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Biomass storage for further energy use through biogas production

A.D. Atem [a,b,c,d,*,1], M.E. Indiveri [b,c,1], S. Llamas [b]

[a] Instituto CEDIAC, Facultad de Ingeniería, Universidad Nacional de Cuyo, Centro Universitario, 5500 Mendoza, Argentina
[b] Instituto de Medio Ambiente, Facultad de Ingeniería, Universidad Nacional de Cuyo, Centro Universitario, 5500 Mendoza, Argentina
[c] Instituto de Energía, Universidad Nacional de Cuyo, Centro Universitario, 5500 Mendoza, Argentina
[d] Consejo Nacional de Investigaciones Científicas y Técnicas – CONICET, Mendoza, Argentina

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ABSTRACT

The present work approaches the residual biomass conservation for later digestion in an anaerobic batch reactor. Twenty 4 L capacity PET reactors were used. A measuring device was constructed to quantify the biogas production. As substrate were used tomato wastes from local industry and rumen fluid as inoculum. Digestion start up was able to be controlled by varying the temperature, during a period of 118 days was not verified biogas production. After re-inoculated with rumen fluid stabilized for 34 days, biogas production was verified. They were obtained 0.10 m^3 of biogas per kilogram of volatile solids, with 50% of methane content.

1. Introduction

1.1. Objective

The objective of this work, is to control the beginning of biogas production from agro-industrial wastes, to store energy as biomass instead of keeping it as gas, due the fact that the volume needed to store biomass is several times minor than the volume required to store gas. For this purpose it is needed to preserve biomass in such form for further biogas production.

It must be considered that the agroindustry in the province of Mendoza, Argentina produces its wastes in summer, against the station of its energetic unsatisfied demand (winter).

The present work informs about the control of the methanogenesis start up in laboratory scale. The parameters that influence the beginning of the methanogenic production are physical, biological and chemical [1].

This work considers the mixing, the influence of the light, the substrate aggregation state and the inoculation, meaning the introduction of microorganisms in quantity and quality, in such a way that the start up is guaranteed.

2. Material and methods

2.1. Experience

Tomato waste was used as substrate, principally composed by pip and peel. The sample was taken from a local industry and transported in plastic packages. The first inoculum used was fresh rumen fluid taken from a local slaughter house. The second inoculum used was the same rumen fluid, but it was stabilized for 110 days at room temperature.

The experiences were carried out in twenty transparent PET reactors, of 4 L of capacity each one. They were sealed

* *Corresponding author*. Instituto CEDIAC, Facultad de Ingeniería, Universidad Nacional de Cuyo, Centro Universitario, 5500 Mendoza, Argentina. Tel.: +54 261 4135000x2187.
E-mail addresses: alexis.atem@gmail.com (A.D. Atem), elisaindiveri@gmail.com (M.E. Indiveri), sllamas@uncu.edu.ar (S. Llamas).
[1] Tel.: +54 261 155108343.

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Image 1 – Reactors disposition in thermostatized bath.

with silicone. The gas exit for the reactors is a ½″ tank adapter with a spherical valve. The reactors were arranged in a thermostatized bath at 37 °C, according to Image 1. The arrangement follows a matricial order, where the different rows are:

Row A: The load was processed by a crushing machine and they were mixed during the experience.
Row B: The load was processed by a crushing machine and they were not mixed.
Row C: The load was processed by a crushing machine; they were mixed during all the experience and covered to observe the light influence.
Row D: The load was not processed and they were mixed during all the experience (Table 1).

Each column reflects the inoculum concentration, Reactor 0 is the one without inoculation; Reactor 1 was inoculated by 10% of ruminal fluid, Reactor 2 by 20%, 3 by 30% and 4 by 40% of the substratum weight.

To calculate the substrate proportion, water and inoculum, were considered that:

The total weight of substratum, water and inoculum was 1000 g.
The total solids percentage inside the digestor was 15%. The relation inoculum/substrate was increasing from 0% to 40%.
The quantification of total and volatile solids is shown in Table 2. The loading of the reactors was according to this value.

