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EVALUATION OF BIOGAS PRODUCTION FROM SWINE MANURE THROUGH CONTINUOUS REACTOR

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Abstract. *The performance of swine manure in Itapiranga (West side of State of Santa Catarina, Brazil) was evaluated in terms of biogas production and COD removal. Swine manure was treated in a CSTR digester at 35 °C with 20 days HRT and 5 L working volume. Stable biogas production from 0,052 to 0,136* $m^3.m^{-3}.d^{-1}$ *and COD removal from 6,8 to 13,8* $gCOD.L^{-1}$ *were achieved. Lab-scale experiments showed that continuous digestion could improve biogas yields when compared to conventional batch process. Anaerobic digestion from manure produced has the potential to provide a part of total electrical power required in the swine farm studied.*

Keywords: *Anaerobic digestion, Biogas, Swine manure, CSTR.*

1. INTRODUCTION

Swine manure is a great source of odour production, freshwater contamination and greenhouse gases emissions (Bernet and Béline, 2009). Meanwhile, Brazilian swine production is an important activity, with a herd of 35 million heads, representing the fourth largest producer (3 millions ton/year), fourth largest exporter (600 thousand ton/year) and the sixth largest consumer (11-13 kg/inhabitant/year) (Kunz *et al.*, 2009). Futhermore, environmental legislation (Conama, 2006) has placed constraints on land application of swine manure. In order to reduce this problems, anaerobic digestion is a excellent technology when compared with traditional land application of swine manure due to the following reasons: (i)can be used to convert organic matter into biogas for energy recovery; (ii) achieve waste stabilisation; (iii) produces an effluent stream that can be used as a crop fertilizer; and (iv) reduction in pathogen load and odour (Ward *et al.*, 2008).

There are many unsuccessful anaerobic digesters currently treating swine manure in Brazil, because the technology applied do not permitted appropriated mixing, temperature control and continuous organic matter application. A conventional digester in Brazil (commonly named "Canadian biodigester") is simple to operate but less efficient when compared with another technologies in terms of effluent quality and biogas production. In this way, continuous-flow stirred tank reactor (CSTR) is a good technology to treat swine manure, for the reason that promotes contact between the incoming substrate and a viable bacterial population (Kaparaju *et al.*, 2008).

Biogas, a product of anaerobic digestion composed of methane (CH_4) and carbon dioxide (CO_2), is gaining relative magnitude in Brazil, specially in States with extensive focus on agribusiness. There are many advantages and benefits of biogas, including: the production of renewable energy, in form of electricity and heating, reduction of greenhouse gas emissions and can be upgraded to biomethane, and used as a vehicle fuel or injected into the natural gas grid (Khan *et al.*, 2017). Thus, biogas is a good alternative to promote distributed generation and environmental sanitation in the countryside.

In this work, the performance of 5 L CSTR anaerobic digester treating swine manure from Itapiranga was tested. Biogas production and the efficiency of COD removal was also measured at the lab scale.

2. MATERIALS AND METHODS

2.1 Substrate characteristic

Swine manure was obtained from Kauffmann swine farm located in Itapiranga, Santa Catarina, Brazil, and stored at 4 °C. Anaerobic sludge obtained from full-scale UASB reactor was used as inoculum. Feed was prepared twice a week by diluting fresh manure with tap water (1:1 ratio). Characteristic of inoculum and feed are presented in Tab. 1.

Table 1. Average composition of inoculum and feed swine manure.

	Inoculum	Swine Manure
Total Solids (%)	6.55	8.5
Volatile Solids (%)	3.93	6.39
COD ($mg.L^{-1}$)	38367	26042

2.2 Experimental setup

The duration of experiment was 40 days. A single CSTR reactor was used with 20 days of Hydraulic Retention Time (HRT) and Organic Loading Rate (OLR) of 650 $mgCOD.m^{-3}.d^{-1}$. The reactor was built from double stainless steel cylinder (working volume of 5 L) fitted with removable flanges as top and bottom. The top flange supported the mixer, feed tube, pHmeter, level meter, gas tube and effluent tube. Reactor temperature was maintained at 35 °C by circulating hot water from in the space between reactor walls. Swine manure was semi-continuously fed into the reactor four times a day at 6 h interval by peristaltic pump from a 5 L feed bottle. Reactor mixer operated on a cycle of 10 s mixing followed by 50 s stop. The setup up of lab-scale reactor is shown in Fig. 1.

