for the microbial communities to sustain without interferences. The significant advantage of the reactor type is its ability to separate different phases of the AD process longitudinally, allowing the reactor to behave as a 'phase separated' system, which may offer the best choice for high efficiency removal rates (Mohan and Bindhu, 2008). FW, which possesses about 75% moisture content and 24% volatile solids (VS) (97% VS/total solids (TS) ratio), qualifies as a perfect substrate type for this type of reactor design due to its high solids retention capacity.

Although extensive studies have been conducted on anaerobic baffled reactor (ABR) as mentioned in the review by Barber and Stuckey (1999), little is known about biogas production from FW, except for the work of Tawfik et al. (2011a,b), using a laboratory scale five-chambered ABR for biological hydrogen production from diluted kitchen waste. The main objective of this study was to assess the performance of the MP-ABR system treating FW for biogas production, to isolate the different phases of the AD process and to promote an efficient energy recovery and treatment method for the wastes with high organic content. Various performance indicators including chemical oxygen demand (COD), volatile fatty acid (VFA), TS and VS were also investigated to evaluate the efficiency of reactor performance.

2. Methods

2.1. Feed and inocula characteristics

FW was collected from a canteen inside the university campus, which mainly composed of rice, noodles, meat, vegetables and condiments. After removing the bones and inorganic materials, the waste was homogenized using a kitchen blender to disintegrate the particulate organics into size < 2 mm. The feed was diluted with tap water according to the influent organic loading rate (OLR) and flow rate before being fed to the reactor. The characteristics of the feed were pH (5.36 ± 0.82); total COD (COD_t) (17.31 ± 5.05 g/L); soluble COD (COD_s) (4.98 ± 2.03 g/L); VS (14.78 g/L); total VFA (VFA) (1.214 g-COD/L) on an average. Inoculum was obtained from a local wastewater treatment plant (Ulu Pandan Wastewater Treatment Plant) that uses AD technology for sewage sludge treatment. The reactor was filled up with 70% of the seed sludge and 30% with tap water. The seed sludge contained TS of 1.77 g/kg, of which VS was 70%. The pH and alkalinity were about 6.9 and 1916 mg-$CaCO_3$/L respectively.

2.2. MP-ABR system

A rectangular acrylic container with internal vertical baffles hanging and standing alternately embodied the basic design of the reactor (Fig. 1). To allow the number of compartments and width of each to be adjustable, the baffles were designed to be movable. The design of the reactor was slightly different from the conventional ABR. As the FW contain very high solid content, the widths of the downflow segment were increased for this study to allow the solids to flow over smoothly without any blockage. The reactor was operated in two operational periods with a modification to the reactor configuration in the second period. A four compartment (N1, N2, N3 and N4) reactor model was selected to isolate the different phases of the AD process, which is also considered to perform better (Boopathy, 1998). The individual working volumes were 10.7 L each for the first three and 21.4 L for the last compartment during the first period of operation. Subsequently, the volumes of N3 and N4 were adjusted to be 16.05 L each in

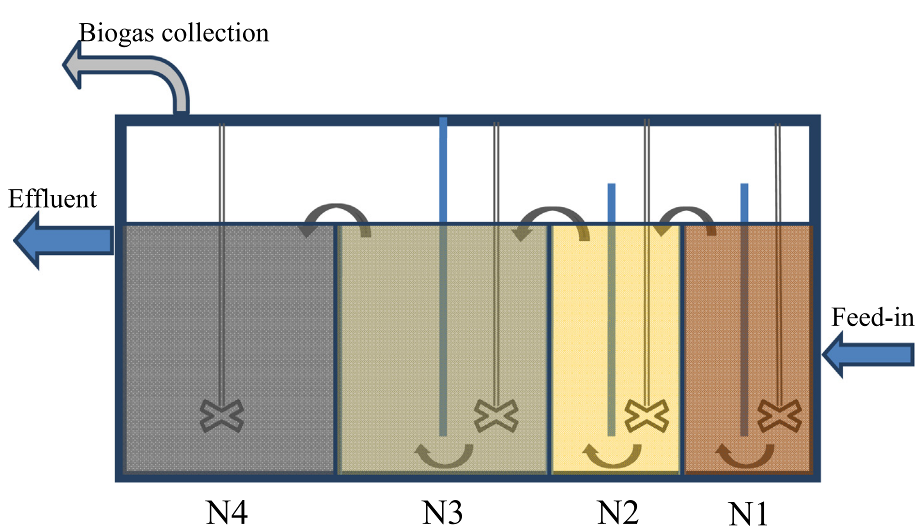

Fig. 1. Flow scheme of the MP-ABR with the direction of sludge flow.