Influence of Temperature on Anaerobic Co-Digestion Process of Organic Solid Waste

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Abstract

The process of anaerobic co-digestion (ACD) of organic solid vegetable waste (OSVW) with anaerobic sewage sludge (ASS) in the proportion of 80% and 20% (weight percent) respectively in anaerobic batch reactors (ABR), investigating the influence of temperatures at 25.5, 40.0 and 50.0 ºC, has been studied. The experimental system was composed of nine ABR with volumetric capacity of 1.15 liters each, of which 15 % of the total volume of each reactor was destined for the head-space. The reactors were monitored for the period of 160 days with weekly qualitative characterization, and daily quantification of the biogas produced. After completion of the monitoring period, the reactors were unloaded and the partially biostabilized waste was submitted to physico-chemical characterization, for the same parameters that were determined of the waste "in nature" used for loading the reactors. Among the conditions studied, it was observed that the best favored treatment by the ACD process was for the reactors monitored at 25.5 ºC, yielding total COD removal efficiency of 28.5%, volume of biogas accumulated 23.85 liters, volume of accumulated CH_4 9.05 liters and maximum percentage of CH_4 in biogas of 56%.

Keywords: solid vegetable waste; anaerobic sewage sludge; anaerobic co-digestion; batch reactors.

INTRODUCTION

According Casado et al. (2010) and Santos and Mota (2010) around 30% of the volumetric composition of municipal solid waste (MSW) produced and collected in Brazil consists of materials liable to recycle 50% of organic solid waste (OSW) and 20% of inert waste. When these wastes are disposed irregularly, a portion of OSW undergoes biodegradation, becoming responsible for the generation of byproducts, mainly biogas and leachate that may generate significant impacts on the environment. Therefore, for the rational utilization of such waste arises anaerobic co-digestion that consists of performing the process biomethanation of two or more substrates in a single digester (Mata-Alvarez et al. 2000).

The anaerobic co-digestion of biodegradable organic solid waste is presented as a viable alternative in view to contribute to the stability of the entire treatment process. This is mainly by balance of nutrients, organic load applied, the percentage of moisture and the hydraulic retention time. According van Lier et al, (2001), in different situations anaerobic co-digestion may be applied when there is no technical possibility of treating a single waste separately. The technical capability of the co-digestion is to contribute to the adjustment of the final pH of the substrate (mixture of biodegradable organic waste), leaving it to the appropriate level in the process, encourage increased biodegradability of the substrate, stimulate microbial activity and may even within certain limits attenuate the toxicity inherent to certain types of biodegradable organic waste (Leite, 2004).

The anaerobic co-digestion has been studied by several researchers, among which we can cite Demirekler (1998), Dinsdale et al (2000), Stroot (et al, (2001), Misi & Forster (2001), Kim et al, (2003) Sosnowski (2003), Murto et al (2004), Rodrigues (2006) and Leite et al (2004). A typical example of the anaerobic co-digestion is the addition of sanitary sewage sludge to organic solid waste in predetermined proportions. In the specific case of this work a substrate was prepared with 80% of solid vegetable waste and 20% (percentage by weight) of sewage sludge.

The basic objective of this work was to study the influence of temperature on anaerobic co-digestion of solid vegetable waste with sanitary sewage sludge with total solids concentration of 36.2 g L^{-1} in anaerobic batch reactors.

MATERIAL AND METHODS

The experimental system was installed and monitored in physical dependencies of Experimental Station for Biological Sewage Treatment (EXTRABES), State University of Paraíba (UEPB) in the city of Campina Grande, Paraíba State, Northeast Brazil. The substrates used for loading the ABR were prepared from the mixture of organic solid vegetable waste (OSVW) and anaerobic sewage sludge (ASS), collected in a UASB reactor. The OSWV consisted of leftover fruits and vegetables and were collected from the Agricultural Supply Company of Paraiba, Campina Grande City, Paraíba State, Brazil.

The substrate that is the result of mixing OSWV with anaerobic sewage sludge (ASS) was prepared in the proportion (by weight) of 80% OSWV plus 20% ASS and for adjustment of the desired total solids concentration (36.2 g L^{-1}) municipal sewage was added, following recommendations of Leite (2004). It was followed by the chemical characterization of the substrate, by using the analytical methods recommended by APHA (2005).

The experimental study was realized at three temperature levels: 25.5, 40.0 and 50.0 ºC, with three replications. Nine anaerobic batch reactors (ABR) of 1.15 L each were used. In each reactor monitored, 15 % of the total volume of the reactor was destined for the head-space. The reactors were monitored for a period of 160 days and consisted basically of monitoring daily record of the temperature of the three levels studied, the daily quantification of biogas and qualitative characterization of biogas with weekly frequency and was carried out by using a gas chromatograph with thermal conductivity detector of 250 mA, a stainless steel column, filled with Porapak Q 100, internal diameter 2 mm, outer diameter 6.4 mm and a length 3.0 m. Helium as carrier gas with a flow rate of 30 L min^{-1} was used for the determinations. The temperatures of vaporizer, column and detector were maintained at 75.0, 75.0 and 100.0 ºC, respectively. Upon completing the functioning period, the reactors were removed from operation and then characterization of the partially biostabilized waste mass discharged from each reactor was performed, adopting the same analytical procedures employed for the substrate.

