Biogas production under different cattle manure concentrations and temperature ranges

Producción de biogás bajo diferente concentración de estiércol bovino y rangos de temperatura

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Abstract

Experimental anaerobic biodigestion test results are presented to obtain biogas from varying bovine manure loads and temperature. In this experiment a batch type biodigester was employed, it was constructed using polyurethane hermetic sealed bottles, high temperature silicon was used for sealing assurance. Four levels of bovine fecal organic matter (FOM) were used as degradation material (0, 62.5, 125, 250 g) under 2 different temperature grades (27 and 35 °C). Generated biogas production was measured under temperature grade conditions, methane production was also estimated (CH_4). Better effectiveness in biogas production was obtained in the FOM concentration and temperature highest levels samples.

Biogas, Methane, Temperature

Resumen

Se exponen los resultados de un ensayo experimenta de biodigestión anaeróbica para obtener biogás variando las condiciones de carga y temperatura. Para ello se utilizó el biodigestor tipo batch construido a partir de bottellas de poliuretano sellados herméticamente con silicon de resistente a altas temperatura. Como materia prima se utiliza materia orgánica fecal (MOF) bovino en diferentes concentraciones (0, 62.5, 125, 250g) y se colocan los digestores en diferentes temperaturas (27°C, 35°C) donde se miden la producción de biogás generado en las condiciones establecidas de temperatura estimándose la producción de metano (CH_4). Los valores obtenidos indican que la mayor concentración de MOF bovina a una mayor temperatura tiene una mayor efectividad en la producción de biogás.

Biogás, Metano, Temperatura

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Introduction

Energy is the main ingredient of the world economy, and even if we work hard on energy efficiency and invest in new technologies to reduce energy costs, oil and natural gas will remain the main source of energy for many years to come. The exponential development of industrial activities suggests that global demand for oil and gas will continue to grow in the short term. However, demand will be affected by the decline of gas fields, thus increasing the cost of fuel sources (Soler, 2009; Forsberg, 2008 and Demirbas & Balat, 2006).

However, the uses of manure can be beneficial in today's livestock economy, since bovine faecal organic matter (FOM) or manure has the capacity to produce methane (CH_4) for energy use, at the same time it treats water, using FOM as a source of energy, apart from obtaining a manure free of pathogenic organisms (Weiland, 2010).

The Comarca Lagunera is one of the main livestock basins, producing around 925,000 tons annually, where a large part of this is used to fertilise agricultural land (Figueroa et al., 2009). These remnants go on to generate methane (CH_4), the second most important long-lived greenhouse gas, 60% of which is caused by anthropogenic activities (livestock, fossil fuel exploration, etc.) (WMO, 2013).

The importance of using bovine MOF produced by cattle as stable waste is to take advantage of the CH_4 generated from the fermentation of bovine MOF and to avoid CH_4 pollution by transforming it into lower greenhouse gases and energy that can be used in the stable and thus reduce the energy costs of the process.

The objective of this work was to determine the best temperature-concentration interaction of bovine faecal organic matter layers to generate the highest number of gases without the use of a gas chromatograph.

Methodology

Location of the experimental site

The present investigation was carried out in the laboratory of the Universidad Politécnica de Gómez Palacio, located at carretera El Vergel-La Torreña km 0.820, C.P 25120 locality El Vergel, Gómez Palacio, Durango. México (25°38'20.0 "N 103°31'51.1 "W) and in the laboratory of the laboratory of the Universidad Autónoma Chapingo. Unidad Regional Universitaria de Zonas Aridas, Bermejillo, Durango. Mexico (25°53'44.4 "N 103°36'05.1 "W). During the period from September to December 2014.

Characteristics of the manure

The manure was donated by the stable Antonio Rodriguez Ramirez in Ejido Esmeralda, municipality of Gomez Palacio, Durango (25.7459133, -103.4281867). The manure had the following properties (Table 1).

Analysis	Unit	Result
pH		8.93
Conductivity	dS m^{-1}	1.724

Table 1 Manure characteristics

Experimental design

A two-factorial design (2x4) with 3 repletions was used with the following study factors: A) Temperature (27°C, 35°C) B) concentration of bovine MOF (0 g, 62.5 g, 125 g, 250 g).

Incubator design

An incubator was designed using everyday materials such as high-density polyethylene bags which were cut into 1.5x2m pieces.

A solid cement table, which served as the side of the incubator, was then placed on the wall where a solid cement table is located. The Taylor model 5327 liquid thermometer with direct reading was placed on the wall where the different treatments were placed (27°C and 35°C respectively), due to an extension of one of the thermometers.

