Biogas production assessment for a semi-continuous anaerobic co-digestion pilot plant

J. Mosquera1, W. Beltran1, N.D. Alvarez1, S.D. Nova2, A. Santis 2, P. Acevedo1,2, I. Cabeza1,3

1 Department of Environmental Engineering, Universidad Santo Tomás, Bogotá, Carrera 9 No. 51 - 11, Colombia
2Department of Industrial Engineering, Universidad Cooperativa de Colombia, Bogotá, Avenida Caracas 37 - 63, Colombia
3Engineering Department, Politécnico Grancolombiano, Bogotá, Calle 57 No. 3 – 00 Este, Colombia

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Introduction

In Colombia, the national energy demand has increase in the last decades, also, is estimated that between 2016 and 2030 the electric energy demand will raise over 52% [2]..

Biomass for energy production is a renewable alternative for the valorization of organic waste through biochemical conversion, such as anaerobic digestion of byproducts for biogas production [5].

Lab-scale and pilot-scale experiments are useful as input the simulation of AD under different conditions [10].

Materials and Methods

Raw materials and Inoculum

Pig Manure (PM) obtained from the Agricultural Research Center Marengo (C.A.M), the animals are fed with commercial feeding formulas.

Residues from the Bottled Fruit Drinks Industry (RBFDI) simulated in laboratory based on the references related to the residual streams of this sector: mango, banana, blackberry, lulo, and passion fruit.

Sewage Sludge (SS) was obtained from a water treatment plant in Madrid – Cundinamarca.

Cocoa Industry Residue (CIR) simulated from different references found of this industry, there were used the cocoa husks and pods, obtained from a private farm in Santander – Colombia

The inoculum was obtained from an anaerobic digester (water treatment plant of the dairy industry) of Alpina Company in Sopó - Cundinamarca

Table 1. Chemical characteristics of the inoculum and substrates.

		Substrates				
		CIR	**SS**	**PM**	**RBFDI**	**Inoculum**
pH (1:5 extract) [b]		5,42± 0,87	7,55± 0,85	7,16± 0,78	4,2± 0,80	--
Moisture[b]	%	89.62± 0.07	39.56± 0.03	74.65± 0.02	70.67± 0.03	91.45± 0.02
KTN[c]	%	0.70 ± 0.02	0.91 ±0.07	1.38 ± 0.08	1.16 ± 0.01	--
TS	%	10.37±0.02	60.43 ± 0.18	29.32 ±0.04	26.12±0.01	20.50±0.01
VS	%	7.94±0.01	8.49±0.04	22.92±0.07	22.73±0.07	16.72±0.08
C/N		59.57	14.88	33.18	48.01	--
COD[b]	g/L	8.17	13.14	24.6	8.62	--

[a] Average ± standard deviation, over three samples.

[b] Sample on wet basis.

[c] Sample on dry basis

Table 2. Experimental design description and composition.

Combination	C/N	%*	OLR (gVS fed d-1)
1	25	0	3.25
2	45	0	3.25
3	25	100	3.25
4	45	100	3.25
5	25	50	2.5
6	45	50	2.5
7	25	50	4
8	45	50	4
9	35	0	2.5
10	35	100	2.5
11	35	0	4
12	35	100	4
13	35	50	3.25

* Where 0% responds to the addition of only sewage sludge as nitrogen source, 100% only pig manure and 50% both substrates in equal quantities.

Analytical Methods

Total Solids and Volatile Solids of the initial substrates and the digestate were determined by drying the samples at 105±5°C in a drying oven and ignition at 550±10°C in a muffle furnace, this according to 2540B APHA SM and D3174 of the America Society for Testing and Materials (ASTM) respectively. Measurements **of pH** were determined using a pH meter Edge model HI2002, following the standard test method D 4972-01 of the ASTM. Volatile fatty acids (VFA) and Alkalinity where measured according to (APHA, 2005). **The Chemical Demand of Oxygen** (COD) was measured using commercial vials with a range of 0 to 150 mg/L (HI 93752). **Total Kjeldahl Nitrogen (NTK**) according to the D1426 of the ASTM. The quantification of the volume of biogas produced was performed by RITTER flowmeters (MiligasCounter - RIGAMO software), which allows the total gas measurement in real time. Finally, the gas composition measurements (CO2, CH4 and O2%) was determined by the gas analyzer Biogas 5000 (Geotech

Experimental set up

Fig. 1 Semi-continuous anaerobic co-digestion pilot plant.

