Evaluation of operational stability of anaerobic sludge digester in terms of volatile fatty acids dynamics.

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Abstract
This study aimed evaluate the operational stability of a mesophilic anaerobic sludge digester through the dynamics of production and consumption of volatile fatty acids (VFA) besides degradation of the organic fraction and methane production in order to prepare the digester for further temperature conversion. The results belong to an operational period with gradually decrease of the hydraulic retention time - HRT (from 15 to 7 days) and another with constant HRT (7 days). The removal of organics of the sludge was higher for constant HRT than for others and resulted in lower concentration of acetic acid. Furthermore it was achieved higher concentration of methane in biogas. The highest methane (> 53% CH4) occurred when the acetic acid, its main precursor, was minimal (less than 650 $mg \cdot L^{-1}$). Thus the constant 7 days HRT was the most favorable condition tested which provides more stability for the process, essential condition given the future change on operating temperature.

Keywords
Operational stability, anaerobic sludge digestion, temperature conversion, volatile fatty acids, methane.

INTRODUCTION

Anaerobic digestion (AD) of sludge from wastewater treatment plants (WWTP) is the most important process for the stabilization of volatile solids and a way for energy recovery as methane gas. According to Nges and Liu (2010) the main advantages of this process include: a reduction of 30-50% on the required volume for the final disposal, generation of an odorless waste and a high rate pathogens inactivation, especially for thermophilic process.

The start-up of thermophilic digesters is an extreme sensitive step for microbial anaerobes. Griffin et al. (1998) reported that an inappropriate temperature conversion can result in long acclimation periods besides low removal of organic matter. Several studies have discussed protocols for mesophilic-thermophilic conversion in bioreactors (De La Rubia et al. 2005; Riau et al. 2,007; Ortega et al. 2,008; Palatsi et al. 2,009; Cavinato et al., 2010). Operational stability is previously desired due the changes in the environmental conditions of the digester in order to reduce their negative effects for anaerobic microorganisms, especially methanogens.

The operational stability of a bioreactor can be measured by the production and consumption of organic acids, methane gas generation and removal of organic sludge load. In this way this study aims to assess the operational stability of a mesophilic anaerobic digester in terms of organic matter and volatile fatty acids production and consumption and biogas methane composition, considering different strategies for the digester operation.

METHODOLOGY

The pilot scale 100 – L anaerobic digester was installed at a WWTP in Florianopolis, Santa Catarina, Brazil. The unit was still composed of an agitation system for homogenization and a heating system, comprising a bayonet-type electrical resistance.

One hundred and twelve samples were evaluated in 567 operational days, which 160 are related to the preparation of the digester for the temperature conversion, i.e., constant HRT applied (Table 1). The removal of organic load in terms of COD was measured as well as VFA concentrations by high performance liquid chromatography (HPLC) following instructions in Standard Methods for the Examination of Water and Wastewater (APHA, 2005). The composition of biogas was measured using a portable gas analyzer GEM 2000.

Table 1 Retention times and operational periods in pilot digester.

Experimental time	Operational set-up	Operational Period
26 days	15 – day decreasing HRT (start)	First period
87 days	10 – day decreasing HRT	Second period
292 days	7 – day decreasing HRT (final)	Third period
162 days	7 – day constant HRT	Fourth period

RESULTS & DISCUSSION

Throughout nineteen months of continuous operation, anaerobic digestion of sewage sludge was studied in different operational conditions at mesophilic (35°C) temperature. Figure 1 shows the dynamics of production of acetic acid (HAc) in the digester. It was observed the existence of four common data set with different tendencies among themselves. High levels were detected until the 26th experimental day (1st period), followed by lower results up to 113th day (2nd period). Concentrations were high again until the 405th day (3rd period). These three sets had the highest concentrations of HAc, possibly due the long time of sample preservation until its effective analysis (13 months). Moreover, the gradual HRT reduction during this period (15, 10 and 7 days for 1st, 2nd and 3rd periods respectively) resulted in instability in the fermentation of organic acids and therefore did not favor the maximum rate of methanogenesis given the high remaining concentrations in the digested sludge (acidified digester). In this period, the highest methane (> 6

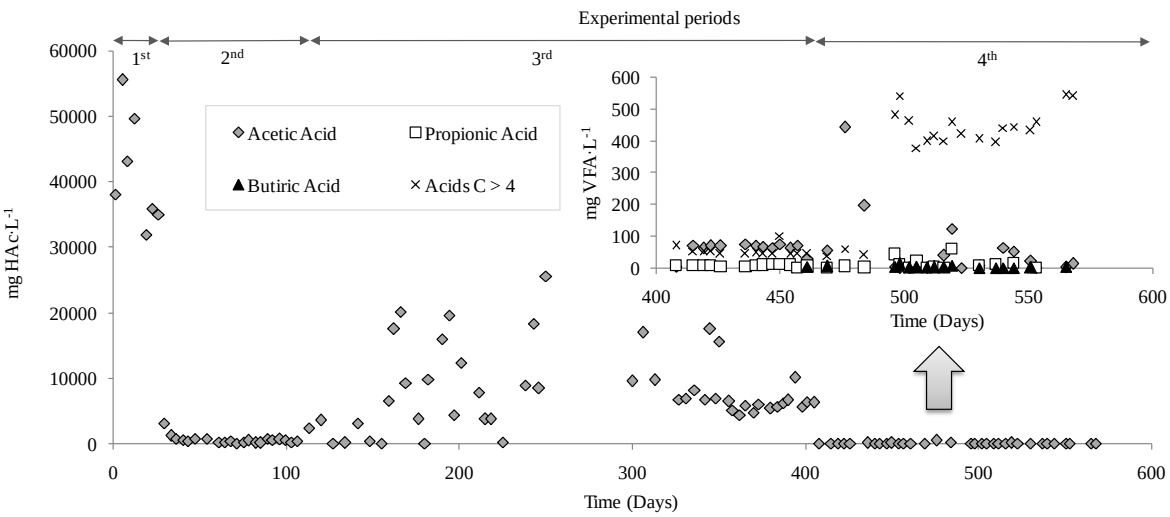

Figure 1 Dynamic production of acetic acid in anaerobic digester. The highlighted chart shows the individual VFA behavior in the 4th period.