RESULTS AND DISCUSSION

Data on the chemical composition of the substrate which was used in anaerobic co-digestion studied in this work are presented in Table 1.

Based on the data presented in Table 1 it can be seen that the substrate consisted of representative percentage of organic matter, given the concentration of total volatile solids and COD being respectively 21.3 and 34.3 g/L in relation to the total solids concentration. This means that out of the concentration of total solids, more than 93% is the concentration of COD, which justifies the application of the process of anaerobic co-digestion from the technical point of view for this type of waste, aiming at the production of biogas and biosolids. It is noteworthy that the pH of the substrate was 6.5 and was favored by the mixture of these types of waste, where the OSVW presents acidic characteristics and the sludge contributes in raising the pH, making it higher than 6 pH, which contributes positively in performance of the anaerobic co-digestion.

The chemical characterization data of the partially biostabilized waste mass are presented Table 2. Analyzing the data in Table 2, it can be seen that for a period of 160 days, there was a reduction efficiency of COD concentration of 40.9% for temperature 25.5 °C, 33.7% for temperature 40.0 ºC and 16.6% for temperature 50.0 ºC. Even when working with substrate containing 36.7 g TS L^{-1}, the solids retention time of 160 days was sufficient to biostabilized only 40.9% of the COD concentration in the case of reactors monitored at temperature 25.5 °C.

The cumulative volumes of biogas produced during the monitoring period due to the three temperature levels studied are presented in Table 3. Regarding the volume of biogas produced, no significant difference was found in relation to temperature increase, given the volume of biogas produced is varied from 23.8 to 23.3 L.

The temporal behavior of variations of the volumes of the accumulated methane for the substrate at temperatures of 25.5 40.0 and 50.0°C are demonstrated in Figure 1. It is observed that among the conditions of temperature studied, until the end of functioning, the largest cumulative volume of CH_4 was observed on treatment performed at a temperature of 25.5 °C which was 9 L CH_4. For a temperature of 40.0 ºC, the cumulative volume of CH_4 was 7.1 L and the temperature of 50.0 º C, the cumulative volume was only 1.2 L of CH_4.

According Deublin and Steinhauser (2008), in anaerobic digestion process much of methanogens are mesophilic which probably explains the low volume of methane produced by reactors monitored temperature of 50.0 ºC. The high sensitivity of methanogens in relation to temperature variation is well known, noting that even small variations in temperature can cause reduction in the activity of these microorganisms. It is recommended the range of variation be maintained within ± 2 ºC.

The percentage of CH_4 in biogas for the condition of temperature of 25.5 °C was always increasing during the functioning, presenting at the end of 160 days, biogas with 60% CH_4 in its qualitative composition. For the temperature of 40.0 ºC, the biogas generated showed a constant behavior in relation to the percentage of CH_4, staying in the range of approximately 36% up to 140 days of functioning, and then decreasing significantly in the range of 140 to 160 days. For the temperature of 50.0 °C, it was observed that CH_4 gas just started to be formed in about 100 days of functioning, reaching maximum percentage of 19% CH_4 in 153 days. Probably, for this case study heating at 50.0 °C contributed to the slowing of the development of thermophile microorganisms.

The data of theoretical volume of CH_4 estimated in function of the concentration of total organic carbon (TOC) present in the substrate and the volumes of the experimental and consequently the conversion efficiency of total organic carbon in CH_4 gas for the three treatments studied are presented in Table 4. It is noted that among the treatments studied, which presented the experimental volume closest to that of the theoretical were the treatments at temperatures 25.5 °C and 40.0 °C, which allowed TOC conversion efficiencies of gas CH_4 95.5 % and 94.6%, respectively. For treatment functioned at a temperature 50.0 °C, the conversion efficiency of TOC to CH_4 gas was 20%, indicating once again the influence of temperature on the anaerobic co-digestion of solid organic waste.

CONCLUSION

Out of the three treatments, the treatment monitored at 25.5 °C presented the best results, which produced an average of 23.8 liters of biogas with average percentage of 50% (percentage by volume) CH_4 gas. The biostabilization efficiency of organic matter expressed in terms of COD from 50% to monitoring period of 160 days was presented by this treatment. The third treatment, monitored at a temperature of 50.0 °C, gave low biostabilization concentration of COD (16.6%), which also explains the low yield of biogas and CH_4 gas. It is expected that with statistical treatment of all the data of this work the influence of temperature on the anaerobic co-digestion of solid organic waste may be better understood and consequently the extraction of a wider range of technical information may be produced. Overall, one can say that the process of anaerobic co-digestion of organic solid waste can be a promising alternative technology and meet some of the demands of the Brazilian energy sector, in addition to producing biosolids that will substantially contribute to the fertility of agricultural soils. Therefore, further significant investments will be needed in the field of science and technology so that the process of anaerobic co-digestion of organic solid waste may become a reality for applying in real scale in a short period of time.

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