Results and discussion

Box Behnken methane yields

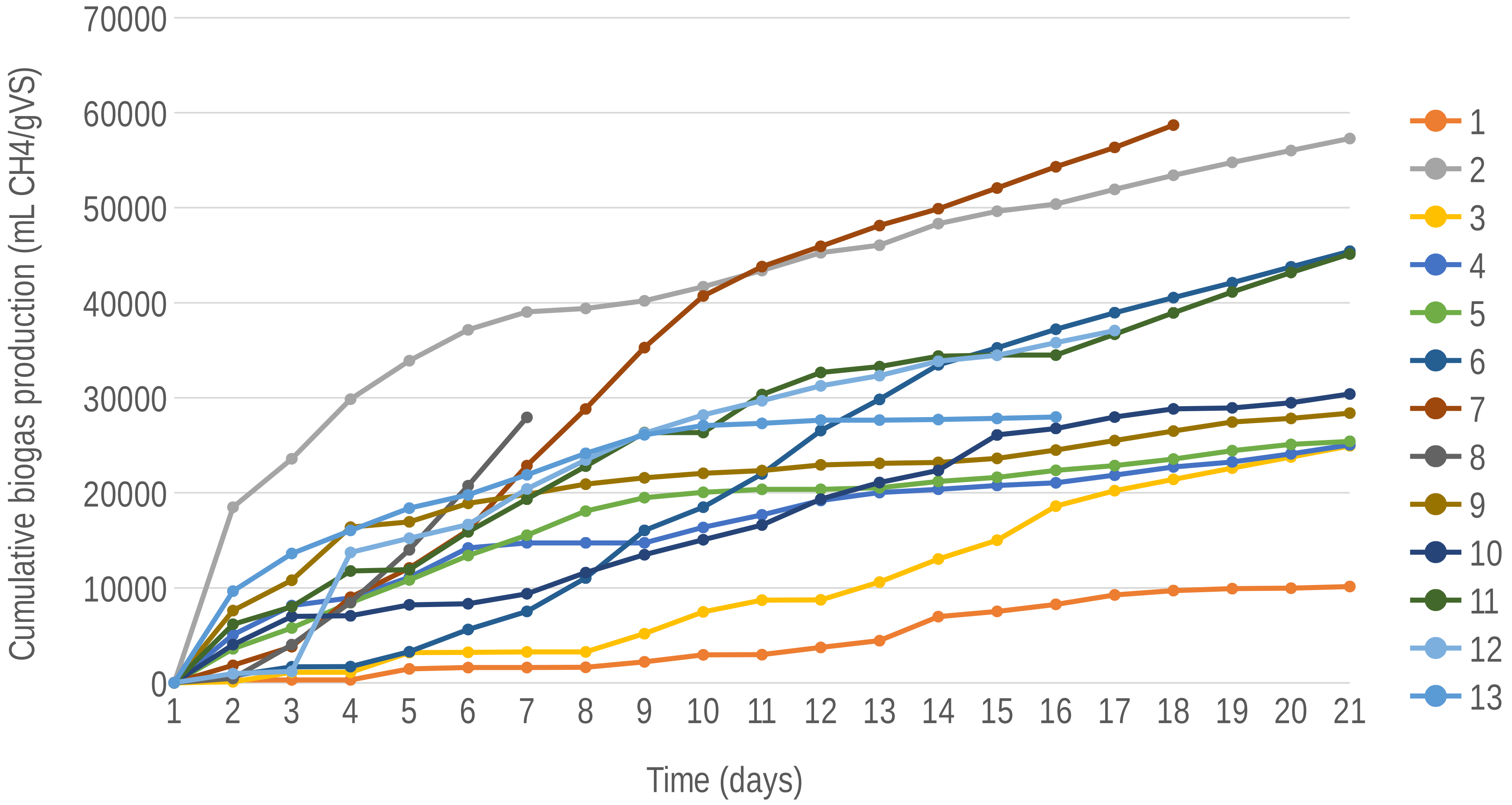

Fig. 2 Cumulative biogas production of each combination evaluated.

Monitoring results

A stable behaviour was achieved in 12 of the 13 experiments proposed, with productions between 400 – 2000 mL d^{-1} and low values of production of VFA's. The highest value of daily biogas production was 2200.15mL d^{-1} obtained in combination 7, with a stabilization time of 14 days.

