Biogas yields from the co-digestion of agro-industrial residues in continuous cycle pilot reactors

M. Soldano[1], S. Piccinini[1], L. Rossi[1], N. Labartino[1], P. Mantovi[2]
[1] CRPA - Research Centre on Animal Production, Reggio Emilia, Italy m.soldano@crpa.it
[2] CRPA Foundation Studies and Researchs, Reggio Emilia, Italy

Abstract

Biogas and energetic yield of anaerobic digestion process is variable and it depends on the biodegradability of the treated substrate. CRPA has developed a pilot laboratory plant to evaluate the anaerobic biodegradability of organic fractions of interest. The paper describes the results of two anaerobic digestion tests of different mixtures of agro-industry organic residues. Reactor 1 was loaded with a mixture of molasses pulp coming from distillation processing and floatation sludge from a poultry slaughterhouse. The mixture used in reactor 2 was made up of dairy milk processing sludge and floatation sludge from a poultry slaughterhouse. Biogas yields obtained were high (0.735 and 0.653 m^3 of biogas for kg of volatile solids added).

Keywords: Agro-industrial residues; Anaerobic digestion; Biogas yield; Pilot laboratory plant.

Introduction

The co-digestion of livestock effluent with other organic waste for the purpose of increasing biogas production has now been a standard practice in Europe for several years. The reason for farmers' interest in co-digestion is essentially based on the possibility of selling the excess electrical energy produced combined with income from the producers of the organic residue used to form the co-substrate. The biomasses currently most used in co-digestion with livestock effluent are agro-industrial residues and energy crops. The organic residues generally used as co-substrates originate from a wide variety of sources and hence differ greatly from each other with respect to chemical composition and biodegradability.

It is clearly important to assess the energy efficiency of organic residues from industry involved in the processing of crop and animal production with a view to assessing anaerobic co-digestion as a viable means for the exploitation of such residues in management terms. Furthermore, in the context of the size of the biogas plant and related feasibility studies, it is of interest to have information relating to biogas yields of the different substrates and the mixtures used to supply the plant.

CRPA has set up a pilot laboratory plant to determine the anaerobic biodegradability of the materials of interest in which the measurement of the biogas produced is effected by the exploitation of the increase in pressure generated within a closed system.

Materials and Methods

A system has been set up using a glass Mariotte bottles (reactors) with a capacity of 22.5 litres each with an opening at the base used for the introduction of the substrates to be digested. At the top of the bottles there are three openings, one for the emission of the gas produced, one for the emission of recirculating gas used for mixing and the third for taking samples of the digestate.

The bottles are placed in a thermostatically controlled stainless steel water tank where the water is maintained at the process temperature (about 38°C for mesophilic conditions and 50° C for thermophilic conditions).

There is an opaque polycarbonate inspection lid with a heat seal which stop light getting in. The gas is cooled in a refrigeration cell with the resulting condensation collected in a trap. The reactor are also fitted with a differential pressure data logger measuring the pressure generated inside the reactors and a hydraulic guard preventing the inlet of air from the outside into the reactor during the discharge of the biogas.

Two test cycles of anaerobic digestion were carried out over a total of six weeks to establish the anaerobic biodegradability of two mixtures made up of agro-industrial residues. Reactor 1 was loaded with a mixture of molasses pulp coming from distillation processing and floatation sludge from a poultry slaughterhouse. The mixture used in reactor 2 was made up of dairy milk processing sludge and floatation sludge from a poultry slaughterhouse.

Two mixtures were tested in parallel, filling two reactor with a known volume of biomass (10 kg) taken from the inside of a biogas plant used for the treatment of distillery pulp. The system was then closed with a hermetic seal. Measured amounts of the mixtures were then added on a periodical basis, discharging the same amount of digested materials. The biogas produced in anaerobic conditions following the loading of the materials was accumulated in the head space of the reactor, resulting in an increase in pressure with respect to the initial situation.

Table 1 sets out the analytical characteristics of the two mixtures and the volumetric ratio of the matrices from which they were made up.

Table 1: Average values of the mixtures used in the two cycles

	MIXTURE 1 Molasses pulp : poultry floatation sludge		MIXTURE 2 Dairy milk processing sludge : poultry floatation sludge	
	70% : 30 %	65% : 35%	75% : 25%	68% : 32%
	1st cycle	2nd cycle	1st cycle	2nd cycle
pH [-]	5.5	5.5	7.2	6.6
TS [g/kg]	51.6	44.8	58.2	64.2
VS [g/kg]	37.0	33.3	47.6	52.3
VS [%TS]	72	75	82	81
TKN [mg/kg]	2424	2454	3592	3851
TKN [%TS]	4.7	5.5	6.2	6.0
NH_3-N [mg/kg]	501	544	1584	1628
NH_3-N [% TKN]	21	22	44	43

VS = volatile solids, TS = total solids

The parameters monitored during the tests were the following:

- quantities of substrate loaded into and removed from the reactors;
- the internal system pressure using pressure;
- Gas temperature in the head space;
- Qualitative analysis of the biogas sampled using a specific Geotechnical Instruments gas analyser, Model GA2000PLUS, that quantifies the percentage volumes of CH_4, CO_2, O_2 and the concentrations of H_2S and NH_3;
- the chemical characteristics of the materials loaded into the reactors and the digestate removed, together with the digestate loaded at the beginning of the test.

