PSYCHROPHILIC ANAEROBIC DIGESTION OF LIVESTOCK'S WASTEWATER AT HIGH ALTITUDE

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Abstract

Anaerobic digestion of livestock's wastewater can be a solution for decentralised sanitation of rural communities of the Andes. In addition, the biogas produced constitutes a clean fuel for cooking, which may replace fire-wood and air-dried manure that are currently used without improved cookstoves. The aim of this research was to study the psychrophilic anaerobic digestion of guinea pig and cow manure in low-cost tubular digesters at high altitude. To this end, the performance of three pilot digesters operating at ambient temperature was monitored during 6 months. The results highlight the viability of the process in low-cost plastic tubular digesters adapted to the extreme conditions of the Andean Plateau. Biogas production is relatively low (0.03 – 0.1 m^3_{biogas} $m^3_{digester}$ d^{-1}), covering some 40-60% of rural families' needs for cooking. Pathogen removal (1 order of magnitude) suggests the need of some post-treatment, such as filtration. Alternatives to improve the performance of the system are currently being addressed.

Keywords: Appropriate technologies; biogas; wastewater treatment; low-cost digester.

Introduction

In rural areas of the Andes recycling manure to produce biogas in low-cost tubular digesters constitutes a promising solution to treat wastewater from livestock and to provide clean fuel for cooking. For this purpose low-cost tubular digesters originally developed in tropical regions have been adapted to the extreme weather conditions of the Andean Plateau (3,000-4,000 m.a.s.l.) (Martí, 2007; Poggio et al., 2009). The most common livestock are cow, guinea pig and llama. This study describes the experiments carried out for a period of 6 months in a full-scale pilot plant located in Cajamarca (Peru), at an altitude of 2,800 m.a.s.l.. The aim was to characterize the low-cost tubular digesters' operation at high altitude, in order to compare the effectiveness of the process digesting guinea pig and cow manure, and codigesting their mixture.

Methods

The pilot plant consists of three low-cost tubular digesters with a total volume of 10 m^3 and a useful volume of 7.5 m^3, operating at ambient temperature. The digesters treat guinea pig manure (D1), a mixture of guinea pig and cow manure (D2), and cow manure.(D3). Table 1 summarises the main design and operational parameters. The process was monitored during 6 months, measuring process temperature, biogas production with diaphragm gas meters and biogas composition (CH_4, CO_2, H_2S) with colorimetric tubes. The feedstock and effluent were periodically analysed for total solids (TS), volatile solids (VS), nutrients like nitrogen (TKN), pH, total coliforms and E.coli , according to Standard Methods (APHA, 1999).

Table 1 Pilot plant design and operational parameters.

Digester	D1	D2	D3
Digester design and material	Plug flow, PVC		
Temperature range (°C)	Psychrophilic (<25°C)		
Hydraulic residence time (d)	60	90	60
Substrate (TS%)	Guinea pig manure (6–8%)	Guinea pig and cow manure (6–8%)	Cow manure (3–4%)
Organic Loading Rate ($kg_{VS}\ m^{-3}\ day^{-1}$)	1	0.8	0.34

Results and discussion

In all digesters, the average liquor's temperature was around 23 °C, within the psychrophilic range of temperature. The highest biogas production was obtained in digesters D3 and D2, being clearly lower in D1 (Figure 1). Indeed, average biogas production rates were 0.12, 0.07 and 0.03 $m^3_{biogas}\ m^3_{digester}\ d^{-1}$ in digesters D3, D2 and D1, respectively (Table 2). According to this, cow manure yields more biogas, even at lower organic loading rate (0.34 vs. 0.8-1 $kg_{vs}\ m^{-3}\ d^{-1}$) (Table 1). The specific biogas production was 0.35 $m^3_{biogas}\ kg_{VS}^{-1}$ in D3, compared to 0.08 and 0.03 $m^3_{biogas}\ kg_{VS}^{-1}$ in D2 and D1 (Table 2). Such low values with guinea pig manure could be attributed to: 1) the pre-compost of the feedstock material, and 2) the digestive system of guinea pigs, which is highly efficient and results in highly digested manure. The values obtained with cow manure are within the range reported in the literature for psychrophilic digesters (Alvarez and Lidén, 2009), but much lower than those obtained in tubular low-cost digesters implemented in tropical areas (Lansing et al., 2008; Lansing et al., 2010). This increases the costs of the treatment in the Andean Plateau. With current biogas production, only 40-60% of rural families' needs for cooking are covered. According to the analytical results in Table 3, the system retains must of the solids; total coliforms and E.coli are reduced 1 order of magnitude. The post-treatment of the effluent in sand filters to retain pathogens is currently being assessed.

