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RESEARCH ARTICLE

BIOGAS PRODUCTION FROM ANAEROBIC DIGESTION OF VINASSE IN UPFLOW ANAEROBIC SLUDGE BLANKET REACTOR

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ABSTRACT

The expansion in the production of ethanol from sugarcane in Brazil resulted in increased production of vinasse, which is the main by-product of the sugar industry.The vinasse is a highly polluting effluent is generated in large volumes, which aggravates the problem of its final disposal.An treatment alternative of vinasse is its use for the generation of biogas in UASB (Upflow Anaerobic Sludge Blanket) that can be used as an alternative source of sustainable energy.In this study, the UASB efficiency for the production of biogas from the anaerobic digestion of vinasse from sugarcane was evaluated. The experiment was conducted in laboratory scale using the UASB in mesophilic temperature and 87 L capacity, and using as raw material the vinasse from the process of the production of ethanol.The UASB reactor has operated for 15 days with VOC 2 kg DQO m^{-3} d^{-3} and TDHof 11.5 days. The results obtained in this study showsa good functioning of the UASB applied vinasse. This study obtained an COD removal efficiency of 71% and the volume of accumulated biogas 1160 liter andmethane concentration around 48-57%.

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INTRODUCTION

The world's energy supply is based on fossil fuels (75%); the scale at which fossil fuels are used quickly led to depletion of these resources.In addition, the use of fossil fuels is responsible for many environmental problems and most greenhouse gases.The use of energy is expected to grow as a result of advances in many developing regions of the world.The current challenge is to seek renewable energy sources and increase efficiency in energy generation and use on an unprecedented scale (UNICA, 2007). In this scenario, biogas production from anaerobic digestion of organic waste technology emerges as an attractive and sustainable alternative because its combustion does not contribute to the greenhouse effect because of its renewable sources. Anaerobic digestion of organic waste has two advantages, namely, the treatment of waste and generation of biogas which can be used as an alternative energy source (Budiyono e sumardiono, 2013). This technology has been successfully used to cure a variety of potential with waste to generate biogas, such as industrial and domestic wastewater, municipal solid waste and agricultural, sewage sludge, animal waste and other (Nguyen *et al.,* 2015).Furthermore, liquid wastes, such as vinasse was treated most effectively by use of anaerobic treatment (Espinoza-escalante *et al.,* 2009; Siles *et al.,* 2011). Pushed by the demand for renewable energy, the ethanol industry in Brazil and the world is expanding.However, the Brazilian sugar and alcohol industry is known to generate large amounts of sugar processing residues, due to their size. Production of 1 liter of ethanol produces about 13 L of liquid wastes (vinasse) and this expansion results in a growing need for a more appropriate use

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of such waste (Boncz *et al.,* 2012). The vinasse is predominantly composed of water and solids, respectively, 93% and 7% (Carrilho *et al.,* 2016). In general, the vinasse has a high content of organic matter and potassium, and relatively poor nitrogen content, calcium, phosphorus and magnesium (Unique, 2007). Due to its characteristics, the vinasse is commonly scattered on the sugar cane fields in the practice of fertigation, however, anaerobic digestion of this waste can be a better solution additionally offering an alternative source of energy. The stillage contains organic matter digestible and is a potential substrate to produce biogas (Moraes *et al.,* 2015). Anaerobic digestion using vinasse as a substrate for biogas production should focus on these types of reactors, such as fixed bed reactors, fluidized bed reactors or granular sludge systems, especially the anaerobic upflow reactor sludge blanket (UASB, Upflow Anaerobic Sludge Blanket).The UASB reactor can treat wastewater with more than 30 kg COD / m3 reactor / day, and for this reason a good option for technological ethanol producing countries(Cortez *et al.,* 1996).This reactor is already used successfully in Brazil for the treatment of different kinds of waste water (Janke *et al.,* 2015). According to Von Sperling (2005), the UASB reactors are the most adapted to the vinasse. In view of the above aim with this research, evaluate the UASB efficiency for the production of biogas from vinasse sugarcane.

MATERIAIS AND METHODS

General features: The research was conducted at the Department of waste management and material flow of the Environmental Engineering Institute of the University of Rostock, Germany. The UASB reactor was operated for 15 days, corresponding to the period from 5 May 2015 until 19 May 2015.

Characterization of vinasse: The vinasse used in this study was obtained from an ethanol industry and sugar during the 2013/2014 harvest season. The ethanol industry is located in the State of São Paulo, where ethanol is produced from sugarcane molasses. vinasse samples were submitted for Germany in heat containers and maintained at low temperature (4 ° C) until use. The vinasse samples were submitted for analysis: total solids (TS) (EN 12879, 2001) and volatile solids (VS) (EN 12880, 2001); pH (APHA *et al.,* 1995); chemical oxygen demand (COD) (DIN 38 409- H41-1, 1980). Features of the stillage used in this study are shown in Table 1.

