Biogas production assessment from anaerobic digestion of different sludge

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Abstract

In this work, biogas production using rice (used for fungi cultivation) and leather residues with addition of sludge from different wastewater treatment plant were assessed. Anaerobic digestion generates biogas and it can be an alternative for waste treatment. The aim of this study was to evaluate biogas volume and its molar fraction. For the test were used as substrates pretreated leather waste and rice waste. Sludge from a tannery wastewater treatment plant (WWTP) and sludge from UCS WWTP were used as inoculum. The samples were placed in vials with total volume of 100 mL; the test was conducted at 35°C. The influence of inoculum addition was evaluated for the volume and the molar fraction of generated gases. It was possible to observe that the rice sample with sludge from UCS WWTP presented the highest volume of generated gas (62.58 mL). The sludge from UCS WWTP showed the molar fraction that bests represents biogas, since its composition is approximately 76% methane and the biogas amount produced (53.07mL) was also suitable. The addition of sludge from UCS WWTP into the rice waste resulted in an increase of hydrogen molar fraction and the same sludge added to the leather wastes results in a methane molar fraction increase. Hence, the anaerobic digestion process is a promising alternative to waste and sludge co-digestion.

Key-words: biogas, wastewater treatment plant sludge, anaerobic digestion.

Area: 16 – Clean Technologies

1 Introduction

Waste disposed without restraint or adequate treatment can cause greenhouse gases, mainly methane. Researchers have evaluated different technologies in order to treat and allocate the waste generated in different processes. Therefore, anaerobic digestion (AD) can be an environmentally viable alternative because it converts waste into energy (biogas).

The anaerobic digestion is an oxygen free process. In AD process, anaerobic microorganisms transform the organic matter under specific conditions. The benefits of this process are: energy recovery in biogas form, waste stabilization, odor reduction and an alternative treatment for the most hazardous and non-hazardous wastes (CHRISTY et al., 2014; COVINGTON et al., 2003; KAFLE et al., 2013; THANGAMANI et al., 2010; DHAYALAN et al., 2007 e MAO et al., 2015).

According to Mao et al. (2015), biogas is a promising way to follow the global energy needs and also to provide environmental benefits. Furthermore, from a socio-economic point of view, biogas has a relatively low cost of raw materials and it reduces waste disposal costs. Biogas is mainly comprised of methane (60%), carbon dioxide (40%), water vapor, hydrogen sulphide and ammonia trace amounts. The methane content in biogas may vary due to its different substrates, biological consortia and AD conditions (Zhang et al., 2014).

The most often employed substrates to convert waste-to-energy are the wastewater and municipal sludge from wastewater treatment plant. In order to improve the AD process, other residues can be added. Industrial wastes (41%), agricultural wastes (23%) and municipal waste (20%) are the most used (Alvarez et al., 2014). In this context, rice wastes and chromium leather tanned wastes may also be mentioned.

The parboiled rice besides being an important cereal for human consumption can be used in fungi cultivation for plants treatment. Companies sell products obtained from *Trichoderma* sp. cultivation. These products act in the preventive and curative control against diseases caused by pathogenic fungi.

Leather industry has its fundamental importance in the Brazilian economy. According to the Centre for the Brazilian Tanning Industry (CICB), the country produced an average of 45 million hides annually in the last two years. For each treated hide, approximately 4.5 kg of waste from the shaving operation (leather thickness adjustment) are generated (DAUDT, GRUSZYNSKI e KAMPF, 2007). Thus, it is estimated that 202 tons of shaving waste are generated per year and usually destined for landfills.

Wastewater sludge contains a considerable amount of water, organic matter and microorganisms (KALOUM et al., 2011 e TRAVERSI et al., 2015). The wastewater treatment plant aims to eliminate pollution contained in domestic and industrial effluents, thus the sludge can be regarded as a residue, which can be treated by anaerobic digestion.

The objective of this study was to evaluate the biogas generated from rice and leather wastes with addition of different wastewater sludge.

2 Materials and Methods

2.1. Materials

Rice residue was provided by Empresa Caxiense de Controle Biológico Ltda. (ECCB). The sludge from a tannery wastewater treatment plant (WWTP) and chromed tanned leather (TLS) wastes were made available by a local tannery. The WWTP sludge from University of Caxias do Sul (UCS) was made available by the institution.

