PROCESS PERFOMANCE OF SWINE CARCASS AND MANURE CO-DIGESTION IN COMPARING OF MANURE MONO-DIGESTION: IMPACT OF ORGANIC LOADING RATE

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ABSTRACT: Swine farming is important agriculture activity in Brazil, and intensive production increases the necessity of efficient animal residues management and treatment. Anaerobic co-digestion of two main residues of swine production (dead animal carcass and manure) are an excellent alternative to management and produced biogas. Considering this, the present study aimed to evaluate swine carcass and manure co-digestion in comparison of swine manure mono-digestion in a mesophilic CSTR biodigester. Two CSTR (R1 and R2) biodigester (12 L) was operated in a lab scale and maintained at mesophilic conditions (37˚C ± 1) and fed once a day. The R1 reactor was fed only with swine manure and R2 fed with swine carcass and manure. The R2 organic loading rate progression was performed increasing the swine carcass and manure ratio at four different phases. At phase I the reactors were operated only with swine manure, and presented similar biogas productiveness of $0.40 \pm 0.03 L_{N\ biogas}.L_{reactor}^{-1}.d^{-1}$ and $0.41 \pm 0.03\ L_{N\ biogas}.L_{reactor}^{-1}.d^{-1}$, R1 and R2 respectively. Comparing R1 and R2 during other phases, biogas productiveness increased up to 200%, 450% and 500%, for phase II, III, and IV respectively. However, when comparing phase III and IV in R2, the increment in biogas productiveness was not expressive, at the same time the free ammonia concentration and VFA/TA ratio increased. Besides that, begun foam formation, indicating a possible imbalance. Comparing mono-digestion and co-digestion, biogas productiveness increased until 500 %, showing that anaerobic co-digestion of carcass and manure is an excellent alternative for VS concentration increases in the reactor, and consequently biogas yield improvement.

Keywords: swine farming, animal residues, biogas.

INTRODUCTION

Anaerobic digestion (AD) has considerable importance in the scenario of residues treatment because occurs biogas generation, a form of renewable energy, and organic materials stabilization (Weiland, 2010). A variety of substrates can be used in digesters, and many factors exert influence in the process.

Swine farming is important livestock activity in Brazil, and intensive production increases the necessity of efficient manure management and treatment due to the amount of waste produced (Kunz et al., 2012). In addition to manure volume produced another concern of swine production is the disposal of dead animal carcasses. Substrates of lipids-rich (like carcass and slaughterhouse wastes) are excellent for AD, according described by Tápparo et al (2018), swine carcass has a higher biogas potential, around $1076 \pm 48\ L_{Nbiogas}.kg_{VSadd}^{-1}$, five times more than swine manure. However during carcass degradation inhibitory compounds can be produced (free ammonia and volatile fatty acid accumulation).

Besides that swine manure mono-digestion is one alternative of management already consolidated in Brazil, and the co-digestion with carcass is an excellent opportunity to increase biogas production. It has been suggested that co-digestion (AcoD) can significantly attenuate inhibitory compounds. Furthermore the AcoD process can be improving methane production, nutrient balance, and the synergistic effects of microorganisms (Mata-Alvarez et al. 2011; Xie et al. 2016).

Considering this, the present study aimed to evaluate the effect of swine carcass and manure co-digestion on biogas production and process stability in comparison of swine manure mono-digestion in a mesophilic CSTR.

MATERIAL AND METHODS

CSTR reactor configuration

Two Continuous Stirred Tank Reactors were used in this experiment, built in acrylic, with 12 L working volume and jacketed, with water circulation for temperature control. Temperature was controlled by a thermostatic bath (JULABO, Model M8) maintained in mesophilic range (37˚C ± 1).

Start-up strategy

9 L of CSTR reactor digestate (fed with swine manure), for both reactors (R1 and R2), were collected and used with an inoculum source, after reactors were feed with manure until the useful volume. Reactors were fed once a day. After biogas productiveness stabilization of R2 (phase I), was started the organic loading rate progression. The R1 was feed in all phases only with swine manure.

Reactor feeding medium

Representative swine manure samples, were collected from a swine manure treatment system (SMTS), with 500 breeder sows, located in Concórdia, Santa Catarina-State, Brazil. Swine carcass (a sow, approximately 250 kg in weight, that include blood and viscera), were processed through a meat grinder, after which a representative sample (30 kg) was collected and stored (-10˚C) for use in the experiment.

Organic Loading Rate (OLR) progression in R2

It was performed increasing swine carcass and swine manure ratio in the CSTR reactor. The OLR increase was of 0.5 $kg_{VSadd}.m^{-3}reactor.d^{-1}$ whenever the reactor reaches stationary conditions of biogas productiveness (it is considered stablish when the variation was lower than 10% after 8 consecutive days).

Biogas monitoring

Biogas production was measured using Milligascounter (Ritter, MGC-1 V3.3 PMMA). Methane concentration was evaluated using BIOGAS 5000 (Geotech).

Analytical techniques

Volatile fatty acid/total alkalinity (VFA/TA) was performed according to the procedure described by Liebetrau et al. (2016), pH and ammonia as described in Standard Methods for the Examination of Water and Wastewater, and free ammonia as proposed by Hansen et al. (1998).

