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Biogas production from cattle manure and sugar cane tip *(Saccharum officinarum)*

Producción de biogás a partir de estiércol de ganado bovino y punta de caña de azúcar *(Saccharum officinarum)*

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Abstract

The purpose was to study the use of bovine manure mixed with sugarcane tip (*Saccharum officinarum*) in the production of biogas. A semicontinuous biodigester prototype of 1.7 m long and 6 in. diameter was designed and built with CPVC material. The waste was collected fresh for physical-chemical characterization, based on basic laboratory methods. Then the prototype was put into operation under controlled conditions. The biodigester was fed in two moments: the first, with 200 g of manure diluted in 750 ml of water and the second with a mixture of 200 g of manure and 50 g of cane tip, diluted in 750 ml of water. Finally, the volume of biogas produced and its quality were measured, with a water column pressure gauge and with a 540 multitec device, respectively. The results show that manure with the cane tip generates more biogas, this is attributed to the higher percentage of volatile solids in the mixture, whose organic components were converted to methane. The biogas production studied is a management option for waste from the agricultural sector and thus mitigate CO_2 emissions in the region.

Bovine manure, Sugar cane tip, Biogas

Resumen

El propósito fue estudiar el uso de estiércol bovino mezclado con punta de caña de azúcar (*Saccharum officinarum*) en la producción de biogás. Se diseñó y construyó un prototipo de biodigestor semicontinuo de 1.7 m. de largo y 6 pulg. de diámetro, con material CPVC. Se recolectaron en fresco los residuos para su caracterización físico-química, basada en métodos básicos de laboratorio. Después se puso en operación el prototipo bajo condiciones controladas. Se alimentó el biodigestor en dos momentos: el primero, con 200 g de estiércol diluido en 750 ml de agua y el segundo con una mezcla de 200 g de estiércol y 50 g de punta de caña, diluida en 750 ml de agua. Finalmente, se midieron el volumen producido de biogás y su calidad, con un manómetro de columna de agua y con un equipo multitec 540, respectivamente. Los resultados muestran que el estiércol con la punta de caña genera más biogás, esto se atribuye al mayor porcentaje de sólidos volátiles en la mezcla, cuyos componentes orgánicos se convirtieron en metano. La producción de biogás estudiada es una opción de manejo para los residuos del sector agropecuario y de esta manera mitigar las emisiones de CO_2 en la región.

Estiércol bovino, Punta de caña de azúcar, Biogás

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Introducction

Currently the world is suffering from environmental deterioration due to climate change. This is because today man performs various activities that negatively impact the environment. Currently, according to data from the Mauna Loa observatory in Hawaii, the CO2 concentration recorded in the month of May this year, more than 415 ppm, much more than at any other time in human history (CO2.earth, 2019).

Some of the activities considered with the highest greenhouse gas emissions (methane and carbon dioxide) are those of the livestock sector, particularly the generation of manure that pollutes the soil, water and air, impacting the environment considerably (Varnero, 2011).

On the other hand, in agricultural production waste is also generated, as in the case of sugarcane with its high production of green and dry matter per unit area that translates into non-industrializable biomass (tips, leaves, sprouts, stems immature) that can be valued. Although these wastes are used for feeding cattle, their use is not total because they have low levels of protein, which do not cover the needs of ruminants, so they are used only to supplement diets (Galina, 2007).

The proper use and management of biomass is an important issue, as it is also considered susceptible to being transformed into alternative energy (García, 2016). It is necessary to study and know the useful resources that each region has in order to quantify the potential available for energy generation and contribute to national policies for the benefit of climate change and sustainable development of the planet (Acevedo and Rojas, 2017) .

According to Torres, 2016, sugar cane produces a large amount of biomass, composed in its state of maturity by 71.8% of stems, 12.6% of cane tips (buds), 8.7% of leaves and 6.9% of sprouts (Torres, 2006). In the State of San Luis Potosí, at the close of the 2016-2017 harvest, the production volume was 653 thousand tons of sugar, occupying the third national place. These data illustrate the large amount of cane tip that is available in the sugarcane region (Huasteca) as biomass for the production of biogas, considering its use in feeding cattle with the limitation that is not a total use.

