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Destabilization of an anaerobic reactor by wash-out episode: Effect on the biomethanization performance

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HIGHLIGHTS

- ▶ The effects of a transient wash-out episode on biomethanization performance were investigated.
- ▶ The acetate-utilizing methanogenic *archaea* are washed-out at 10-day SRT.
- ▶ An important accumulation of acetic acid is observed at 10-day SRT.
- ▶ The methane production drops near to zero at 10-day SRT.
- ▶ The biomethanization performance is restored when 15-day SRT is imposed.

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ABSTRACT

In anaerobic processes, the volatile fatty acid profile (VFA) is closely related with the methanogenic activity and, hence, the knowledge of the relationship between these two parameters (VFA evolution and methane production) is fundamental to characterize the behavior of anaerobic reactors for treatment of organic wastes.

In this study, a destabilization episode in a 5-l continuously stirred tank reactor (CSTR) at laboratory scale was induced to evaluate the influence of a wash-out episode in the biomethanization performance/efficiency (at thermophilic-dry conditions) of the organic fraction of municipal solid waste coming from a full-scale mechanical biological treatment (MBT) plant.

To do this, from a stable reactor operating at 15-day solids retention time (SRT), the organic loading rate was increased in two stages: firstly from 2.93 gVS/L_R day^{-1} (15-day SRT) to 3.66 gVS/L_R day^{-1} (12-day SRT) during 36 days and secondly from 3.66 gVS/L_R day^{-1} to 4.39 gVS/L_R day^{-1} (10-day SRT) along 30 days.

The results indicate that acetate-utilizing methanogenic *archaea* are practically washed-out during the destabilization episode at 10-day SRT. Thus, the VFA and methane profiles indicate that this group is the first population of microorganisms unbalanced on the system, since the methane production drops rapidly near to zero and an important accumulation of VFA (acetic acid mainly), from 314 mg/l to 552 mg/l (increment of 75.8%), was observed.

Finally, after the destabilization episode at 10-day SRT and in order to estimate the capacity of the system to recover the biomethanization performance, the SRT was increased from 10 to 15 days and then it was gradually decreased in two stages again: first from 15 to 13 days and finally from 13 to 12 days (initial value of SRT tested in this study). The results have shown that when the same SRT (12 days) is imposed to the reactor twice and a destabilization episode by wash-out occurs between these periods, it is not possible a full recovery of the biomethanization performance.

1. Introduction

The anaerobic digestion (AD) has been commonly employed as a suitable strategy for managing organic wastes such as the organic fraction of municipal solid wastes (OFMSWs) [1]. This process presents many advantages as low net power consumption and biogas generation mainly with high content in methane and/or hydrogen. With regard to the latter aspect, the AD may be optimized to generate biogas rich in methane by biomethanation process or hydrogen through *Dark Fermentation* (acidogenic fermentation). It is very important to highlight that nowadays the hydrogen is considered a promising energetic vector of the future and in this case both gases

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could be recognized as renewable energy sources. However, the most important disadvantage of AD is that hydrolysis rate is low when organic wastes with high particle size are treated. This fact is more marked at lower temperature regimes, for example at mesophilic range (35 °C) [2].

To avoid this drawback, different options have been studied in the literature. Thermochemical and biological pretreatments may be used to pre-hydrolyze the wastes before the anaerobic biodegradation in order to increase the overall rate and yields of the process [3–6]. Other option is to increase the operational temperature of the anaerobic digesters from mesophilic to thermophilic regime (55 °C).

In this sense, the thermophilic AD has gained much attention in the last years, however, at this condition the volatile fatty acids (VFAs) generation is higher with regard to the mesophilic range and, therefore, inhibitory effects by acids accumulation may decrease the stability of the process and the biomethanization performance. This destabilization of the process may be induced if the system is operated at low solid retention times (SRTs) since overloading episodes or washing-out phenomena could take place.