The results prior the temperature conversions are referring to 406th to 567th operational days (4th period). Analytical time for these samples had an average lower than five months, and all organic acid concentrations evaluated (according to the detailed chart in Figure 1) were lower rather than those from the 2nd group. The seven days retention time provided good conditions for the process given the lower VFA concentrations (1.3 to 442 mgVFA·L^{-1}); in addition it increased the proportion of methane in the biogas (53%) (Figure 2).

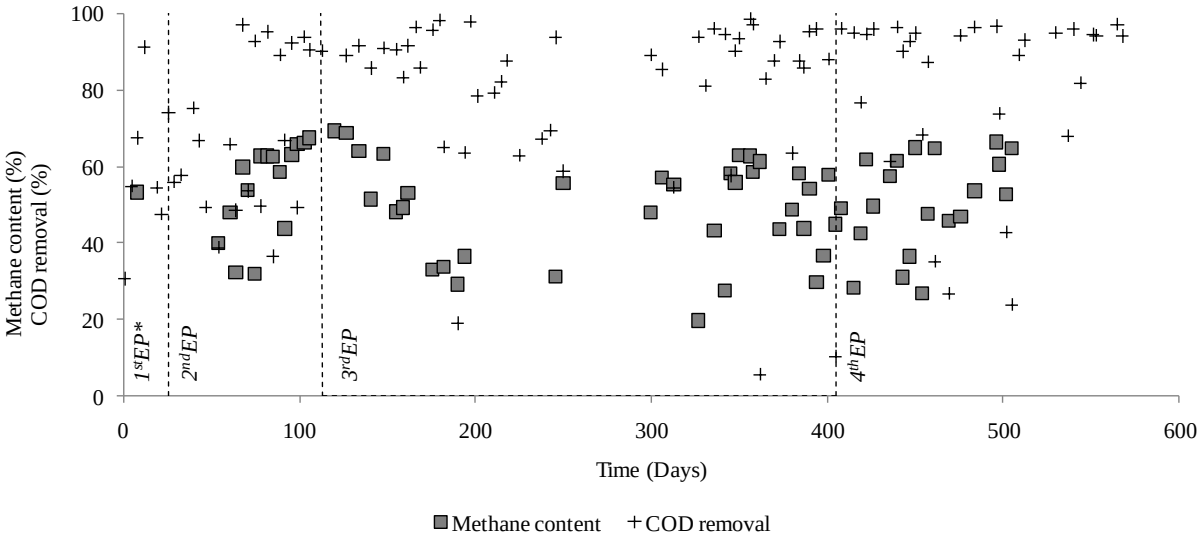

Figure 2 Methane and COD removal obtained profiles during the four experimental periods (**EP*).

Sludge fermentation along 4th period favored the acidogenic stage producing propionic acid (HPr), butyric acid (HBu) and other higher carbon chain acids (C > 4), which mean values are shown in Table 1. However the concentration of these other byproducts was generally lower than HAc. The acid fermentation, which produces HAc and others VFA, was active and the high levels of methane in biogas highlights the balance with the methanogenic stage as already observed in other organic AD studies (Wang et al. 1999; Nagao et al., 2012).

Table 1 – Mean results for organic matter removal, methane and volatile fatty acids along the experiment.

	Period 1	**Period 2**	**Period 3**	**Period 4**
	High values HRT 15d	Low values HRT 10d	High values HRT 7d	Low values HRT 7 d
COD removal (%)	59.5	70.0	81.2	82.9
CH_4 (%)	53.3	51.6± 12.0	49.2 ± 13.2	52.5 ± 12.2
HAc (mg·L^{-1})	41299 ± 8599	651 ± 729	8008 ± 5900	67.0 ± 86.0
HPr (mg·L^{-1})	ND	ND	ND	9.7 ± 12.7
HBu (mg·L^{-1})	ND	0.2 ± 0.1	0.2 ± 0.1	3.0 ± 3.2
Others (mg·L^{-1})	12.6 ± 8.4	41.8 ± 20.4	65.1 ± 15.4	377 ± 205

Notes: *ND = not detected.*

The results obtained during the 4th period showed higher efficiency in COD load removal (approximately 83% - Figure 2), low concentration of HAc (approximately 67 $mg \cdot L^{-1}$) and high CH_4 composition. In this way this is the best operating condition and presents as the most favorable and stable for the process. These features are essential for a future change in the environmental conditions of the digester, i.e., the conversion to thermophilic temperature.

CONCLUSIONS

The anaerobic sludge digester presented operational stability evaluated based on the production of volatile fatty acids. During the HRT decreasing, different behaviors were observed, all of them higher than 600 $mgHAc \cdot L^{-1}$. The invariable 7 days HRT (4th period) resulted in constant VFA production and consumption, resulting in low concentrations for all acids evaluated; moreover, providing high methane concentration and destruction of organic matter in the sludge. In this way, after 100 hundred experimental days with an operational and invariable 7 days HRT the anaerobic biomass could get over the instable stage and maintain good conditions for the process. This *pseudo* steady – state condition contributes to prepare the digester for its further temperature conversion (mesophilic to thermophilic).

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