RESULTS AND DISCUSION

Technical coefficients of CSTR reactors (R1 and R2) are presented in Table 1, the results presented are the averages of stationary period, both reactors were fed with the same manure. In phase I the reactors were operated only with swine manure and presented similar coefficients of biogas productiveness (0.40 ± 0.03 $L_{N\ biogas}.L_{reactor}^{-1}.d^{-1}$ and 0.41 ± 0.03 $L_{N\ biogas}.L_{reactor}^{-1}.d^{-1}$), respectively for R1 and R2, biogas yield of 0.33 ± 0.01 $L_{N\ biogas}.kg_{VSadd}^{-1}$ and 0.33 ± 0.03 $L_{N\ biogas}.kg_{VSadd}^{-1}$ respectively for R1 and R2. Comparing reactor R1 and R2 during other phases biogas productiveness increased up to 200%, 450% and 500%, for phase II, III, and IV respectively. Different OLR in R1 reactor are because different manure samples.

During all phases the R1 reactor presented high stability in the anaerobic digestion process, proved by the low variation in the results of the VFA/TA ratio, average of 0.109mgHAc.$mgCaCO_3^{-1}$ and average of 0.113 mgHAc.$mgCaCO_3^{-1}$ until phase III and increase on the last phase for R2. (Table 2). Despite the increase VFA/TA ratio according Mézes et al. (2011), suggest that until 0.400 mgHAc.$mgCaCO_3^{-1}$ no problems occurs in the process for volatile fatty acids.

Free ammonia in R1 reactor remained around 200 $mg.L^{-1}$ instead R2 reactor that free ammonia concentration increased with carcass/manure ratio increase (from 0 to 100 $kg_{carcass}.m^{-3manure}$) . Hasen et al (1998) studding swine manure mono-digestion defined that ammonia will only be a serious problem after the free ammonia concentration has exceeded threshold value of 1.10g-$N.L^{-1}$.

When comparing phase III and IV in R2, the increment in biogas productiveness was not expressive, at the same time the free ammonia concentration and VFA/TA ratio increased. Besides that, with increase on OLR begun foam formation, indicating a possible imbalance. Several studies demonstrated a decrease of methane production because foaming problems and accumulation of fats occurred in the reactor during digestion or co-digestion of animal by-products (Pitk et al. 2013; Borowski and Kubacki 2015; Pagés-Díaz et al. 2015), because when residues with high-lipids concentrations are degraded have a tendency to form floating aggregates of lipids and forming foam (Cuetos et al. 2008). An ideal ratio between animal by-products and others residues are necessary for the process occurred without declining in biogas production., R2 has a better biogas yield in phase III, suggested co-digestion should be maintained at a $68kg_{carcass}.m^{-3}_{manure}$ ratio.

CONCLUSION

Comparing R1 (mono-digestion) and R2 (co-digestion), the increase in biogas productiveness until 500 %, representing that anaerobic co-digestion of carcass and manure is an excellent opportunity for increase concentration of solids in the reactor, and consequently biogas production on swine farming.

The increment in OLR from 1.3 to 2.1 $kg_{VSadd}.m^{-3}_{reactor}.d^{-1}$, in R2 reactor contributes to better biogas yield, which results in a substancial increase on biogas productiveness. However considering foam generation, in phase IV, suggested that is better reactor operated in $68kg_{carcass}.m^{-3}_{manure}$ ratio, corresponding to phase III. For a full scale application it is important to consider carcass pre-treatment for sanitary reasons (EC, 2009; Kirby, 2018).

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Table 1. Technical coefficient of swine manure mono-digestion (R1) and co-digestion with swine carcass (R2) using a CSTR reactor.

	R1				R2				
	OLR ($kg_{VSadd}.m^{-3}{}_{reactor}.d^{-1}$)	Biogas Productivity ($L_{N\ biogas}.L_{reactor}{}^{-1}.d^{-1}$)	Biogas Yield ($L_{N\ biogas}.kg_{VSadd}{}^{-1}$)	CH4 (%)	OLR ($kg_{VSadd}.m^{-3}{}_{reactor}.d^{-1}$)	Carcass/manure ratio ($kg.m^{-3}$)	Biogas Productivity ($L_{N\ biogas}.L_{reactor}{}^{-1}.d^{-1}$)	Biogas Yield ($L_{N\ biogas}.kg_{VSadd}{}^{-1}$)	CH4 (%)
Phase I	1.30	0.40 ± 0.03	0.33 ± 0.01	58	1.30	0	0.41 ± 0.03	0.33 ± 0.03	65
Phase II	0.87	0.34 ± 0.03	0.39 ± 0.03	57	1.43	35	1.05 ± 0.03	0.70 ± 0.07	64
Phase III	0.87	0.34 ± 0.14	0.39 ± 0.07	55	1.93	68	1.63 ± 0.14	0.87 ± 0.10	59
Phase IV	0.53	0.31 ± 0.08	0.52 ± 0.07	51	2.10	100	1.64 ± 0.08	0.76 ± 0.07	52

Table 2. Free ammonia concentration and VFA/TA ratio during swine manure mono-digestion (R1) and your co-digestion with swine carcass (R2) using a CSTR reactor.

	R1			R2		
	pH	VFA/TA ratio ($mgHAc.mgCaCO_3{}^{-1}$)	Free ammonia (NH_3-N mg. L^{-1})	pH	VFA/TA ratio ($mgHAc.mgCaCO_3{}^{-1}$)	Free ammonia (NH_3-N mg. L^{-1})
Phase I	7.86 ± 0.05	0.123 ± 0.012	187 ± 38	7.80 ± 0.2	0.125 ± 0.005	164 ± 50
Phase II	7.86 ± 0.04	0.100 ± 0.005	182 ± 21	7.93 ± 0.04	0.109 ± 0.006	262 ± 51
Phase III	7.85 ± 0.06	0.100 ± 0.008	198 ± 14	7.89 ± 0.26	0.107 ± 0.004	254 ± 15.5
Phase IV	7.69 ± 0.09	0.113 ± 0.014	127 ± 37	7.88 ± 0.10	0.258 ± 0.090	308 ± 86