2.2 Methods

2.2.1 Products characterization

The total solids (TS) percentage determination of rice and leather waste were based on ASTM D3790-12 standard. The TS content of WWTP sludges were analyzed based on ABNT NBR 14550 standard. The organic carbon content was determined by the sample carbon oxidation. Afterwards, the titration with ferrous sulphate was done. The methodology was based on Walkley-Black (1934).

2.2.2 Anaerobic digestion experiments

The sludge addition influence was evaluated for volume and molar fraction of the generated gas. Pretreated (chemical and thermal process) leather waste and rice residue were used as substrates, with addition of TLS and WWTP sludge. The samples were placed in vials with 100 mL total volume. The experiment was conducted at 35 °C and during the period in which it was found the biogas generation.

The leather waste thermal pre-treatment consisted in disposing itself in a sealed glass container and autoclaved in Prismatec model CS equipment under 1 atm for 15 minutes. The chemical pretreatment was adapted from the methodology used by Dhayalan et al. (2007), using 200% of distilled water, 0.003 g of oxalic acid and 0.003 g of ethylenediaminetetraacetic acid (EDTA). The solids content for all the tests was maintained at 9%.

2.2.3 Volume and molar fraction of the generated biogas

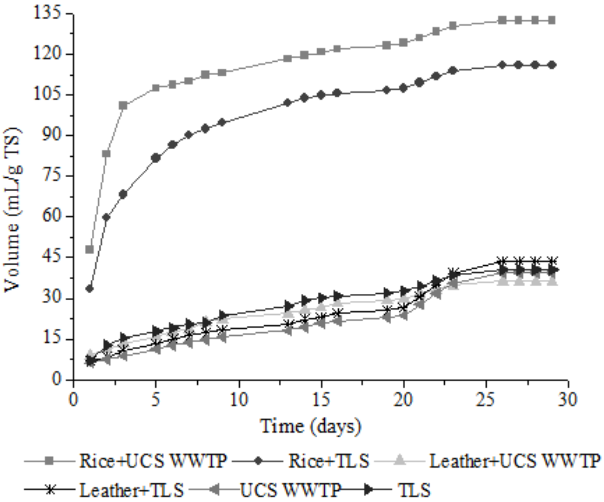
The volume and the molar fraction of biogas generated in each sample were measures daily. The generated gas volume verification was performed using the volumetric method. For the chromatographic analysis, nitrogen was used as carrier gas. Thermal conductivity detector and capillary column Supelco Carboxen TM 1006 (30m x 0,53mm) were employed. For sample collection, it was used a Gasthight 1 ml Hamilton syringe (SILVA, 2015).

3 Results and Discussion

3.1 Anaerobic digestion experiments

Figure 1 shows the amount of generated biogas by different combinations of wastes and sludges.

Figure 1. Biogas volume generated by the sludge fromUCS WWTP with addition of TLS and rice.



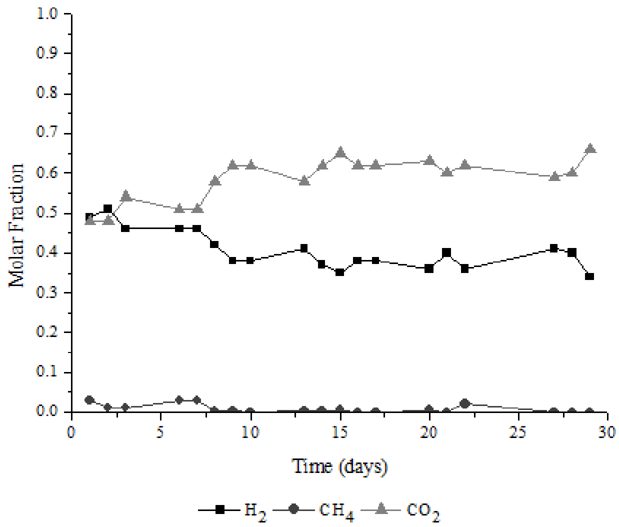
According to Figure 1 it is possible to identify that the rice samples, with addition of sludge from UCS or a tanery WWTP generated the highest biogas volume. This result can be justified by the presence of microorganisms in the sludge, which contributed in the anaerobic digestion process.