In the country, goals for the mitigation of climate change have been established, there are also laws on energy matters that consider the incorporation of clean energy into the National Electricity Sector (SEN). While in the rural sector the use of biogas has generated interest in being an easily implemented technology (SENER, 2016). Biogas is mainly composed of a mixture of gases such as methane (CH4), carbon dioxide (CO2), hydrogen sulfide (H2S), among others. In addition, it is a gas that originates from the natural process of the decomposition of organic matter in the absence of air (FIRCO, 2010).

Therefore, the objective of this research was to study the use of manure from fresh cattle mixed with sugarcane tip (Saccharum officinarum) in the production of biogas. For this, a semi-continuous type CPVC biodigester was used, fed with the mentioned residues. The physical-chemical characterization was carried out and the quantity and quality of the biogas generated from them was evaluated.

Methodology

This research was carried out in the Chemistry Laboratory of the Technological Institute of Ciudad Valles, located in Ciudad Valles, S.L.P, Mexico. The Municipality of Ciudad Valles, is located to the East of the state of San Luis Potosí, in the Huasteca region. It is at an average height of 200 meters above sea level. Its climate is hot humid; in spring and summer times, maximum temperatures of up to 50 ° C are presented and in winter there are minimum temperatures of 6 to 8 ° C with a humid cold.

According to the objectives set forth in this paper, an investigation was carried out that conforms to the experimental and explanatory type. It is considered experimental because the organic waste (manure and cane tip) was subjected to the biodigestion process in order to study the production of biogas from them; and it is considered explanatory because of the need to look for cause and effect relationships to explain why the results. A work strategy was designed, which consisted of four phases:

Sample collection

Fresh samples of cattle manure and cane tip were collected for the study, in a cattle ranch and cane of Ciudad Valles.

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The samples were collected every week, the material was kept refrigerated, and from there the waste was prepared to feed the biodigester daily.

Physical-chemical analysis of manure and manure with sugarcane tip

The samples were tested to identify the conformation of the residues, as illustrated in Figure 1. These tests included basic laboratory analysis methods based on the procedures of the respective Official Mexican Standards. The tests performed were moisture, ash, and total nitrogen. Likewise, the percentages of total solids, volatile solids, organic carbon and the C / N ratio were calculated. A sample with three repetitions of 5 g was taken from each residue mixture, to perform the corresponding analyzes, which are described below:

1) Humidity: As established by NMX-F-083-1986, samples were introduced in a drying oven at 105 ° C, until constant weight was obtained between two consecutive weighings. To calculate the moisture percentage, equation 1 was applied:

$$\% \text{ moisture} = \frac{(B-A)-(C-A)}{B-A} \text{x}100 \quad (1)$$

Where:
A = Weight of the bottle at constant weight (g)
B = Bottle weight at constant weight with wet sample (g)
C = Weight of the bottle with dry sample (g)

Figure 1 Moisture determination of organic waste
Own Source

2) Total solids (St): They were obtained by difference, with respect to the percentage of humidity. The content of ashes and volatile solids was determined.

Ashes: This test was carried out using NMX-F-066-S-1978, where 2 g of the wastes were taken from which the humidity was determined and the ashes percentages were calculated. This percentage was obtained by difference in weights, using equation 2:

$$\% \text{ of ashes} = \frac{(Crucible\ weight + ash) - (crucible\ weight)}{Sample\ weight} \text{x}100 \quad (2)$$

Volatile solids (Sv): Once the percentage of ashes was determined, the percentage of volatile solids was calculated by difference.

Total nitrogen: It was determined by the Kjeldahl method, based on the destruction of organic matter with concentrated sulfuric acid. Due to chemical reactions, ammonia is released, which is recovered by distillation and receiving it in sulfuric acid. Upon reacting, ammonium sulfate is formed, the excess acid is titrated (titrated), with sodium hydroxide using as a methyl red indicator. (NOM-F-68-S-1980).

