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Energy efficiency: Importance of indigenous microorganisms contained in the municipal solid wastes

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ABSTRACT

2016 was an extraordinary year for renewable energy, as it had the largest global capacity additions seen to date. However, challenges remain, particularly beyond the power sector. Overcoming these challenges means pursuing goals on development and optimization of strategies focused in causing an increase in bioenergy usage. Considering the seriousness of the challenge this paper has been developed. In the present study, indigenous microorganisms gathered from municipal solid waste will be analysed at to find out the role such organisms have on an anaerobic digester and its performance, with the aim of producing biogas in order for it to be used as electricity or treated to produce high quality fuel. The presence of such anaerobic microbiota can help avoid the two most tragic situations of an anaerobic digestion plant: overloading and washing out. The information of the present paper would have to be considered in future researchers about pre-treatments because most novelty studies are focused on hard pre-treatment to destroy microorganisms in the substrate (to increase the biogas production). In the present paper, it is underlined that the destruction of the microbiota in the substrate could produce adverse effects in the performance in the reactor.

1. Introduction

In 2007, Europe set a goal to have 20% of energy used being renewable by 2020, and 27% by 2030 (2009). According to Renewable Global Status Report (2016), 2015 was a year of great commitment to renewable energy worldwide. Renewables were at the top of high-profile policy agendas throughout the year, which culminated with the Paris Agreement. In wake of the Paris Agreement, governments have announced their support to foster the development of renewable energy and adopt energy efficiency measures.

In 2014, renewable energies accounted for almost 16% of the European Union's (EU) energy consumption; however, this upward trend should not be taken for granted.

Anaerobic digestion (AD) represents an opportunity to decrease environmental pollution while simultaneously, providing biogas (H_2 and CH_4) and organic fertiliser. AD from biowastes is widely popular (Contents, 2011; Feng et al., 2017; Wang et al., 2015, 2012; Xing et al., 2014; Tyagi et al., 2014) and it is characterized by four steps: hydrolysis, acidogenesis, acetogenesis and methanogenesis. In the first two steps, hydrolysis and acidification take place by hydrolytic-acidogenic bacteria (HAB), and intermediate products such as volatile fatty acids (VFA), hydrogen (H_2) and carbon dioxide (CO_2) are generated. In the third step, VFA are transformed into acetate, H_2 and CO_2 by acetogenic bacteria. In the fourth step, acetate-utilizing methanogens (AUM) and hydrogen-utilizing methanogens (HUM) are capable of converting acetate or H_2 and CO_2 to methane (CH_4), respectively.

Most current sources that study anaerobic digestion are heavily focused on the biogas increase (Ennouri et al., 2016; Kong et al., 2016), while very few reports discuss in detail how the changes influence the microbial populations and stability of the AD system. Some papers have pointed that links between the microbial composition and VFA profiles, as well as the change in organic loading rate (OLR) or hydraulic retention time (HRT) induce changes in the microbial activity community, and structure (abundance and dynamics) and those decreases in biogas were linked to decrease in both bacterial and methanogens biomass or activity (Ferguson et al., 2016; Zahedi et al., 2014, 2013a, 2013b, 2013c).

The present paper emphasizes the importance of the presence of anaerobic microbiota in the affluent of reactor and how it would help avoid the two most tragic situations of an anaerobic digestion plant: overloading and washing out. On the one hand, overload means loading an excessive amount of substrate in the reactor. Overloading in a reactor causes an intense organic matter solubilization and organic matter accumulation in the reactor due to kinetic decoupling between hydrolysis and methanogenenic activities (Chen et al., 2012; Gianico et al., 2015). On the other hand,

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washing out of microorganisms in a reactor is a phenomenon that could be developed in anaerobic digester when the microbiota or solid retention time is very low. The most common anaerobic reactor is a continuously stirred tank reactor (CSTR) without recycling of solids. In these systems the solid retention time (SRT) and the hydraulic retention time (HRT) are equal.

Low HRT could produce a washing out of the microorganisms, as part of the microbiota could get washed down with the effluent, before being able to reach a high enough concentration to avoid the gradual diminishment of the population with every cycle. This happens when the HRT is lower than the microbial duplication time, and it causes an inhibition of the anaerobic process. This study gives important information about some considerations to be taken into account in the anaerobic digestion of municipal solid waste, in order to optimize its management (reducing cost and space: lower HRT in a reactor means economical savings and low size of the reactors), as well as produce more bioenergy. This leads to: energy efficiency; less energy or resources to provide the same service.

The present paper provides useful information to achieve in-depth knowledge of the strategies to improve the bioenergy and energy efficiency in the anaerobic digestion.

2. Materials and methods

2.1. Reactors

Two laboratory-scale continuously stirred tank reactors (hydrogen reactor and methane reactor) were employed (Fig. 1).