Table 1. Properties of vinasse used in this study

Parameters	Values
COD(mg/ L O_2)	23000
DM(% total)	8,10
VS(% total)	7,30
VS(% total of DM)	90,1
pH	4,11

COD:Chemical oxygen demand; DM:Drymatter; VS:Volatilesolids; pH:Hydrogenpotential.

Inóculum: This study used as inoculum, the sludge digested from the anaerobic digestion of potato waste, obtained from an industrial biodigester located in a cultivator potato farm in the state of Mecklenburg-Vorpommern, Germany.The biomass used as an inoculum containing bacteria and methanogenicarchaea capable of degrading the effluent.In a starting process, filling the reactor with sludge from stabilized reactor already containing anaerobic micro-organisms, especially methanogenicarchaea accelerate the onset of anaerobic digestion.

UASB

This study utilized as digester anaerobic UASB reactor (Fig. 1) which allows movement of the vinasse through a region which has a high concentration of micro-organisms. The UASB reactor used for this research was glass with a diameter of 0.3 m, cross-sectional area of 0, 0707 m2 and a useful volume of about 85 liters, with two sample collection points throughout the body.

Figure 1. UASB used in the experiment

Experimental procedure

The UASB reactor was initially inoculated with sludge from an industrial anaerobic reactor, used to treat potato waste. The feeding of the reactor with vinasse was performed by a peristaltic pump and intermittently operated in a condition: every two hours the reactor was fed for 1 minute as a flow rate of 617.95 mL / min, thus, the power operated system 12 d^{-1}. The feed system consisted of a 10 L plastic container, which was supplied daily with the effluent maintained under refrigeration at 4 ° C. This feed vessel was maintained at room temperature on a magnetic stirrer to avoid any sedimentation of solids. The reactor was maintained at mesophilic temperature range of 30 to 35 ° C by means of heated water around the reactor and insulating foam. The reactor operated with hydraulic retention time (HRT) of 11.5 d and volumetric organic load (VOC) 2 kg COD m^{-3} d^{-3}, which was required daily intake 7.39 L d^{-1} of vinasse. The upflow velocity was estimated at 0.583 m hr^{-1}. This value is recommended in the range (0.5 to 0.7 m / hour) for Chernicharo (2007). Upon reaching the three-phase separator, formed biogas was routed through the baffles to the accumulation system and gas collection. Gas production was measured by a Ritter trademark of biogas flow meter installed at the reactor to measure the production of biogas daily. Biogas volume was quantified every 30 minutes per day. For the biogas storage bags were made of metallic materials (Fig. 2). The reading of the biogas composition was made daily through the Software (method) Visit 3.

Figure 2. Bags used for biogas storage in laboratory scale

Analytical methods

The following analyzes were carried out during the experiment: pH (pH meter); COD (DIN 38409-H41-1, 1980); alkalinity ratio (German: FOS / Taq volatile fatty acids / total inorganic carbon) based on the method Nordmann (1977); the composite effluent samples.

RESULTS AND DISCUSSION

Stability of the digester

Methane formation is influenced by a number of parameters. Thus, it is necessary to ensure that the anaerobic digestion process to be performed in stable conditions in order to obtain a greater yield of biogas. The pH and temperature are one of the important indicators used to monitor the process stability in the digester. The growth rate of microorganisms is significantly affected by pH change.The pH value recorded during the experiment remained in the range of 7.3-7.6. The optimum pH range for the anaerobic digestion has been reported as being between 6.8-7.4 (MAO *et al.,* 2015).The temperature inside the reactor remained in the mesophilic range, ranging between 32 and 35 ° C. The temperature range in which they operate mesophilic bacteria is between 25 ° C and 40 ° C, but the process of biogas generation has increased yield above 32 ° C as the optimum temperature for the formation of methane is between 35 ° C and 37 ° C (Karlsson *et al.,* 2014). According Wilkie, Riedesel and Owens (2000), with the mesophilic digestion is possible to obtain a COD removal efficiencies higher than 70% and an average yield of methane exceeding 0.25 m 3 / kg COD. The influence of temperature on the performance of a UASB reactor is very important since it greatly affects the hydrolysis process, the utilization rate of the substrate, the sedimentation of solids and gas transfer rates (Lettinga, et al. 1993; Lettinga, et al, 2001). For this reason it is necessary that the fermentation temperature is kept stable and show no major changes during the process. Another parameter indicator of stability of the digestion process is alkalinity ratio (FOS / TAQ). The TAC value is an estimate of the sample buffer capacity in the digester and the FOS value corresponds to the volatile fatty acid content and is an important indicator of problems in the process. According Drosg (2013), the buffer capacity due to bicarbonate is important in the biogas process so that a moderate accumulation of volatile fatty acids do not cause a decrease in pH that would eventually lead to end the production of biogas. The value of FOS / TAQ obtained in this study was 0,157- 0.195. The biogas system is stable BETWEEN FOS / TAC 0.3-0.4 values based on practice (Mezes; Tamas; Borbely, 2011). The anaerobic degradation process state is correct also in agreement with the results E. Voss et al. (2009), which led to another ideal range between 0.15 and 0.45. The value of FOS / TAQ obtained in this study is in the ideal range according to other studies, which shows the stability of the UASB digester operating with vinasse.

