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Comparison of the methane potential obtained by anaerobic codigestion of urban solid waste and lignocellulosic biomass

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Abstract

The purpose of this research was to compare the methane gas (CH₄) obtained through the anaerobic co-digestion between bean rind (*Vicia faba*) and pea rind (*Pisum sativum*) and the solid residues of El Macho stream of the city of Machala. For this, three 250 ml glass bioreactors were used, with the following composition: Reactor A (bean / sediment); Reactor B (pea / sediment); and Reactor C (bean + vetch / sediment). All bioreactors had a ratio of 1.7 between the lignocellulosic biomass (peel of bean and pea) and the RSU (sediment). A gas chromatograph was used to determine the methane concentration in the biogas obtained in the bioreactors. For the storage of the biogas, propylene bags were used. It was determined that, in Reactor A, after two weeks of anaerobic digestion, a greater concentration of methane was produced, with $39.52 \pm 0.28\%$; compared to $10.71 \pm 0.16\%$ produced in Reactor B; and $2.11 \pm 0.03\%$ in Reactor C. A comparison analysis of means was performed, where the statistical significance (p -value < 0.05) allows to conclude that the composition of the co-digested biomass does influence the production of methane gas.

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Keywords: Biogas; Methane; Organic sediment

1. Introduction

Global warming is the product of emissions in high concentrations of greenhouse gases product of human activities, among these gases the main ones are CH₄ and CO₂. These gases cause unbalanced changes in the temperature of the oceans and air, causing geographical changes such as the melting of the poles and, along with this, the rise in sea level and all kinds of natural disasters [1].

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Likewise, climatic patterns with high alteration rates produce diseases in humans, direct effects such as physiological changes by cold or heat. In this sense, the dynamics of contagious diseases derived from climatic modifications cause populations of epidemiological vectors to appear in areas eradicated due to their reproductive increase, causing ecohealth problems. All of the aforementioned, together with the decline of natural resources, puts the health of the population worldwide at risk [2].

Anaerobic digestion is a process in which the organic matter degrades in lack of oxygen, generating an alloy of gases product of microbial fermentation [3].

The most important product of anaerobic digestion is biogas which is composed of a set of gases, among them the most important one is methane in an approximation of 50–70, another important one is carbon dioxide in a proportion of 30–50, in addition there are some quantities of other gases such as hydrogen, oxygen, nitrogen and hydrogen sulphide depending on the organic matter of easily biodegradable material and the decomposition process [4].

Anaerobic digestion is currently used as a residual treatment process where energy is recovered as well as controlling environmental pollution [5].

The waste is the result of the activities that man performs daily. In Ecuador, the main sources of waste generation are agriculture, with an approximate percentage of 36%, among them we find plant and animal waste and 9% in the generation of urban solid waste (wastewater) [6–8]. The disproportionate growth of the population has contributed to the massive generation of urban solid waste, which has caused an increase in environmental pollution generated by the discharge of fluent sewage without previous treatment and control. A clear example is the Estero El Macho located in the city of Machala — Ecuador, which receives the discharge of these waters, generating sedimentation that is detrimental to the health of the population [9].

These wastes can be fed into an anaerobic digester to produce biogas. Co-digestion refers to the anaerobic digestion of multiple biodegradable substrates in a digester. The idea is to maximize the production of biogas in the digester by adding substrates that produce much more biogas per unit mass than a base substrate [10].

Biodigesters are a valuable alternative for the treatment of organic waste generated in agricultural enterprises, because they reduce the pollution load, eliminate odors and generate a renewable energy called biogas, which is a fuel gas that can be used to cook food, heat water, generate electricity, and obtain light directly using gas lamps [11,12].

The pure dung yielded appreciable biogas after seven days [13], researched on biogas produced from the anaerobic digestion of cow dung, spent grains and cassava peels/rice husk. They discovered that cow dung yields biogas faster than spent grains/ cow dung and cassava peels/rice husk. Spent grains/ cow dung were found to produce larger amount of biogas on complete digestion of the three wastes. The studies focused on the rate of biogas production and ultimately the cumulative biogas yield [10].

The objective of this research work was to design biodigesters at a laboratory scale in order to produce biogas from the anaerobic codigestion of lignocellulosic mass (pea peel, bean) and sediment from Estero El Macho in different proportions, applying new technologies to the production of new clean and renewable energies such as obtaining biogas [14]. It is important the reliability of an analytical method to validate the proposed in this article giving it a high degree of confidence therefore the research group, electroanalytical applications and bioenergy of the Technical University of Machala, is developing and validating several analytical methods, among which are those of gas chromatography [15].

2. Materials and methods

The sediments were collected in El Macho stream, located in the city of Machala, province of El Oro. The sediment samples taken were stored in sterilized glass containers of 400 ml volume, which were transported immediately to the Laboratory, for its codigestion later. The lignocellulosic biomass (bean peel + peas) was collected and stored and transported to the laboratory, in sterilized plastic bags and labeled. For the determination of biogas production, from the anaerobic co-digestion of urban solid waste (sediments) and lignocellulosic biomass (bean shell + peas), three bioreactors were prepared with a mixture of substrate (husk/sediment) in proportions 1.7. Bioreactor for the production, storage and measurement of the concentration of biogas generated. The analysis of the biogas composition generated was carried out in situ, through a FULI Gas Chromatograph. Hydrogen was used as carrier gas, with a temperature in the oven and injector of 250 °C, and the flame ionization detector (FID) at a temperature of 350 °C. A calibration curve was performed, with methane (CH₄) and carbon dioxide (CO₂) used as reference standards. All the readings were made in triplicate. For the statistical analysis of methane gas production, STATA software was used.