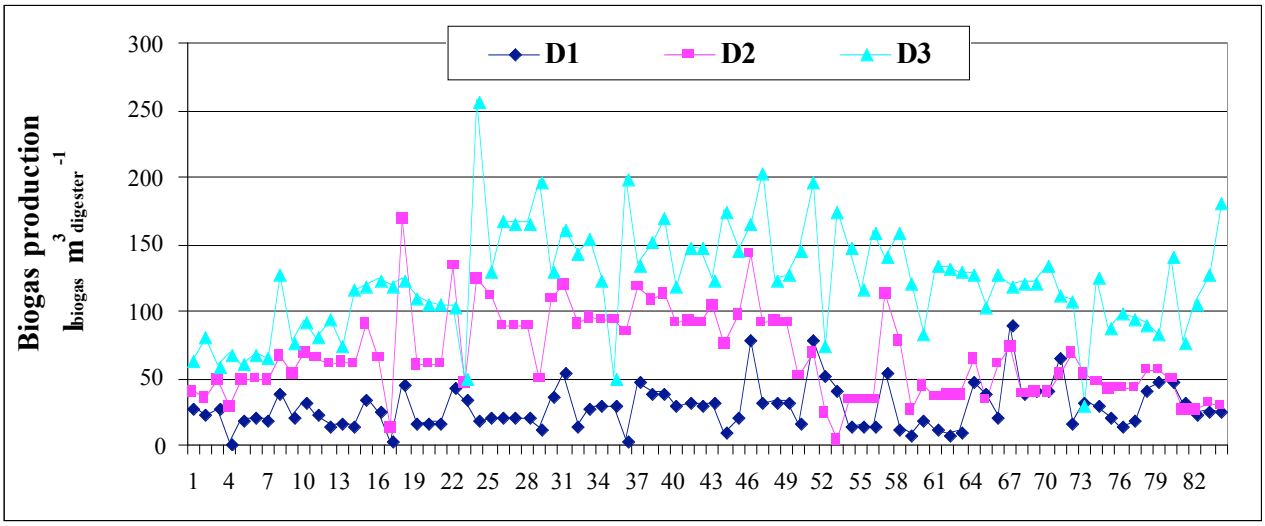

Figure 1. Biogas production rate (expressed at standard conditions).

Table 2. Average biogas production (expressed at standard conditions) and composition.

Digester	D1	D2	D3
Biogas production rate ($m^3_{biogas}\ m^3_{digester}\ d^{-1}$)	0.03 ± 0.02	0.07 ± 0.02	0.12 ± 0.04
Specific biogas production ($m^3_{biogas}\ kg_{sv}^{-1}$)	0.03 ± 0.02	0.08 ± 0.04	0.35 ± 0.12
Methane (% CH_4)	63.34 ± 0.02	60.2 ± 0.03	61.5 ± 0.03

Table 3. Average feedstock and effluent characteristics.

Digester		D1		D2		D3	
Parameters	**Unit**	**Guinea pig manure**	**Effluent**	**Cow manure**	**Effluent**	**Cow manure**	**Effluent**
pH		8.82 ± 0.26	7.16 ± 0.2	8.1 ± 0.4	6.89 ± 0.2	8.4 ± 0.3	6.98 ± 0.2
TS	(%)	25.96 ± 5.5	0.68 ± 0.15	18.8 ± 3.87	0.8 ± 0.05	16.74 ± 1.3	0.91 ± 1.4
VS	(% TS)	67.61 ± 6.8	46.87 ± 8.9	83.03 ± 2.09	50.6 ± 7.1	81.16 ± 3.2	63.8 ± 4.8
TKN	(% TS)	0.22 ± 0.01	0.05 ± 0.01	0.3 ± 0.01	0.04 ± 0.01	0.4 ± 0.02	0.02 ± 0.01
Total coliforms	cfu	3.86E+4 ± 20562.1	3.72E+3 ± 2519.3	–	–	–	–
E.coli	cfu	1.24E+4 ± 9044.3	2.32E+3 ±	–	–	–	–

Conclusions

The results of this study highlight the feasibility to produce biogas in low-cost plastic tubular digesters adapted to the extreme conditions of the Andean Plateau. The biogas produced from cow manure is within the range obtained under psychrophilic conditions, but much lower than in low-cost tubular digesters originally developed in tropical areas. As a result, in the Andes bigger digesters are needed, increasing the treatment costs. For this reason, alternatives to improve the effectiveness of the process are being addressed, to ensure that small-scale digesters provide families a clean fuel, reducing family's expenses or physical workload, especially for women and children.

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