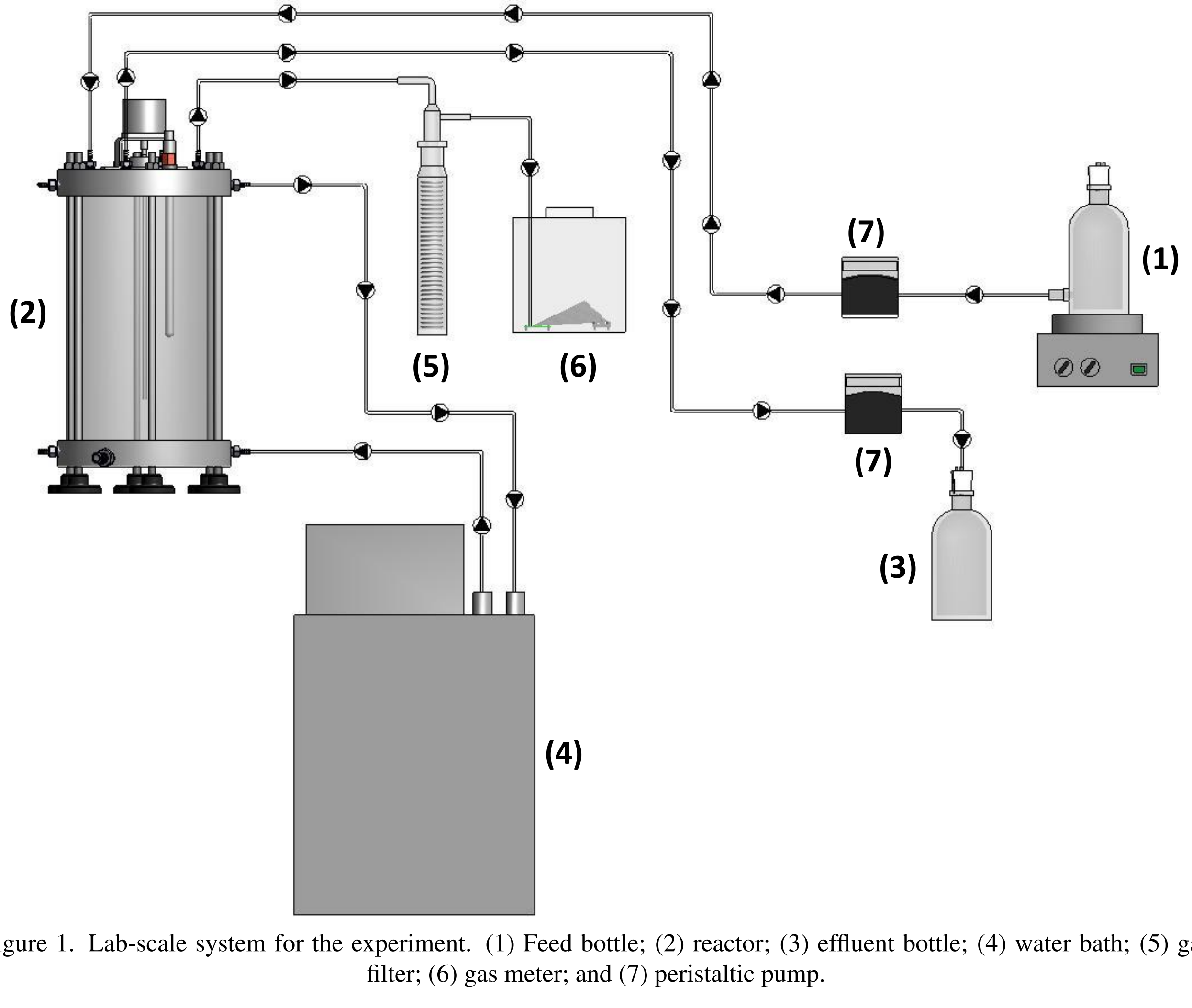

Figure 1. Lab-scale system for the experiment. (1) Feed bottle; (2) reactor; (3) effluent bottle; (4) water bath; (5) gas filter; (6) gas meter; and (7) peristaltic pump.

2.3 Analytical methods

Samples of reactor were taken for measuring Solids and Chemical Oxygen Demand (COD) 2-3 times per week. Total Solids (TS), Volatile Solids (VS) and COD were determined according to Standard Methods for the Examination of Water and Wastewater (Eaton *et al.*, 2005). Biogas production was recorded by continuous gas flow meter (Kispergher *et al.*, 2017). Methane content in biogas was measured by gas chromatograph (GC) equipped with flame ionization detector (FID).

3. RESULTS AND DISCUSSION

3.1 Degradation of organic matter

The experimental results of swine manure employed as feed and the effluent are shown in Fig. 2. Organic content of manure was affected because the feed was separated in different bottles and prepared twice a week. The first 10 days of experiment was considered the inoculation period and the effluent was not collected. The mean value of COD concentration in affluent was 13755 mgCOD.L^{-1}, while the minimum archive of COD concentration in effluent was 2.528 mgCOD.L^{-1} found on day 36.