The samples that contain only sludge presented lower biogas production. This can be attributed to carbon and nitrogen ratio, the addition of rice and leather wastes can increase this ratio and favoring biogas production. Samples containing rice with sludge addition showed higher volume of gas generated in relation to leather samples with sludge addition.

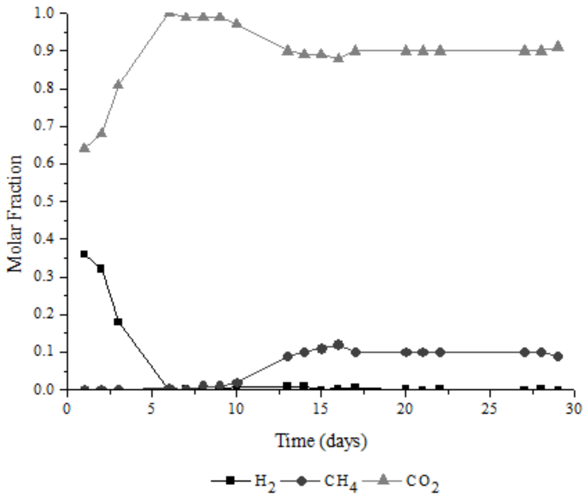
Gas chromatography was carried out to evaluate the molar fraction of the generated biogas. Figure 2 shows the molar fractions obtained from each sample.

Figure 2. Molar fraction of biogas generated from the anaerobic digestion of waste.

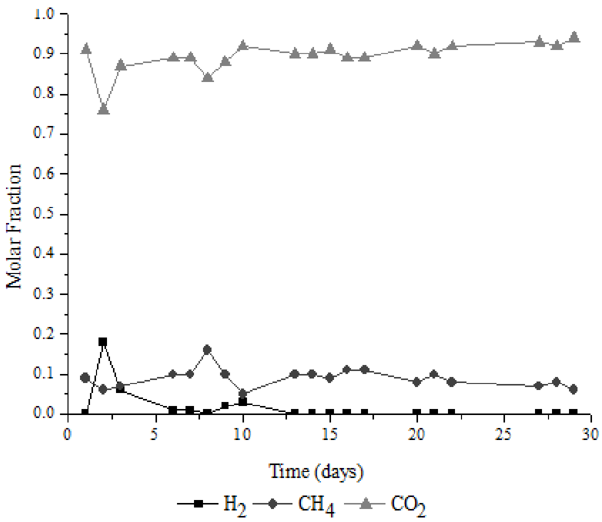
a) Rice + UCS sludge.



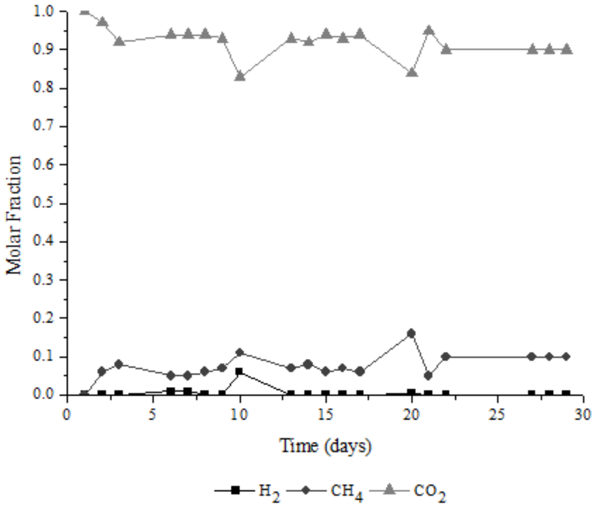
b) Rice + TLS



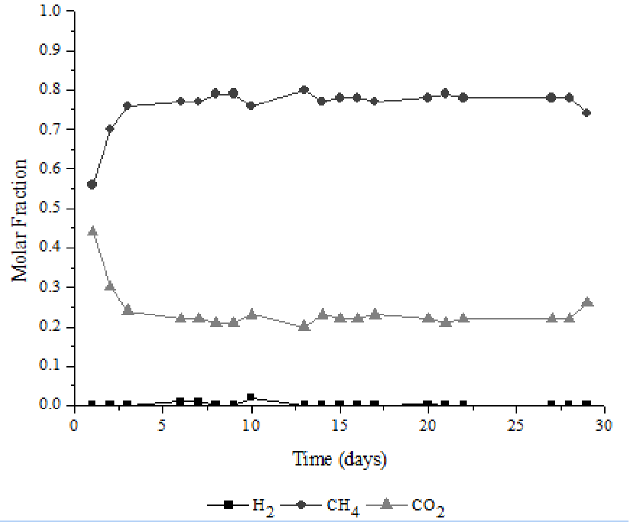
c) Leather + UCS sludge.