2.2. *Agitation*

Reactors were manually mixed on Monday, Wednesday and Friday.

Table 1 – Reactors distribution.

A–0	A–1	A–2	A–3	A–4
B–0	B–1	B–2	B–3	B–4
C–0	C–1	C–2	C–3	C–4
D–0	D–1	D–2	D–3	D–4

Table 2 – Total and volatile solids.

	TS%	VS%
Tomato	17.28%	93.62%
Inoculum	3.39%	80.65%

2.3. *Temperature*

Before the reinoculation, the temperature was kept constant at 37 °C 5 days of the week and then it was left to go down to room temperature. This was made in order to avoid the beginning of the methanogenic activity. Once re-inoculated, the reactors were kept at 37 °C, except in two opportunities.

2.4. *Measurement of gas volume*

The measurements for biogas volume were taken with a device constructed for such purpose [2]. The equipment consists in two PVCs tubes placed vertically, one of them of 0.50 m of height and enclosure in both ends and other one of 1 m of height, opened in the top, reaching approximately 15 and 30 L of capacity respectively. To visualize the water difference provoked by the biogas pressure, were adapted in each of these vertical pipes a crystal PVC's transparent hose. Both pipes are in parallel disposition, they are communicated by their bottoms, creating an opened pipe barometer, besides the volume measure, the device provides all the time the internal pressure value inside the reactor. Image 2 shows the device.

Biogas composition was analyzed by gas chromatography. Also the biogas obtained was forced to pass through a filter filled with iron filings to remove the sulphidric acid contained in the gas. It was measured up once a week: pH, partial and total alkalinity and acidity.

Image 2 – Gas volume measuring device.

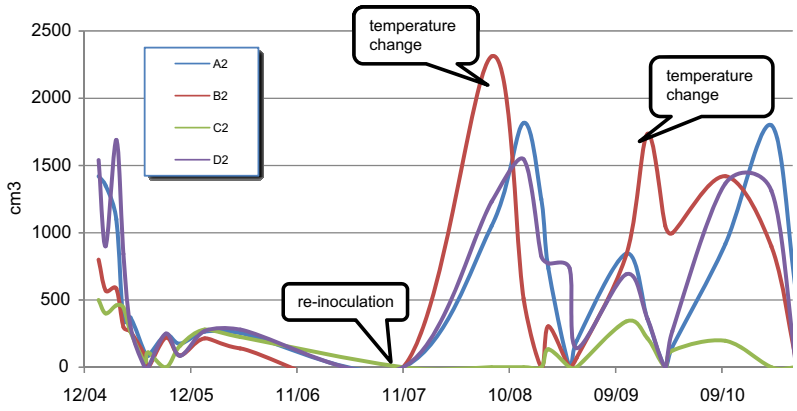

Illustration 1 – Biogas production in re-inoculated reactors [cm³].

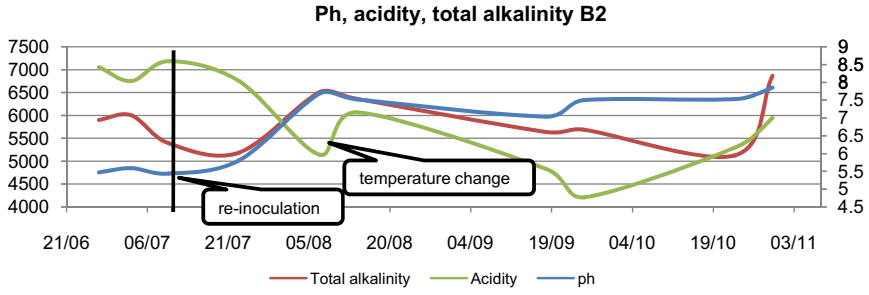

Illustration 2 – Acidity, alkalinity and pH in B2 reactor.