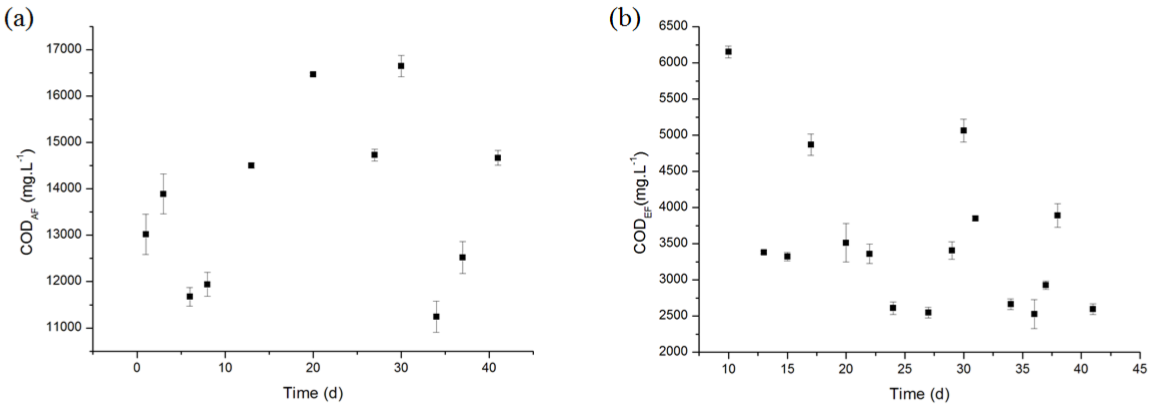

Figure 2. Chemical Oxygen Demand during CSTR operation. (a) affluent; and (b) effluent

Figure 3 shows the efficiency of COD removal in the experiment. During the steady state period, days 11-40, COD removal efficiencies of 80-85% were obtained at ORL 693 mgCOD.m^{-3}.d^{-1}. From day 30 to day 40, inlet COD was decreased to 11000 mgCOD.L^{-1}, although this no caused a significant decrease of COD removal efficiencies, which ranged 82% at the end of this period.

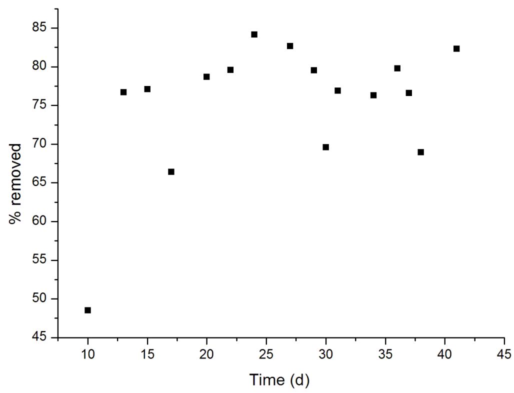

Figure 3. Removal percentage of COD during CSTR operation.

3.2 Biogas production

Figures 4 and 5 show biogas production during the reactor operation. The biogas production was very low until day 28, when the gas production began to continuously increase until day 41. The peak value of biogas production rate was 680 mL.d^{-1} on day 31. The biogas production was stable between days 36-41 with average production of 518,3 mL.d^{-1}.

After day 11, the gas production rate declined and almost ceased after day 44.

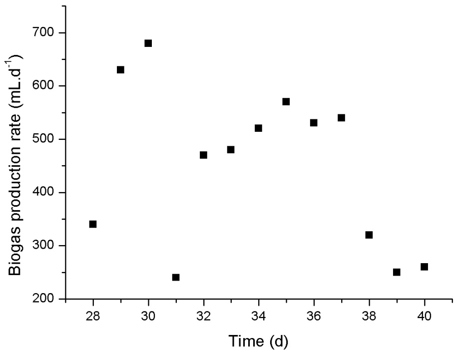

Figure 4. Biogas production rate.

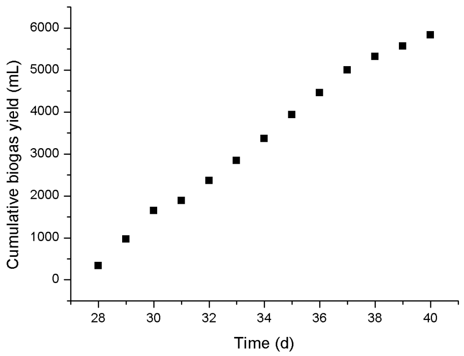

Figure 5. Cumulative biogas yield.

3.3 Pilot scale studies

After the experimental evaluation of lab-scale, a design of a full-scale CSTR reactor to attend all manure produced by swine farm was evaluated. Therefore, the data in Tab. 2 shows the production of manure and the number of animal units in the farm studied.

Table 2. Swine farm data.