3. Results

It was determined that, twenty-one days after beginning the process of anaerobic digestion, the three bioreactors showed the highest concentration of CH₄. Using the previously mentioned experimental conditions, the retention times for CH₄ in reactors A, B and C under the chromatographic study conditions were 4.82; 4.91 and 4.95 min respectively, a peak area of 246,467; 156,917 and 4,012 mV s.

In Reactor A, after two weeks of anaerobic digestion, a greater concentration of methane was produced, with $39.52 \pm 0.28\%$ (Fig. 1); compared to $10.71 \pm 0.16\%$ produced in Reactor B; and $2.11 \pm 0.03\%$ in Reactor C.

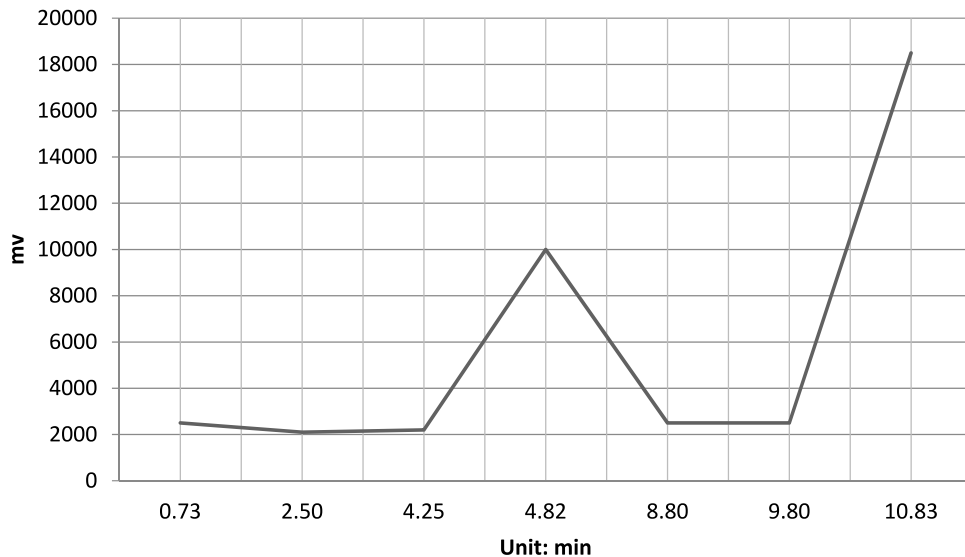


Fig. 1. Chromatogram of the biogas obtained in Reactor A.

From the measurements of CH₄ generated by the peel of bean and pea with sediment, it was obtained that in reactor A comprised of 102 g bean peel/60 g sediment (63% bean peel–37% seiment), it was the one that produced a higher percentage of CH₄ (39.8%). Our results are in agreement with what is reported in Table 1, where it can be observed that the bean residues have a higher production potential of 27.54 CH₄/metric Ton compared to the pea peel 17.50 CH₄/metric Ton. Regarding the retention time for the production of biogas, our results coincide with that reported by [15], where co-digestion was performed between 70% cassava waste water (CWW) + 30% cow dung (CD) system flamed on the 16th day, obtaining the highest yield of biogas, but with a concentration bigger of 79,9%.

Table 1. Biogas potential for different fruit and vegetable residues.

CATEGORY OF WASTE	Type of waste	m ³ /Tm AÑO	CH ₄ %	CH ₄ m ³ /Tm	Reference
Vegetables	Asparagus, peas, carrots	135	55	74,25	[16]
Fruits	Apple pulp	171	60	102.6	[16]
Fruit and vegetable peel	Orange shells	147.6	50	73.5	[17]
	Cocoa shells	95.4	50	47.7	[18]
	Bean shells	55.08	50	27.54	[19]
	Pea shells	35	50	17.5	[16]
	Banana shell	262.8	60	157.08	[20]

A comparison analysis of means was performed (Table 2), where the statistical significance (value $p < 0.05$) allows to conclude that the composition of the co-digested biomass influences the production of methane gas $Pr(T > t) = 0.0000$ and that the values of this product are different in all Reactors

Table 2. Analysis of the proportion of the means.

Group	Obs	Mean	Std. Err	Std. Dev.	(95% Conf. Interval)
A	3	0.3951	0.0015	0.0027	0.3883
B	3	0.1071	0.0009	0.0016	0.1031
Pr(T > t) = 0.0000					
Group	Obs	Mean	Std. Err	Std. Dev.	(95% Conf. Interval)
B	3	0.1071	0.0009	0.0016	0.1031
C	3	0.021	0.0001	0.0002	0.0203
Pr(T > t) = 0.0000					
Group	Obs	Mean	Std. Err	Std. Dev.	(95% Conf. Interval)
A	3	0.3951	0.0015	0.0027	0.3883
C	3	0.021	0.0001	0.0002	0.0203
Pr(T > t) = 0.0000					

4. Conclusions

Using the proportions of bean shells and pea with sediments, and their respective chromatographic analyzes, after twenty-one days beginning the process of anaerobic digestion, the three bioreactors showed the highest concentration of CH₄. Reactor A with a substrate proportion of 102 g/60 g, of bean rind and sediment respectively, produced a higher concentration of CH₄ with a percentage of 39.8%, compared to reactors B and C, with percentages of 10.86% and 2.11%.

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