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Influence of wood shavings bed material for dairy cattle on biogas methane content

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Abstract

The biogas processes are well resolved commercially in Brazil. However, the heterogeneity of the agroindustrial effluents, influenced by the different handlings adopted, demand better understanding, especially of dairy cattle, where normally it applays the use of wood shavings like bed for dairy cows. The wood shavings can negatively influence the process of anaerobic digestion, because it is a tough material for degradation, besides absorbing part of the volatile solids, which are essential to the process of biogas generation. Consequently the wood shavings can lower the calorific value of biogas, reducing the concentration of methane in the biogas. The objective of this study was to evaluate the influence of wood shavings used like bed for bovines, on the methane content in biogas. The experimental delimitation was randomized in blocks with four treatments, performed in triplicate, such as: (T1) raw effluent; (T2) liquid extruded effluent; (T3) pasty extruded effluent; and the (T4) white control or inoculum, totaling 24 sampling units. The laboratory analyses were done in the International Renewable Energy Center (CIbiogás), in the city Foz do Iguaçu, PR. Besides being considered one of the best laboratories in Latin America is the only biogas laboratory in Brazil that provides service. Assays of biogas production were performed in eudiometer batch of 250 mL. Multivariate analysis was adopted by means of multiple linear regression model to delineate a regression model and with significant accuracy ($p < 0.01$) it was found variation in the methane content of 65.30 – 53.65%. Therefore, the wood shavings may significantly affect the anaerobic digestion of effluent.

Key words: Agriculture energy, biomass, bioenergy, volatile solids, biomethane, biogas yield, biodigester, eudiometer, bovine effluent, wastewater treatment, Brazilian agribusiness, lignin, process of separating solid.

Introduction

The dairy cattle, besides being an important sector of Brazilian agribusiness, also are very influential in the national economy, being the biggest exporter of beef and the sixth biggest milk producer [1]. Only the Paraná state produces 3.9 billion of litres per year, being the third biggest milk producer in Brazil, with a milked cows herd of 1.6 million of animals [2]. This represents a manure volume about 29.49 million tons per year.

Adjustment the growing demand of food with the ability of animal production in the farms needs technically optimized installations and by intensive processes confinement control of the environmental conditions in the area of increasing productivity accommodation[3]. In Brazil the common technique used is the free-stall shed, in which the animals are prepared in individual stalls and the main problem is the big production of waste because different materials, such as sawdust, dry grass, straw, and others, are used like bed for stall [4].

The effluents from dairy cattle have large variation in nutrient contents, which is a reflection of the different diets, use of wash water, stormwater and the storage time of manure [5]. It is also rich in lignin, which hinders anaerobic bacterial degradation [6, 7].

There are many research about the anaerobic treatment of bovine effluent with emphasis in the biogas production, but there is shortage in information of the effluent management when combined with bed materials like sawdust, an important variable in the composition of the effluent. Main objectives of this research were to show the influence of separating solid in the effluent of dairy cattle on the methane content in biogas at each treatments.

Experimental

The effluent used in the experiment was collected in the city Céu Azul - PR, at the livestock for milk farm Star Milk (25º02’08"S latitude and 53º45’48"W longitude) with 1100 animals without confinement. The region climate is humid subtropical mesothermic (Cfa) with average annual temperature of 20ºC, altitude 620 m, rains 1300 and 1700 mm [8]. The Star Milk farm has three effluent treatment systems: one full mixture model biodigester; one Canadian model biodigester and one anaerobic pond. The systems get effluent filtered by a extruder make of WAM (model: SEPP161065270231). The experiment was made in the city Foz do Iguaçu - PR, at CIBIOGÁS laboratory, called Labiogás, situated in the Parque Tecnológico de Itaipu (PTI).

The operation used nowaday happens by a scraping off the bed until the channel which surround the sheds. Proportion of solids in the effluent needs reused water to melt the solids before the effluent is routed to treatment system.

The experimental outline was in randomized blocks, with two blocks made in different times. Each block has four treatments with three repetitions each, altogether twelve sample units by block and twenty four sample units at the all experiment. The sample collection was on April 1 and May 9, 2014 at eight o'clock in the morning, and samples were sent to Labiogás.

Treatments were T1 raw effluent; T2 liquid extruded effluent; T3 pasty extruded effluent; and T4 white control or inoculum, totaling 24 sampling units. T1 sampling happened at the homogenization tank entrance in the upstream extruder. T2 was sampled at the inspection box in the upstream of the biodigester systems. T3 collection happened at the extruder outlet mouth. T4 was get at the Labiogás, in the proportion of 1:1 of swine and cattle manure in accordance with the operating procedures of the lab.

The biogas production test under fermentation control conditions happened in accordance with norm VDI 4630 [9], in eudiometer batch, with sampling flask of 250 mL. The eudiometer stayed in water bath with temperature controlled at 37.0 ± 2.0 °C during all experiments, the digestion manure was mixed by magnetic stirrer during ten min followed by about a thirty min break. The analyses were finished when the biogas daily production rate was less than 1% of the total quantity of biogas produced. Then thirty one days of hydraulic retention were necessary.

The biogas amount produced was measured from biogas scale (mL) composition in proportion of methane (CH_4) by a portable gas analyzer "Drager X-am 7000", the model "Multiple Gas Analyzer #2" of GC-SRi Instruments .