C / N Ratio: The percentage of Organic Carbon was calculated from the percentages of organic matter (volatile solids). C / N ratios were calculated for each of the samples, using equations 3 and 4:

$$\% \text{ organic coal} = \frac{\%\ organic\ matter}{1.724} \quad (3)$$

Where:
1.724= Conversion factor

$$\text{C/N} = \frac{\%\ Organic\ Carbon}{\%\ of\ total\ nitrogen} \quad (4)$$

Where C / N = Carbon Nitrogen Ratio

Biodigester Operation

Because there is only one biodigester prototype, the study was done in two moments and under laboratory conditions with a controlled temperature of 26 ° C. In the first moment the biodigester was fed for 50 days with fresh manure, diluted in water in a 1: 3 ratio. In a second moment, the biodigester was fed for 50 days with manure and sugarcane tip, diluted in water in a 1: 4: 15 ratio, as shown in Table 1.

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Organic matter used	Water	Manure	Sugarcane Tip
Manure	750 ml.	250 g.	0 g.
Manure with sugarcane tip	750 ml.	200 g.	50 g.

Table 1 Quantities of organic matter introduced into the biodigester
Own Source

Once the samples were taken, they were homogenized from the amounts expressed in Table 1, and for this purpose a blender was used that allowed the materials to be fully incorporated. The mixtures were poured into the digester daily and in both cases (manure alone and manure mixed with sugarcane tip) the feeding time was 50 days. See figure 2.

Figure 2 Feed to the digester with the mixture of organic waste
Own Source

Study of biogas production

During the operation of the biodigester were measured: days of operation, days of feeding, days without biogas production, days with biogas production, days of biogas production without food and the volume of biogas produced. The latter was estimated daily with the support of a water column manometer that uses the principle of water displacement under the ideal gas law. Finally, in both cases the quality of biogas produced with the multitec 540 equipment (methane concentration, CO2 and H2S) was measured, as shown in Figure 3 and the results are shown in Table 4.

Figure 3 Measurement of biogas quality
Own Source

After the measurements, the generated methane gas was burned, using a Bunsen burner.

Results

Physicochemical characteristics of organic waste

In the present study the physicochemical characteristics of organic waste were determined, the results are shown in Table 2.

Physical-chemical test	Fresh manure		Manure with sugarcane tip	
	Obtained	Theoretical (Varnero, 2011)	Obtained	Theoretical (Varnero, 2011)
% Humidity	89.15	85-51	87.55	ND
% Sól. T	10.85	13.4-56.2	12.45	ND
% Ash	12.8	23.67	8.12	ND
% Sól. V	87.2	76.33	91.88	ND
% Carbon	22	25	22.88	ND
% N	1	1.5	.915	ND
C/N	22:1	25:1	25:1	ND

Table 2 Results of the physical-chemical tests performed on organic matter
Own Source

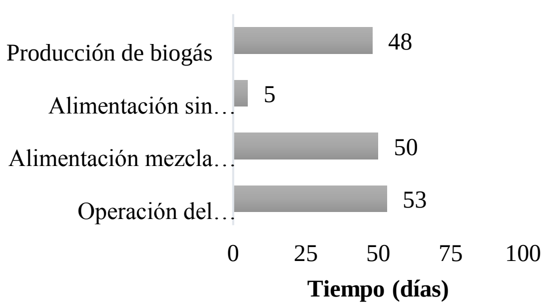
In the chemical analysis it was obtained that of the percentage of total solids shown in Table 2, the amount of volatile solids in the two samples (fresh bovine manure and cane-tipped manure) was above the theoretical reference amount that was 76.33% and thus, below the percentage of ashes. In this case, 87.2% volatile solids were obtained in the sample of bovine manure and 91.88% was obtained in the sample of mixed manure with cane tip.