Parameter	Value
Number of animals	400
Manure production per animal unit ($L.unit^{-1}.d^{-1}$)	90
Daily manure production (m^3)	36
Monthly manure production (m^3)	1080

The operational volume of anaerobic reactor and the biogas flow rate (Tab. 3) were determined through daily manure production available in Tab. 2.

Table 3. Full-scale reactor biogas production.

Parameter	Value
Hydraulic retention time (d)	20
Reactor volume (m^3)	750
Biogas productivity ($m^3_{biogas}.m^{-3}_{reactor}.d^{-1}$)	0.0897
Biogas flow rate ($m^3.d^{-1}$)	67.3

With the biogas flow rate and biogas productivity results, two options for biogas use were considered: (1) replacement of fuel in transport operations or (2) cogeneration in a combined heat and power (CHP). The calculations were made based on the methodology proposed by Moraes *et al.* (2014). The results of anaerobic digestion process related to biogas production and energy generation potential are presented in Tab. 4 according to the full-scale scenario studied.

Table 4. Energy generation potential in full-scale scenario.

Parameter	Value
Biogas production ($m^3.d^{-1}$)	67.3
Lower heating value (LHV) of biogas ($kJ.m^3$)	21500
Potential power generated ($kJ.d^{-1}$)	1447
Electricity generated per day (kWh)[1]	57
Potential diesel displacement ($L.d^{-1}$)[2]	37
Potential gasoline displacement ($L.d^{-1}$)[2]	41
Potential ethanol displacement ($L.d^{-1}$)[2]	53.2

[1] Electricity production in CHP engine.
[2] According to Moraes *et al.* (2014).

For biogas applied in electricity generation, the electric energy accumulated was approximately 57 kWh in a day, whereas for fuel displacement, the production is 37, 41, 85.2 liters per day for diesel, gasoline and ethanol, respectively.

4. CONCLUSIONS

Results from lab-scale experiment showed that continous flow had some influence on COD removal and methane production in CSTR treating swine manure. COD removal efficiencies of 79-82% were obtnained when ORL of 700 $mgCOD.m^{-3}.d^{-1}$ was applied. The reactor showed a stable operation (after inoculation period) reaching a volumetric biogas production rate close to 0,1 $m^3.m^{-3}.d^{-1}$. The potential of biogas production and energy generation from swine manure in the region of Itapiranga represents a good oportunity.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

Bernet, N. and Béline, F., 2009. "Challenges and innovations on biological treatment of livestock effluents". *Bioresource Technology*, Vol. 100, pp. 5431–6.

Conama, 2006. "Resolução conama n. 382". Conselho Nacional do Meio Ambiente-Ministério do Meio Ambiente.

Eaton, A., Franson, M., Association, A.P.H., Association, A.W.W. and Federation, W.E., 2005. *Standard Methods for the Examination of Water & Wastewater*. Standard Methods for the Examination of Water and Wastewater. American Public Health Association.

Kaparaju, P., Buendia, I., Ellegaard, L. and Angelidakia, I., 2008. "Effects of mixing on methane production during thermophilic anaerobic digestion of manure: Lab-scale and pilot-scale studies". *Bioresource technology*, Vol. 99, pp. 4919–4928.

Khan, I.U., Othman, M.H.D., Hashim, H., Matsuura, T., Ismail, A., Rezaei-DashtArzhandi, M. and Azelee, I.W., 2017. "Biogas as a renewable energy fuel âĂŞ a review of biogas upgrading, utilisation and storage". *Energy Conversion and Management*, Vol. 150, No. Supplement C, pp. 277 – 294.

Kispergher, E.M., D'Aquino, C.A., da Costa Junior, L.C., de Mello, T.C., Weinschutz, R. and Mathias, A.L., 2017. "EFFECT OF ORGANIC LOAD AND ALKALINITY ON DAIRY WASTEWATER BIOMETHANATION". *Engenharia Agrícola*, Vol. 37, No. 4, pp. 820–827.

Kunz, a., Miele, M. and Steinmetz, R.L.R., 2009. "Advanced swine manure treatment and utilization in Brazil." *Bioresource technology*, Vol. 100, No. 22, pp. 5485–9.

Moraes, B.S., Junqueira, T.L., Pavanello, L.G., Cavalett, O., Mantelatto, P.E., Bonomi, A. and Zaiat, M., 2014. "Anaerobic digestion of vinasse from sugarcane biorefineries in Brazil from energy, environmental, and economic perspectives: Profit or expense?" *Applied Energy*, Vol. 113, pp. 825–835.

Ward, A.J., Hobbs, P.J., Holliman, P.J. and Jones, D.L., 2008. "Optimisation of the anaerobic digestion of agricultural resources". *Bioresource Technology*, Vol. 99, No. 17, pp. 7928 – 7940.

7. RESPONSIBILITY NOTICE

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