In the literature, the VFA profile and the biogas (or methane) production are considered two of the most important parameters to check and control AD processes and they are closely related with the organic loading rate (OLR), which is inversely proportional to SRT in the case of solid-phase anaerobic systems. Thus, when SRT is diminished, the OLR is increased and the overloading of the system may take place, leading to a diminishing in biogas and methane generation and an increase in VFA concentration. In fact, many system failures by overloading or washed-out have been reported at full-scale biomethanization plants [7].

As it was stated previously, the VFA profile may be considered as a suitable indicator of the biomethanization performance, specifically of the acetogenic and methanogenic activities. Among the main VFAs, acetic and butyric acids are more likely to be transformed into methane, while contribution of acetic acid is more than 70% [8].

With respect to the propionic acid, it must be noted that at thermophilic regime of temperature its accumulation is critical for the stability of AD processes. Indeed, its conversion to other intermediates is very difficult since low hydrogen partial pressure is required and for this reason it is considered one of the most toxic acids in anaerobic systems [9]. In fact, propionic concentrations higher than 1–2 g/l may inhibit methanogenic *archaea* and, however, acetic and butyric acid concentrations higher than 10 g/l are tolerated by this population [10]. Furthermore, when organic wastes with high particle size are anaerobically treated, the propionic acid accumulation predominates over the others VFA [11].

Thus, the first main goal of this work is to characterize the behavior of an anaerobic digester, operated at thermophilic-dry conditions, by means of the VFA (acetic and propionic acids mainly) and biogas profiles in order to study how the biomethanization performance is affected when a destabilization episode by wash-out is induced. This will provide relevant information to operators of plants to prevent this type of failures on anaerobic systems.

The second main objective of this research is to study the viability of a full or partial recovery of the biomethanization performance, after the wash-out episode, in order to define a possible strategy to restore the efficiency of the treatment. This information may be also very useful for operators of full-scale biomethanization plants to know how to correct these failures of destabilization by wash-out of the main microbial populations.

2. Materials and methods

2.1. Experimental equipment

A 5-l continuous stirred tank reactor (CSTR) without recycling of biomass (4.5 l working volume) was employed (Fig. 1). The thermophilic regime of temperature (55 °C) was maintained by means of a thermostatic 7-l circulating water bath. For effluent discharge, the reactor was equipped with a ball valve fitted to the button. At the top, the digester had several input/output ports: a stirring paddle (stirring rate of 13 rpm), a biogas outlet and an inlet for feeding. The pH was controlled by mean of a proportional–integral–derivative controller adding H_3PO_4 and NaOH solutions.

2.2. Feedstock

Organic fraction of municipal solid waste coming from a full-scale plant ($OFMSW_{FSP}$), with an average particle size of 30 mm,

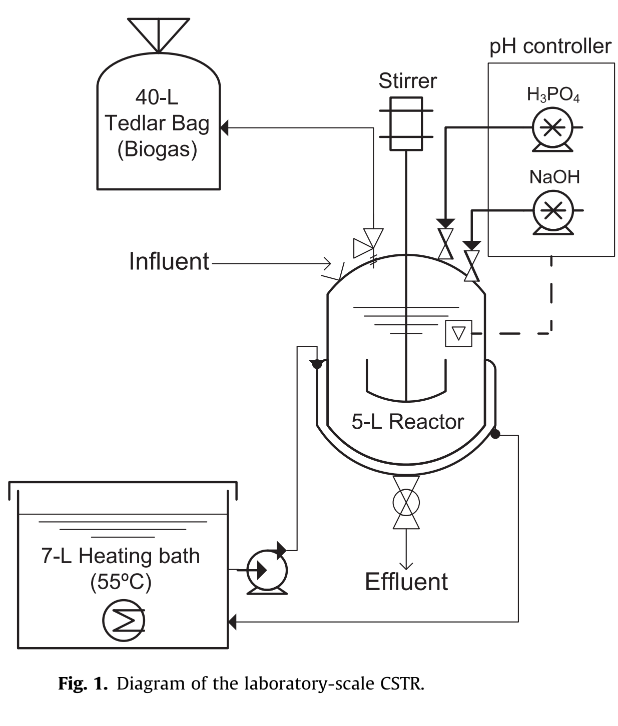

Fig. 1. Diagram of the laboratory-scale CSTR.