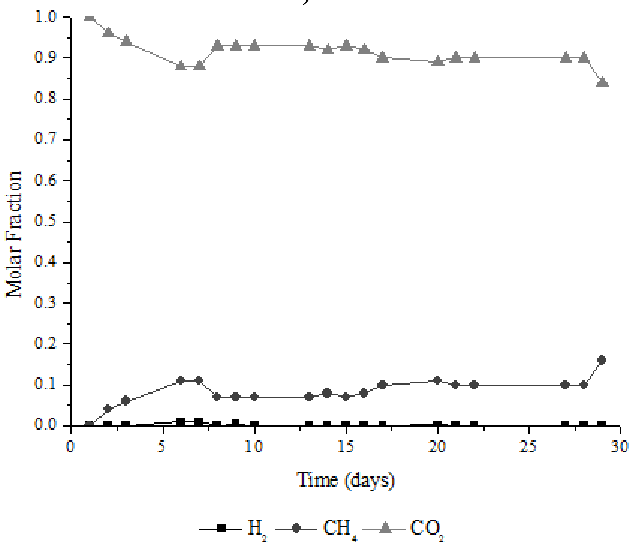
d) Leather + TLS.



e) UCS WWTP.



f) TLS.



The predominant molar fraction of the residues and their combinations was carbon dioxide and consequently, low molar fraction of methane.

The sample that contain leather and sludge from tannery WWTP showed low molar fraction of hydrogen. The sample with leather waste and sludge from UCS WWTP showed low molar fraction of methane.

Rice waste and tannery sludge WWTP sample showed predominant carbon dioxide molar fraction, although it was the highest accumulated gas volume (62.58 mL/g), whilst in the initial period it showed a mole fraction of 35% hydrogen. The sludge from UCS WWTP showed the mole fraction which bests represents the biogas, since its composition is approximately 76% methane and the biogas amount produced (53.07mL) was also suitable. Shanmugam et al. (2009) found 56% methane content for the municipal WWTP. This value is lower in comparison with this experiment, possibly due to its composition and the microorganisms presence which assists in the anaerobic digestion process.

The reduction in organic carbon and TS contents are directly related to anaerobic digestion process. Table 2 shows the carbon and TS contents for residues used in this experiment.

Table 2. Carbon content, TS and waste reduction percentage.

	Carbon content (%)			**TS content (%)**		
	Before	**After**	**Reduction**	**Before**	**After**	**Reduction**
Rice +TLS	21.20	13.34	37.07	33.95	4.50	86.74
Rice + UCS WWTP	16.78	8.94	46.72	41.72	10.40	75.07
Leather + TLS	13.63	9.03	33.74	29.01	7.39	74.53
Leather + UCS WWTP	18.75	17.02	9.23	36.70	10.90	70.30
TLS	30.07	22.06	26.64	11.25	9.89	12.09
UCS WWTP	32.14	26.84	16.49	26.80	23.20	13.43

It was possible to observe that there was a TS content reduction and the carbon content in all samples. These parameters indicate that the residues were digested. The largest reduction in both levels was in rice sample with addition of sludge from UCS WWTP. The same sample presented the higher biogas volume.

4 Conclusion

From the test results that evaluate the biogas production it is concluded that the rice sample with the sludge from UCS WWTP addition showed the greatest volume of biogas production (132.29 ml/g).The addition of sludge from UCS WWTP into the rice residue resulted in a hydrogen molar fraction increase and the same sludge added to the leather residue produced a methane molar fraction increase.

Anaerobic digestion of sludge from UCS WWTP presented high methane mole fraction (76%). All combinations using TLS showed low methane and hydrogen mole fractions. Hence, the anaerobic digestion process is a promising alternative to waste and sludge co-digestion.

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