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Two 100w spotlights were also placed on one side of the bottles at a height of 30 cm from the 1.5 L polyethylene terephthalate bottles, and two 100w lamps were placed on the other side of the bottles at a height of 30 cm from the 1.5 L polyethylene terephthalate bottles.

1.5 L polyethylene terephthalate bottles, and the sensor of one of the thermometers was placed in the middle of the bottles, thus obtaining an average response of the temperature of the bottles.

Design of the biodigesters

The biodigesters were installed on 24 October in the process laboratory facilities located between building A and building B; the biodigesters were made of polyethylene terephthalate bottles with a volume of 1.5 litres, where they were filled with manure in concentrations of 0 g, 62.3 g, 125 g and 250 g and mixed with 1 litre of water; this step was repeated in the 24 bottles with screw caps.

The caps of the polyethylene terephthalate bottles were pierced with a Truper CAU-140 pistol soldering iron and perforations of 1 cm were made. The caps were then sealed with Nasca RTV silicone and carefully placed on the corresponding bottles.

Data analysis

Data analysis was performed using the statistical package SPSS IBM Statistics version 20®. Each treatment was measured in three replicates under a two-factor design for analysis of variance (ANOVA) (F1: Temperature & F2: MOF concentration).

Variables to be evaluated

Independent variable: Temperature 27°C and 35°C and bovine MOF concentration at 0 g, 250 g, 500 g and 750 g.

Dependent variable: Biogas volume. Concentration of bovine MOF: The concentration of bovine MOF is understood as the mixture of different masses of manure as raw material source in 1 L H_2O.

Conduct of the experiment

The different concentrations (62.5 g, 125 g, 250 g) were weighed on a digital balance (Pioneer model Ohaus®) and then the different concentrations were placed in each polyethylene terephthalate bottle containing one litre of water and capped with RTV silicone and sealed.

After 24 hours, the available air inside the polyethylene terephthalate bottles is extracted and the 12 polyethylene terephthalate bottles are placed in the incubator at a temperature of 35°C. The rest of the 24 polyethylene terephthalate bottles are placed at room temperature. For 30 days the biogas is extracted with 20mL, 10 mL and 1mL syringes.

Results and discussion

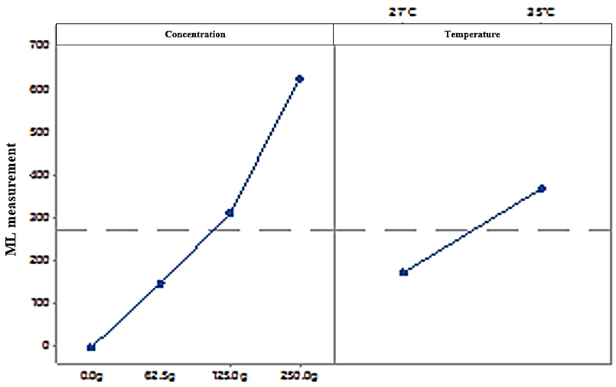
Effect of concentration and temperature on biogas production

The results obtained from the statistical support SSPS IBM, shows the main effects of the factors (concentration and temperature) where a significant difference was found ($p<0.05$) indicating that both concentration and temperature influence biogas production in the bioreactors and their respective interactions (Table 2).

F.V.	Sum of squares	*g.l.*	Mean squares	F value	P V
Conc.	39255009.62	3	1308 13085003.20	2084.14	.00
Temp.	7069774.232	1	7069774.232	1126.05	.00
C*T	5206485.672	3	1735495.224	276.42	.00
Error	4470184.855	712	6278.350		
Total	109403679.03	720	719		
Total	56001454.38				

Table 2 Analysis of Variance of main effects and interactions of biogas production. Using α: 0.05, S= 79.23, R^2= 92.0% and R^2 (adjusted)=91.94%

The main effects of the experiment were found to have a positive interaction with the higher the concentration and the higher the temperature, the higher the biogas production in each of the bioreactors or treatments used (Graphic 1).



Graphic 1 Interaction of main effects on biogas production

Comparison of means of main effects and interactions in biogas production

Based on the results of the two-factor ANOVA, the means were compared by Dunnett's method and the means of biogas production of the concentration factor were compared to verify that biogas production is influenced by concentration; where it was shown that the concentration factor influences biogas production, together with the higher concentration of bovine MOF indicating higher biogas production (Table 3).

Concentration	Half	Group
0 (Control)	0	A
62.5	147.9483	
125	313.0044	
250	628.4122	

Table 3 Comparison of biogas production means comparing concentrations with a control. Means not labelled with the letter A are significantly different from the control Dunnett α: 0.05

Estimating a CH_4 production of 63% of the total volume of the averages can produce around 93.2074, 197.1927, 335.8996 mL per day respectively at the concentrations of 62.5, 125, 250 g.