COD removal

In anaerobic digestion, the organic material which is represented by the COD value is converted into biogas. Thus the COD of the substrate will be decomposed by micro-organisms during the fermentation process in the digester. The percentage value decomposition is called COD COD removal. In this study, the UASB reactor had COD removal efficiency of 71% for volumetric organic load (VOC) applied 2 kg COD m -3 d-3 and d 11.5 HDT, showing excellent performance in the treatment of vinasse. Speece (1996) showed that 1 gram of COD will be destroyed in 0.395 L of biogas at 35 ° C and 1 atm.Pugliano *et al.* (2014) using UASB 40.5 and 21.5 L, and treating vinasse TDH 2.8 VOC from 5.0 to 12.5 g total COD (L d) -1 and the operating temperature range mesophilic, achieved COD removal efficiency 54-60%. Barros et al. (2016) also operated UASB reactor using as substrate vinasse obtained averages and efficiencies of total COD removal varying from 80 to 82%, with VOC 2.5-5.0 g COD (L d) -1 and 2 TDH, 8 to 1.8 days.

Production and biogas composition

Figure 3 shows the production of biogas from stillage in L / g COD. The volume of biogas produced during the experiment remained in the range between 0.5 and 0.6 U / g COD per day. However, there was a higher yield of 0.9 U / g COD. After this peak in production, the volume returned to stabilize in the range of 0.5 L / g COD and was decreasing until the end of the operation.

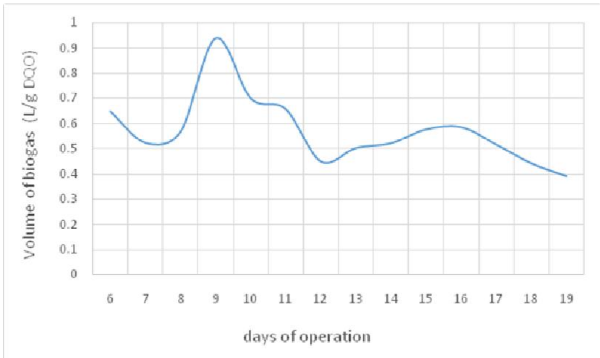

Figure 3. The production of biogas during the anaerobic digestion of vinasse in UASB

According to Drosg (2013), the biogas composition is a useful parameter for monitoring the process. A decrease in the methane content can be a first organic overload signal. Similarly, a sudden increase of H2S can cause process instability. Table 2 shows the quantized components in biogas composition obtained in this experiment from anaerobic digestion of vinasse.

Table 2. Biogas composition obtained from vinasse used.

N. of readings	Content of metano (CH_4) (%)	Content of CO_2 (%)	O_2 (%)	H_2S (ppm)
1	28,1	21,2	9,7	936
2	54,3	38,5	0,6	497
3	56,9	38,4	0,2	682
4	56,4	39,7	0,5	1174
5	57,4	39,4	0,1	1226
6	53,2	35,9	1,2	1191
7	55,4	38	0,3	1281
8	48,2	32,5	2,8	94
9	54,4	37,2	0,4	210

The energy use of biogas is basically its major flammable component, methane (Coimbra-Araujo, *et al.,* 2014). In this work, the methane in the biogas percentages increased from 28, 1 to 54.4% and from then until the end of reactor operation, the methane concentration in the biogas remained in the range 48-57%. According Pompermayer (2000), in the case of waste such as concentrated vinasse, the proportion of CH4 in the produced biogas is 55 to 65%, the remainder consisting primarily of CO2. Larger amounts of methane result in lower amounts of non-combustible substances such as water, H2S and CO2, whose removal is recommended, depending on the desired type of application for biogas (Magalhães *et al.,* 2004; Salomon, 2007).

Conclusion

The UASB reactor operation vinasse fed proved to be an option for recovery and treatment of this waste since, promotes the reduction of the organic load and at the same time produces an alternative energy through the biogas. In this experiment, there was a COD removal efficiency of 71% and a maximum volume of 0.9 g / L COD for biogas production over the 15 days of reactor operation. During the experiment, the parameters evaluated did not show signs of instability in reactor, with a pH of about 7.6, mesophilic temperature in the range of 32 to 35 ° C and FOS / TAC 0,157- 0.195. Based on the results of this experiment, it can be deduced that the vinasse is a potential source for the production of biogas, and the process of anaerobic digestion in UASB reactors presents a safe solution for the treatment of such waste.

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