2.5. *Reinoculation*

The reactors of the number 2 series were re-inoculated to verify the possibility of biogas generation from waste stored during a 118 days period. It was used ruminal fluid stabilized at room temperature for the reinoculation. The inoculum volume added was 10% of the weight content in the reactor, meaning 100 g.

3. Theory/calculation

Commonly the volatile fatty acid concentration in a reactor does not overcome the 2000–3000 mg/L, expressed as acetic acid. If this level is exceeded, the methane production can diminish whereas the acid production continues and the digestion will stop in two or three days due to the fact that the methanogenic bacteria cannot use the acids at the same speed that this are produced.

The ideal pH for the digestion is among 7.0 and 7.2, though the satisfactory range goes from 6.6 to 7.6. The digestion begins at pH 6.5.

Methanogenic bacteria are extremely sensitive to the environmental changes. A sudden decrease for only a few degrees can stop the methane production, but the acidogenic bacteria continues producing acids and this drives to an excessive accumulation of acids stopping the digestion process [3].

4. Results

During the first months were obtained incombustible gases like CO_2 and H_2S that were quantified. Due to the temperature variation to which the reactors were exposed, methane was not produced. This is because the methanogenic bacteria are sensitive to temperature changes, whereas the acidogenic bacteria aren't [3]. These bacteria continue producing acid, causing the pH drop, which prevents the methanogenesis to take place. After the reactors of the series 2 were re-inoculated, the pH and the alkalinity began to increase, whereas the volatile acidity diminished. This was due to the activity of the methanogenic bacteria and associate microorganisms. Combustible biogas was produced after 118 days of inoculation and after 34 days of reinoculation. Meanwhile the other reactors did not produce any combustible gas. This demonstrates that the residues can be stored with low pH for later biogas obtaining.

Illustration 1 shows the reactors behavior in series 2. The gas production at first diminishes until the moment of the reinoculation. From there, it is possible to observe how the biogas production increases.

Illustration 2 graphs acidity, alkalinity and pH behavior, in reactor B2, which has been taken as a reference for having a stable behavior.

Table 3 shows the total biogas production in every reactor. Table 4 shows the combustible biogas volume produced. It has

Table 3 – Total biogas production per reactor [cm^3].

	0	1	2	3	4
A	5504	6622	15 376	5986	4335
B	1997	3688	13 409	2797	8991
C	4690	2275	3553	3045	6540
D	5305	4415	15 413	7855	5255

Table 4 – Total combustible biogas production per reactor [cm^3].

	0	1	2	3	4
A	653	482	7017	0	0
B	0	0	7450	0	0
C	0	0	0	0	0
D	0	0	6837	0	0

been obtained 0.10 m^3 of biogas per kilogram of volatile solid introduced.

5. Discussion

There has been preserved biomass in such conditions that allows its later use as substratum for the biogas production. As principal parameter it has been used the temperature variation in such way that the acidogenic bacteria continue working, whereas methanogenic bacteria are interrupted. This is due to the fact that methanogenic bacteria are sensitive to temperature changes, whereas the acidogenic are not. In addition, the acid produced by the acidogenic bacteria causes the pH drop, preventing also the normal methanogenic development.

Only reactors that were re-inoculated produced biogas. This alternative has been chosen to not diminish the pH using chemical products which would neutralize acids that could be used by the methanogenic bacteria. Storing biomass have been obtained 0.10 m^3 of biogas by kilogram of volatile solid, whereas Nagamani and Ramasamy [4] have obtained 0.42 m^3 of biogas per kilogram of volatile solid in a process without storage. This production pattern is valid only for special cases, as the case of agro-industries in Mendoza, Argentina, which produce its waste during the summer, but have unsatisfied energetic needs during the winter. On the other hand, Mendoza counts with many concrete and epoxi pools, placed in wineries, the same ones have been replaced by stainless steel tanks so they are unoccupied.

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