Table 3. Follow-up parameters of the co-digested assays in a semi-continuous regime.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**9**	**10**	**11**	**12**	**13**
Stabilization day	17	16	17	17	14	16	14	15	16	17	11	9
Daily production (mL CH_4 d-1)	375.62	1400.58	1333.42	795.71	618.63	1707.29	2200.15	794.21	725.94	2110.35	1230,99	884,10
CH_4 (%)	46.9-52.7	50.7-51.3	57.5-59.9	52.4-54.5	54.2-55.8	57.9-59.5	54.7-57.5	58.9-59.1	56.4-59	54.3-55.4	49.8-50.3	49.8-50.1
Methane yield (mL CH_4/gSV)	138.33	744.31	313.73	322.50	411.17	736.70	617.98	463.02	531.00	446.49	363.52	396.59
Volatile solids (g/L)	32.16	22.50	55.66	10.71	14.43	23.63	17.40	23.82	11.64	14.92	14.92	62.84
COD (mg/L)	1750	15362.5	9825	13562,5	13725	3900	17800	1650	15362.5	1350	16550	14150

Monitoring results

Combinations with high organic loads and high C/N values presented inhibitions of the microorganism consortia during the first days of the process, as a consequence of accumulation of VFA.

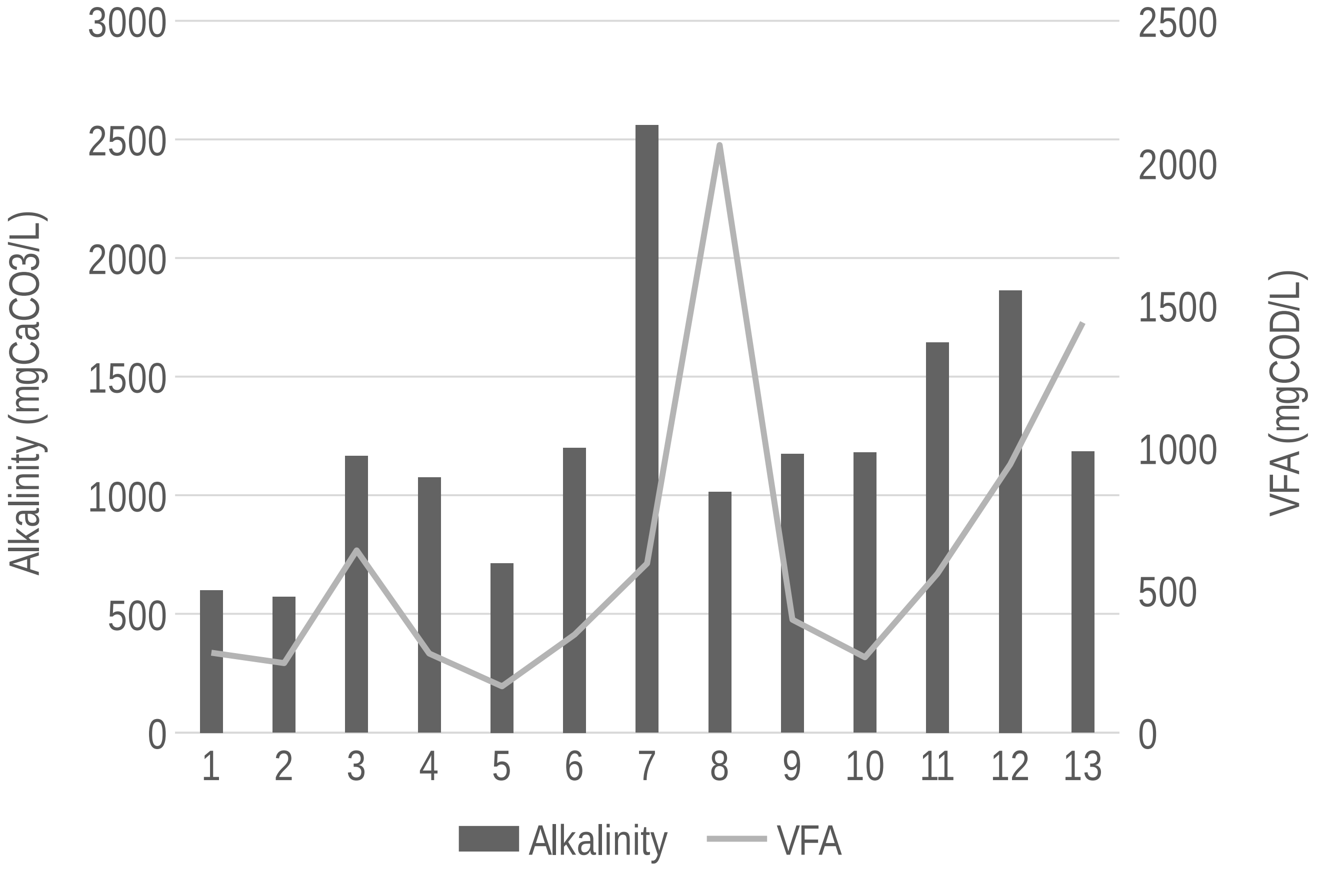

Fig. 3 Alkalinity vs VFA comparison for the evaluated tests.