This indicates that when manure is mixed with the tip of sugarcane there may be a greater amount of methane because the percentage of volatile solids is higher, the organic compounds they contain are converted to methane.

Additionally, in determining the Carbon / Nitrogen ratio of the residues studied, Varnero (2011), reports that the optimal ratio for the methanogenic process to be carried out is 25/1. In the present study, the C / N ratio determined in fresh bovine manure was 22: 1 and in sugarcane-dung manure it was 25: 1. These results show that the mixture of manure with the tip of sugarcane has an optimal C / N ratio for the decomposition of organic matter, being present in appropriate proportions for a good feed of methanogenic bacteria.

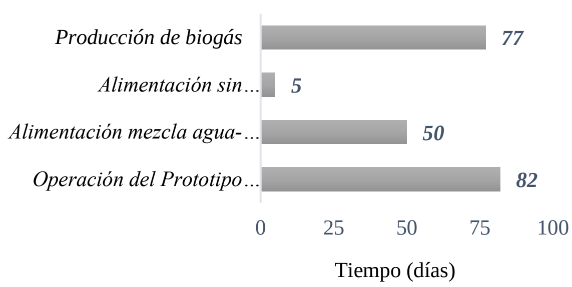
Study of biogas production

In this study, the times and volumes of biogas production were measured both in manure and in manure mixed with sugar cane tip. The measurements of the various activities during the operation of the digester are shown in Graphs 1 and 2.



**Laboratory controlled temperature of 26 ° C*

Graphic 1 Operating times of the laboratory biodigester prototype (water-bovine manure)
Own Source



**Laboratory controlled temperature of 26 ° C*

Graphic 2 Operating times of the biodigester prototype in the laboratory (water-bovine manure-cane tip)
Own Source

Thus, the production of biogas expressed in Table 3 illustrates that there was a greater volume of biogas during the time of operation of the digester, when the manure was mixed with the tip of sugarcane, obtaining 203% more than when only manure was used. This is explained by the greater amount of volatile solids that were obtained in the mixture of manure with the cane tip (91.88%) and the good C / N ratio, which indicates a greater presence of organic components than during the process of biodigestion with the work of methanogenic bacteria became methane.

Fresh manure		Manure with sugarcane tip	
Average biogas production per day (l)	Volume of biogas produced (l)	Average biogas production per day (l)	Volume of biogas produced (l)
3.82	183.23	4.85	373.61

Table 3 Biogas production
Own source

Likewise, with respect to the quality of biogas, this was better when the manure was mixed with the cane tip, since here a higher concentration of methane was obtained and consequently less CO_2 and H_2S, as can be seen in Table 4 The above is attributed to the best conditions for the biodigestion process present in the manure mixture with cane tip, derived from the C / N ratio.

Biogas quality			
Residue Organic	Methane (CH_4)	Carbon dioxide (CO_2)	Hydrogen Sulfide (H_2S)
Fresh cattle manure	61.48%	37.40%	1.125%
Manure with sugarcane tip	66.1%	32.9%	1.0%

Table 4 Biogas quality obtained
Own Source

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December, 2019 Vol.5 No.9 6-11

Conclusions

The amount and composition of the biogas obtained through the biodigestion process depended largely on the digested material. In the present investigation a greater amount of biogas (373.61 l.) Was obtained when the manure was mixed with sugarcane tip, compared to when only manure was used (183.23 l.).

These results are explained by the higher percentage of volatile solids obtained when the cane tip was added, whose organic components were converted to methane. In addition, a better C / N ratio of 25: 1 was obtained, being an optimal ratio for the decomposition of organic matter, being present in appropriate proportions for a good feed of methanogenic bacteria that favored methane quality.

Due to the important sugarcane and livestock activity in Huasteca Potosina, it is recommended from this study, to quantify the energy potential of agricultural waste that allows us to project the capacity of usable energy in the region through biomass technologies. The above, in order to promote the stability of production systems based on the sustainable use of natural resources, so that the needs of future generations are not compromised.

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