For characterization of the substrates lab analyses were used to quantify total solids (TS), volatile solids (VS) and pH. The TS and VS levels of the collected samples during the characterization tests and anaerobic digestion were determined according to the methodology described by APHA [10]. The pH reading was made by a bench pH meter (model PHS-3B).

Multivariate analyses by multiple linear regression model were used to interpret the results. Dependent variable was methane content in biogas and independent variables were TS, VS, pH, biogas/SV yield and production specific biogas. The comparison of means was performed by Student's t-test (5%), and the statistical program used was Excel.

Results and Discussion

Variation of TS, VS and pH: The pH among batches ranged between 7.36 and 8.07, being partly within an acceptable range of 6.0 - 8.0 without damaging the process [11]. The recommended range for anaerobic digestion is 6.8 to 7.2 [12]. However, the shavings may have influenced the obtained values as shown in Table 1.The volume of TS had significant change in medium, 1.4%, 0.5% and 30% for T1, T2 and T3, respectively. The level of VS was proportional to the volume change of TS. This can be explained by the characteristic of shavings to absorb available nutrients in manure.

Table 1. Medium values of TS, VS and pH by treatment (T).

Parameters ($kg.kg^{-1}$ substratum)	Values obtained			
	T1	T2	T3	T4
TS added	0.014	0.005	0.298	0.044
VS added	0.763	0.688	0.943	0.067
pH	7.73	7.36	8.07	7.95

Biogas yield, methane and VS added: The biogas yield, methane and VS, shown in Table 2, had better outcome for T1, which was more efficient compared to T3 and T2 with the lowest income. The low concentration of TS may have affected the performance of T2. Previous studies have presented the quantity of water being used in the management of facilities as an important factor in the production of biogas digester [11].

Table 2. Average yield of TS, VS and pH by treatment.

Parameters ($m^3.kg^{-1}$)	Values obtained			
	T1	T2	T3	T4
Biogas yield/VS added	0.343	0.229	0.235	0.047
Methane yield/VS added	0.219	0.144	0.126	0.031
Biogas yield/TS added	19.144	34.208	0.781	0.071
Methane yield/TS added	12.243	21.538	0.420	0.047

Already slightly higher yield of T3 should be associated with the extrusion process, which may have altered the physical properties of shavings, increasing the availability of nutrients to the anaerobic process. However, a possible explanation for the low yield of T1 to T3 in relation occurs because the extruded fraction, there is a higher proportion of soluble nutrients available than in the non-extruded fraction, wherein the organic matter (fibers) occupied most of the volume [1].

The values found in this study are similar to other researches. Research conducted only with bovine effluent found biogas yield of 0.627 and 0.039 $m^3 kg^{-1}$ VS and TS added, respectively [2]. Similar results were found in the influence of TS content on biogas yield by VS from cattle manure, yield ranged from 0.548 to 0.186 $m^3 kg^{-1}$ VS, with the best yield with 92% of total solids [3]. Studies analyzing the average methane content produced from cattle manure obtained biogas and methane yield of 0.346 and 0.190 $m^3 kg^{-1}$ VS [4].

Biogas production: The specific daily biogas and methane production per m³ of digester, shown in Table 3, had best result for T1 and T2, with 0.284 and 224 m³, respectively. Previous researches are similar to T1, with daily biogas production of 0.171 m³ [14].

Table 3. Medium specific production of biogas and methane.

Parameters ($m^3.dia.m^{-3}$ in biodigester)	Values obtained			
	T1	T2	T3	T4
Specific production of biogas	0.284	0.158	0.224	0.003
Specific production of methane	0.167	0.099	0.119	0.002

The highest mean production of methane in biogas was 64.01% for the T1 and for T3 less than 53.69% (Table 4), being close to the range found in similar studies of the anaerobic treatment of dairy cattle manure in a tubular digester with medium methane concentration of 66.46% [1].

Table 4. Mean percentage of methane per treatment.

Parameter	Values obtained, %			
	T1	T2	T3	T4
Methane content	64.01	62.87	53.69	65.30

The lignin from the effluent from cattle may reduce the biodegradability of the waste and thus T3 is less efficient in methane production. Therefore, the shavings used as bed for cattle absorb part of digestible solids in anaerobic process reducing the mean percentage of methane per treatment around 15%.

The bibliography indicates that pre-treatment of lignocellulosic waste before being added to the digester, following the example as milling, can increase the efficiency of the activities of microorganisms and offers much potential for biogas production[1]. Other studies on the productivity of methane from manure with straw used as bed showed that methane production is higher due to the high content of VS absorbed by the bed and therefore for kg of straw added in manure an increase of 10% in methane production was obtained [2].

There are no studies of biogas production when combined with bovine effluent, but there are studies that show promising results for biodegradation of lignocellulosic material with production of 43% for chemical pre-treatment with acid and alkali to solubilize the lignocellulosic material [3]. Thermal pre-treatment with steam has also been shown to increase the biodegradability of lignocellulosic material [4, 5].

Statistical analysis: Linear regression was obtained: correlation coefficient adjusted of 0.747 (r^2); precision significant ($p < 0.01$) and grades of freedom equal to the residual 24. Therefore, the dependent variables accurately explain the behavior of the mean percentage of methane.

Conclusions

1. The shavings will negatively influence the methane content.
2. Effluent with TS content of around 0.5% shows low biogas production.
3. Effluent from dairy cattle with wood shavings require pretreatment.

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