Hydrogen reactor (HR): In this system, hydrolysis and acidogenesis procedures are carried out (dark-fermentation) and hydrogen is produced by hydrolytic-acidogenic bacteria (HAB).

Methane reactor (MR): In this reactor, where methane is produced, hydrolysis, acidogenesis, acetogenesis and methanogenesis take place in the same reactor.

Both reactors had 5 L working volume, heated by SELECTA baths (T = 55 °C) for optimal metabolic function. They also both had a biogas outlet that led to 40 L Tedlar bags for gas collection, a feed inlet that was fed semi-continuously, once per day, and an opening for the IKA EUROSTAR Power Control visc-P4 overhead stirrers that are coupled to a stainless steel blade with scrapers, for a homgenisation of waste at the speed of 23 rpm. The bottom of the reactors contain discharge valves, which are used for sampling. Tested conditions (the hydraulic retention times; HRTs) are shown in Table 1.

Table 1
Condition tested (the hydraulic retention times; HRT) in each system.

Reactor	HRT (d)				
HR	1.5	1	0.75	0.5	0.25
MR	10	6.6	4.4	3	2

2.2. Substrate

The tested substrate was municipal solid wastes (MSW) from the 30 mm trommel of the municipal solid waste treatment plant in Cadiz, Spain. The MSW was stored in 25 kg drums at −4 °C to avoid AD by the microorganisms found in the solid waste itself (Zahedi et al., 2013c). The total solid (TS) concentration of the feed first reactor was adjusted to 20% (which is characteristic of dry AD) by adding tap water. The medium values of pH, VFA, volatile solid and microbial content were 5.5 ± 0.7, 2.2 ± 1.0, 70 ± 15 g/kg and 90 ± 30 × 10^7 cells/ml.

2.3. Experimental procedure

Production of gas was (volume and composition) was measured according to Zahedi et al. (2013a). It was realized using a gas flow meter (Ritter Company, drum-type wet-test volumetric gas meters), and the composition of the produced gas was determined by gas chromatography separation (SHIMADZU GC-2010). The H_2, CH_4, CO_2, O_2 and N_2 were analysed by means of a thermal conductivity detector (TCD) using a Supelco Carboxen 1010 Plot column. A Supelco Supel-Q Plot column and a flame photometric detector (FPD) were used for H_2S. Samples were taken using a 1 ml Dynatech Gastight gas syringe under the following operating conditions: split = 100; constant pressure in the injection port (70 kPa); 2 min at 40 °C; ramped at 40 °C/min until 200 °C; 1.5 min at 200 °C; detector temperature: 250 °C; injector temperature: 200 °C.

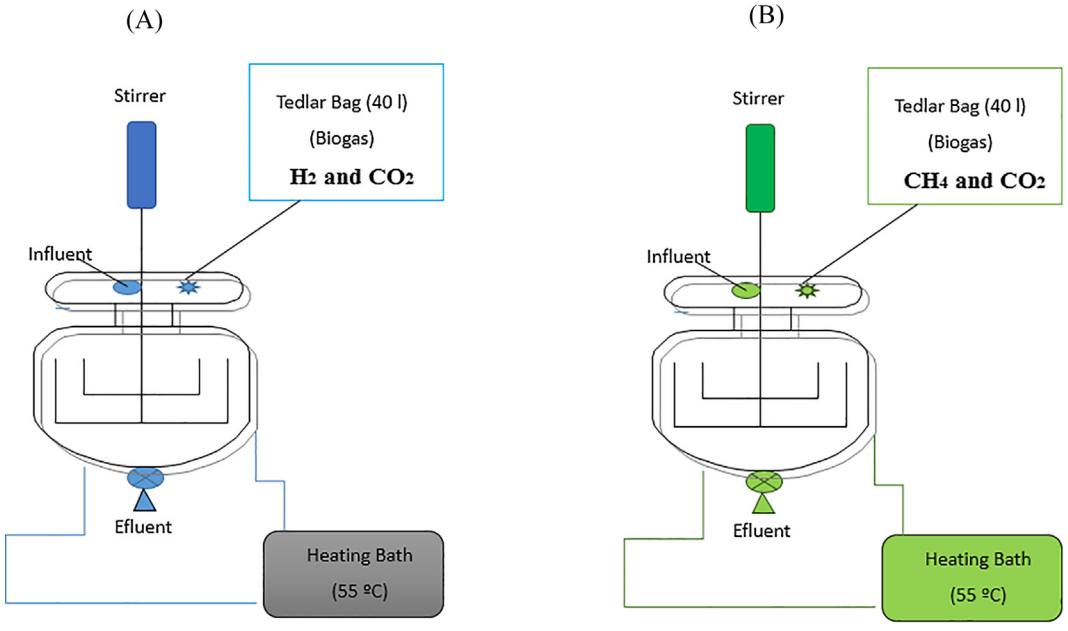

Fig. 1. Schematic diagram of the reactors: (A) Hydrogen reactor and (B) Methane reactor.