Biogas composition

The maximum concentration of methane (62.5%) was reached by day 14, as well as the stabilization in terms of biogas production. Also, can be seen that the methane production started since the first day of the process, CH_4 reached up to 50% at day 10 while CO_2 decreased.

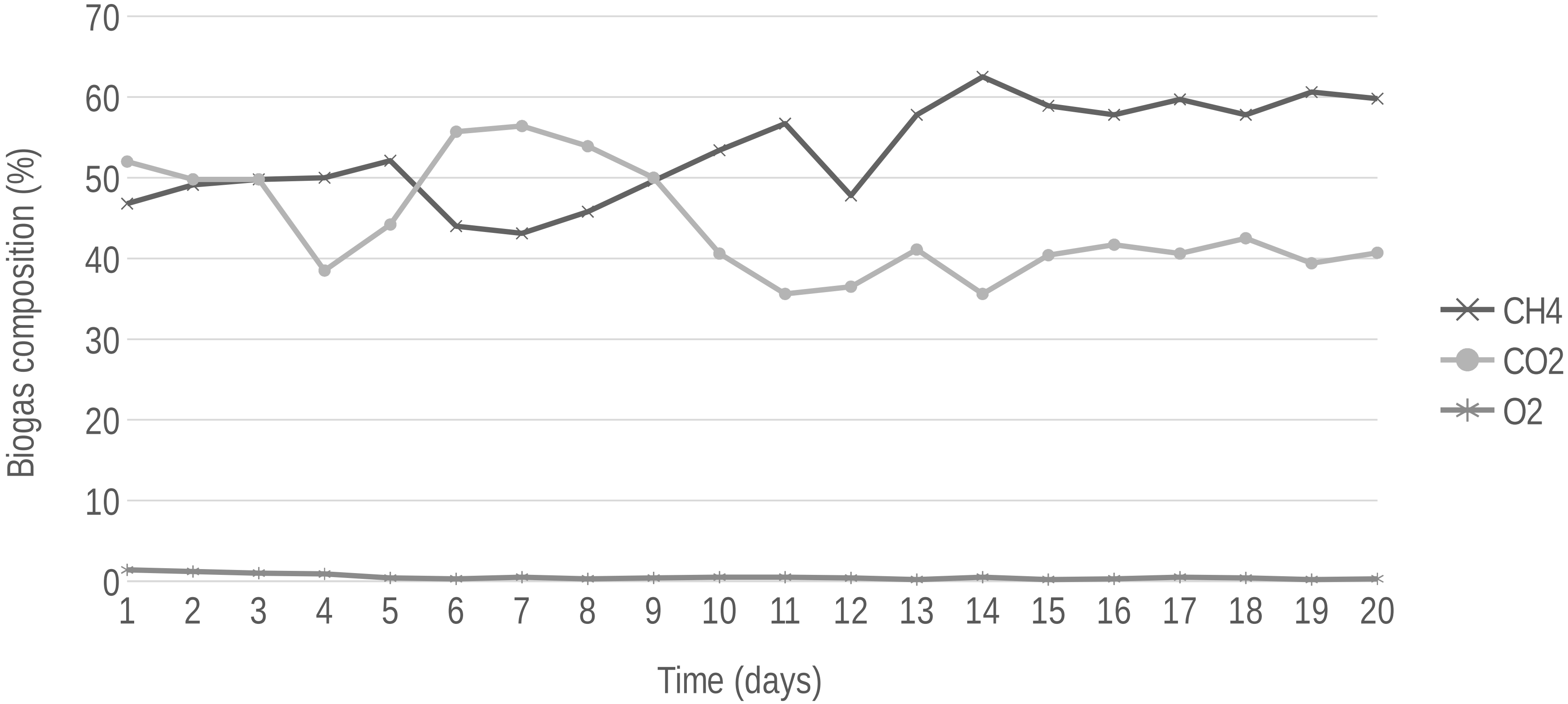

Fig. 4 Biogas composition monitoring over co-digestion process of combination 7.

Conclusions

The present work demonstrated that the anaerobic co-digestion of pig manure (PM), sewage sludge (SS), residues from the bottled fruit drinks industry (RBFDI) and cocoa industry residue (CIR); is favored under low C/N ratios (values under 35); and high organic loading rates (4gVS), both nitrogen providers are suitable for the biogas production, although, high concentrations of sewage sludge may reduce the buffer capacity of the system. In general terms, C/N ratios above 35 together with high organic loads and only sewage sludge as a nitrogen source affects the normal development of the process, independently of the maximization of production. As shown, inhibitions can be managed through chemical agents during the initial days of the process to avoid inhibited stable states. Finally, the co-digestion process evaluated in this paper is a feasible option for the diversification of Colombian energy matrix and the development of the agro-industrial sector.

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Thank you