While the means obtained using the tukey method with shows that temperature influences the biogas production where the highest concentration was at temperatures of 35°C. This proves what Nallthambi (1997) mentioned in his research on anaerobic digestion of biomass for methane production (Table 4).

Temperature	Half	Group
35 °C	371.433	A
25°C	173.250	B

Table 4 Comparison of temperature means for biogas production. Means that do not share letters are significantly different, α=0.05

Both methods indicate that the concentration of 250 g at a temperature of 35 °C yields the highest concentrations of biogas. However, when comparing the means of the interactions between the two factors (concentration and temperature), it is observed that the best treatment was the one with the highest concentration and the highest temperature, which shows a significant difference ($p<0.05$) with respect to the other interactions.

However, the interactions of 125g at 35°C and 250g at 26°C are statistically equal; the same happens with the interactions 62.5g at 35°C and 125g at 27°C, having differences respectively with the interaction of 62.5g at 27°C, where it is the treatment with the lowest yield in comparison with the others (Table 5).

Concentration * Temperature	Half	Group
250 g 35°C	855.020	A
125 g 35°C	432.822	A
250 g 27°C	401.804	B
62.5 g 35°C	197.889	C
125 g 27°C	193.187	C
62.5 g 27°C	98.008	D
0 g 35°C	0	E
0 g 27°C	0	E

Table 5 Comparison of means of concentration and temperature interactions on biogas production. Means not sharing a letter are significantly different, Tukey α: 0.05

Biogas production was affected by temperature conditions; it was theorised that the levels of chemical and biological reaction increase with increasing temperature and hence biogas increase; as in the experiment conducted by Sosa et al. (1999) who used bovine manure as feedstock, a considerable increase in biogas production was observed. The same conclusion was reached by Zeeman (1991) using cattle manure, where he indicated that high temperatures increase rapidly after 30 days at a temperature of 25-30 °C respectively.

However, in the research by Rorick et al. (1980) using feed water as feedstock in reactors at 40-60 °C he obtained a methane production of 166 mL/g volatile solids of feed to the reactor at a temperature of 60°C and 162 mL/g volatile solids of feed to the bioreactor at a temperature of 40°C where he observed this concentration in a retention time of 6 days.

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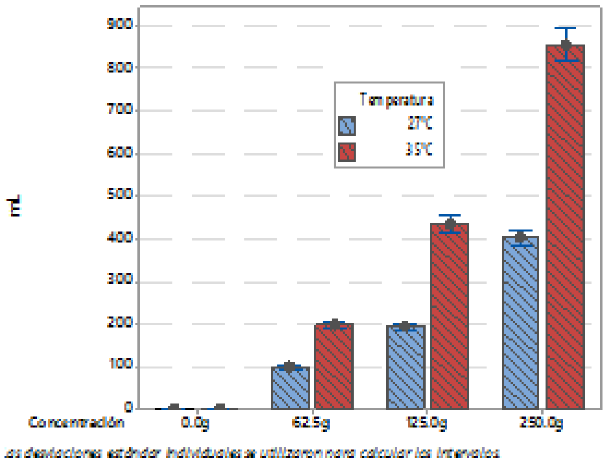
While at a concentration of 250g at 35°C and estimating a methane production of 63% of the volume in 6 days, a volume of 107.7325/g of used bovine manure was obtained, which indicates that the differences between both experiments is similar and is influenced by the temperature and concentration (Graphic 2).



Graphic 2 Effect of MOF concentration and temperature on biogas production

However, some factors that may influence methane production are metals, pH, hydraulic retention time, which were not taken into account, but according to El-Mashad et al. (2004) in their investigation of the effect of temperature on beef cattle manure and Cottle et al. (2011) in their investigation of methane-producing ruminant enterobacteria mention that these factors are important for methane production in biogas as they influence the metabolic effects of the bacteria themselves found in ruminants.

Conclusion

Because the Comarca Lagunera is the second largest dairy basin in the country, producing 925,000 tons of manure per year, without exploiting the energy level of the manure, and with the increasing energy demand and rising prices, an alternative is being sought to reduce the costs of livestock farmers. An alternative to exploit the energy level of the manure is the production of biogas from the manure produced in La Comarca Lagunera and thus reduce the energy consumption of the farms.

In addition, the ambient temperature of La Comarca Lagunera can facilitate the production of biogas and methane. Due to the temperatures of 28 to 40 °C generated there.

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