Table 2 shows the operational parameters relating to the test.

Table 2. Operating parameters relating to the two cycles

MIXTURE 1: Molasses pulp + poultry floatation sludge	Process temperature (°C)	HRT [d]	Organic volumetric loading [kg VS/m^{3}d]
1st Cycle	35.5	18	2.1
2nd Cycle	35.5	18	2.2
MIXTURE 2: Dairy milk processing sludge + poultry floatation sludge			
1st Cycle	35.5	20	2.4
2nd Cycle	35.5	22	2.2

Results and Discussion

The biogas and methane yields of the mixtures subjected to anaerobic digestion were evaluated and the results are summarized Table 3 (average values and standard deviations over the period). The qualitative analyses of the biogas indicate an high average of methane percentage during the two cycles; values above to those that are usually obtained with anaerobic digestion of only livestock manure slurries.

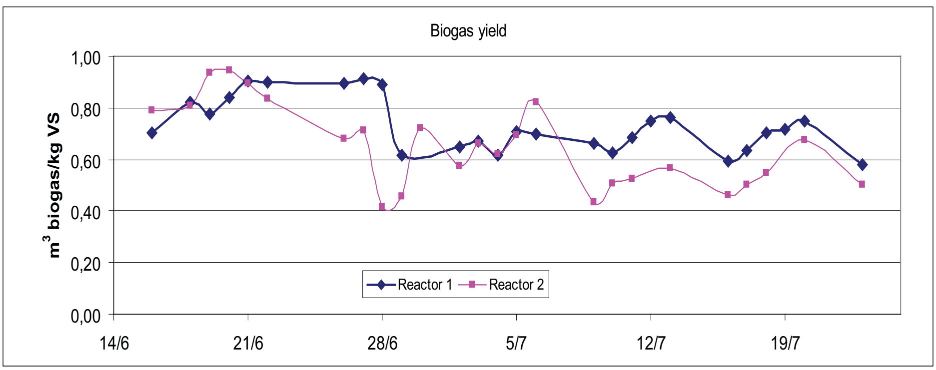
Table 3. Results from the anaerobic digestion test (average values over the entire period)

Mixture		Biogas yield [m^3/kg VS]	Biogas yield [m^3/kg]	CH4 percentage in the biogas [%]	Methane yield [m^3/kg VS]
1	Average	0.735	0.018	69	0.515
	St. Dev.	0.105	0.003	4	0.077
2	Average	0.653	0.023	71	0.456
	St. dev.	0.162	0.005	4	0.116

Biogas and methane yields in mixture 1 resulted higher than in mixture 2. This can be linked to a ratio between alkalinity and volatile acids lower in reactor 2 (about 4) in comparison with reactor 1 (about 30).

Figure 1 shows biogas yield trends of the two mixtures.

Figure 1. Trends in biogas yields during the two cycles



Conclusions

The tests conducted in continuous cycle pilot reactors confirms the validity of the co-digestion of biomass and organic substrates from other sources, guaranteeing high yields of biogas.

There are many distillers, slaughterhouse and agro-industry factories in Emilia-Romagna leading to the production of significant quantities of organic residues. The use their mixtures in anaerobic digestion may help to attribute a proper value to the residues concerned.

Aknowledgements

The CRPA has set up this project within the LITCAR laboratory project (Integrated laboratory on technology and environmental control in waste life cycle) supported by the Emilia-Romagna Region (Italy). The general aim of this project is the optimisation of waste production and treatment system

through prevention, innovation and monitoring.

References

Piccinini. S. (2007) – Situation of Anaerobic Digestion in Italy. Proceedings of AD in European Union. 16th Annual Meeting. Leipzig. February 2007.
CRPA (edited by) (2007) "Energia dal biogas – Manuale pratico", AIEL pp. 94
Soldano M., Fabbri C., Piccinini S. "Co-digestion plant in dairy cattle farm in Emilia Romagna region (Italy). Proceeding of International Congress – Progress in Biogas, Universitat Hohenheim, Stuttgart Germany, 18-20 September 2007
UNI 11734 (2004): "Valutazione della biodegradabilità anaerobica ultima di composti organici in fanghi digeriti"