ANAEROBIC TREATMENT OF DAIRY CATTLE EFFLUENTS IN A TUBULAR BIOREACTOR

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1 INTRODUCTION

Usually the highly productive dairy cattle activity is performed with highly specialized animals, which are maintained in permanent confinement and constantly monitored. The confinement of animals generates a large amount of manure and other waste materials (litter, feces, urine, and water) within a small area. Amaral et al. (2004) report the production of 75.2 kg per day of excrements per lactating cow. Contrarily to the extensive cattle rearing, where the excrements remain on the pasture areas, naturally contributing for the energetic restoring of the environment, these waste materials need an adequate treatment.

The waste materials produced at an intense activity dairy farm, when inadequately discarded and without proper treatment, may generate unfavorable impacts on the environment, causing contamination of superficial, sub-superficial and subterranean bodies of water. The waste materials generated by confined animals can be treated, via microbiological activity, in anaerobic bioreactors yielding biogas, sludge and bio-fertilizers as effluent byproducts. The objective of this research was to verify the effect of the hydraulic retention time in two tubular anaerobic bioreactors, using as substrate the wastewater produced from facilities holding permanently confined dairy cows.

2 MATERIAL AND METHODS

The waste material for the experiment was collected at the rural property “Fazenda Iguaçu”, Céu Azul County, State of Paraná (latitude 25°02’43.07” South; longitude 53°46’51.85” West; altitude 641 m). The material was always screened through a 2 mm mash sieve and totally stored at -18 ºC.

The following parameters were evaluated: Total Solids (TS), Volatile Solids (VS), pH, Total Alkalinity (TA) and Volatile Acidity (VA), according to methodologies described by APHA (1995).

Two anaerobic bioreactors, constituted of vinile polichlorate tubes, with 9.5 L of useful volume each, were used. The loading of the reactors was manually performed, simulating the moment in which the mass of wastes would be pumped into the bioreactor, after the stable cleaning operation. The unloading was done through a siphon, with the aid of an aspirator bulb, at the same volumetric amount of the loading. The functional temperatures were set at 30 ºC and 35 ºC, maintained by a heater connected to a thermostat.

The gasometers were mounted with vinile polichlorate cylinders, totalizing 20 L useful volume each. The volume of biogas daily produced was measured by the displacement of the inner cylinder, and the difference between heights was multiplied by the 0.049 m^2 transversal section, resulting on the daily volume. The calculations of volume were result of the transformation of the read volume, taken to normal condition of temperature and pressure (NCTP).

The biogas was collected in plastic containers and analyzed with a packed column Construmaq Gas Chromatography apparatus, with H_2 as dragging gas.

The reactor was initially loaded with one third of its useful volume and daily additions of 2 L of substrate were then performed until completion of the 9.5 L. After the start, the mean daily load was 8 560 milligrams of organic material.

With bovine substrate, the star-up phase at the reactors was 10 days, after that the biogas volumetric production became stable, differently from Souza et al. (2005) who employed a start-up time higher than 20 days. The daily production of 6 L of biogas was considered as balanced for a provision of 0.480 L of gross material, with a mean content of solids of 45 grams per liter, after a 10 days running period.

It was used a factorial crossover design 4 x 2 x 4, 4 factors of hydraulic retention time (HRT), 2 temperature factors and 4 replications, being the means of Total Solids and Volatile Solids removals compared by Tukey test at 5% probability, using the MINITAB version 15.0 software.

3 RESULTS AND DISCUSSION

The average characteristics of the material affluent into the reactor were: DQO = 18.050 gL^{-1}; TS = 49.780 gL^{-1}; VS = 37.024 gL^{-1}; N = 2.040 gL^{-1}; P = 0.420 gL^{-1}; K = 2.720 gL^{-1}; C: N ratio = 6.21 and pH = 7.5. The high VS values emphasize the great potential of biogas production and indicate that the material has the potential to be microbiologically decomposable (AMARAL et al., 2005).

The mean TS and VS contents as well as statistical comparison of means of TS and VS removals are presented on Table 1.

TABLE 1 **Values of Total Solids (TS) and Volatile Solids (VS) in the material affluent and effluent to the reactors and respective comparisons of removal means.**

	TS									
HRT (days)	**Affluent**		**Effluent**		**Removal**					
	gL^{-1}				**gL^{-1}**		**%**			
	30 °C	35 °C	30 °C	35 °C	30 °C	35 °C	30 °C		35 °C	
8	61.519	45.350	43.826	34.427	17.693	10.923	28.76	a1*	24.09	a1
10	61.519	45.350	29.809	22.599	31.709	22.750	51.54	a2	50.17	a2
15	61.519	42.472	22.339	14.438	39.179	28.034	63.67	a2	66.01	a3
20	61.519	42.472	14.664	12.979	46.854	29.493	76.16	a3	69.44	a3
	VS									
HRT (days)	**Affluent**		**Effluent**		**Removal**					
	gL^{-1}				**gL^{-1}**		**%**			
	30 °C	35 °C	30 °C	35 °C	30 °C	35 °C	30 °C		35 °C	
8	47.693	30.445	33.262	21.655	14.431	8.790	30.26	a1	28.87	a1
10	47.693	30.445	20.205	13.387	27.489	17.058	57.64	a2	56.02	a2
15	47.693	32.935	13.712	6.298	33.981	26.637	71.24	a2	80.88	a3
20	47.693	32.935	6.569	5.551	41.124	27.384	86.23	a3	83.15	a3

*values followed by the same symbol in the column are not statistically different from each other by the Tukey test at 0.5% probability (P 0.05).

The essays performed with lower HRT resulted in higher TS and VS contents and the increase in the retention period of the substrate resulted in the decrease of those same parameters at the outlet of the reactor.

The highest TS and VS reductions occurred at the HRT of 20 days, at 30 °C temperature, reaching values of 76.16% and 86.23% respectively. The essays performed at 35°C temperature did not present equivalent TS removals, since they were performed during lower temperature months and with the substrate being carried still frozen from storage to room temperature.

The local temperatures ranged from 17 °C to 33 °C at the moment of the readings. Thus, during several loading moments, the substrate remained with a mean temperature lower than that of the total mass of waste material inside the reactor, until the thermal equilibrium was reached and the final temperature of 35 °C was achieved. So, during a short period of time, ranging from 60 to 120 minutes, the temperature inside the reactor was inferior to 35 °C. According to Amorin et al. (2004) and Chernicharo (2007), with the reduction in the temperature, the microorganisms decrease their activity, reducing the decomposition process until the moment in which the affluent reaches thermal balance.

These values confirm the necessity of adequate periods for the growth of the *Archea metanogenica*, which needs 15 days to grow, since lower retention times would wash away the microorganisms in the effluent.

Chromatographic analysis of the gas showed that it was composed of 67.42% CH_4, 27.07% CO_2, and 5.51% of the $N_2 + O_2$ mixture.

The average daily performance of TS and VS removals and of the biogas productions are shown on Figure 1.

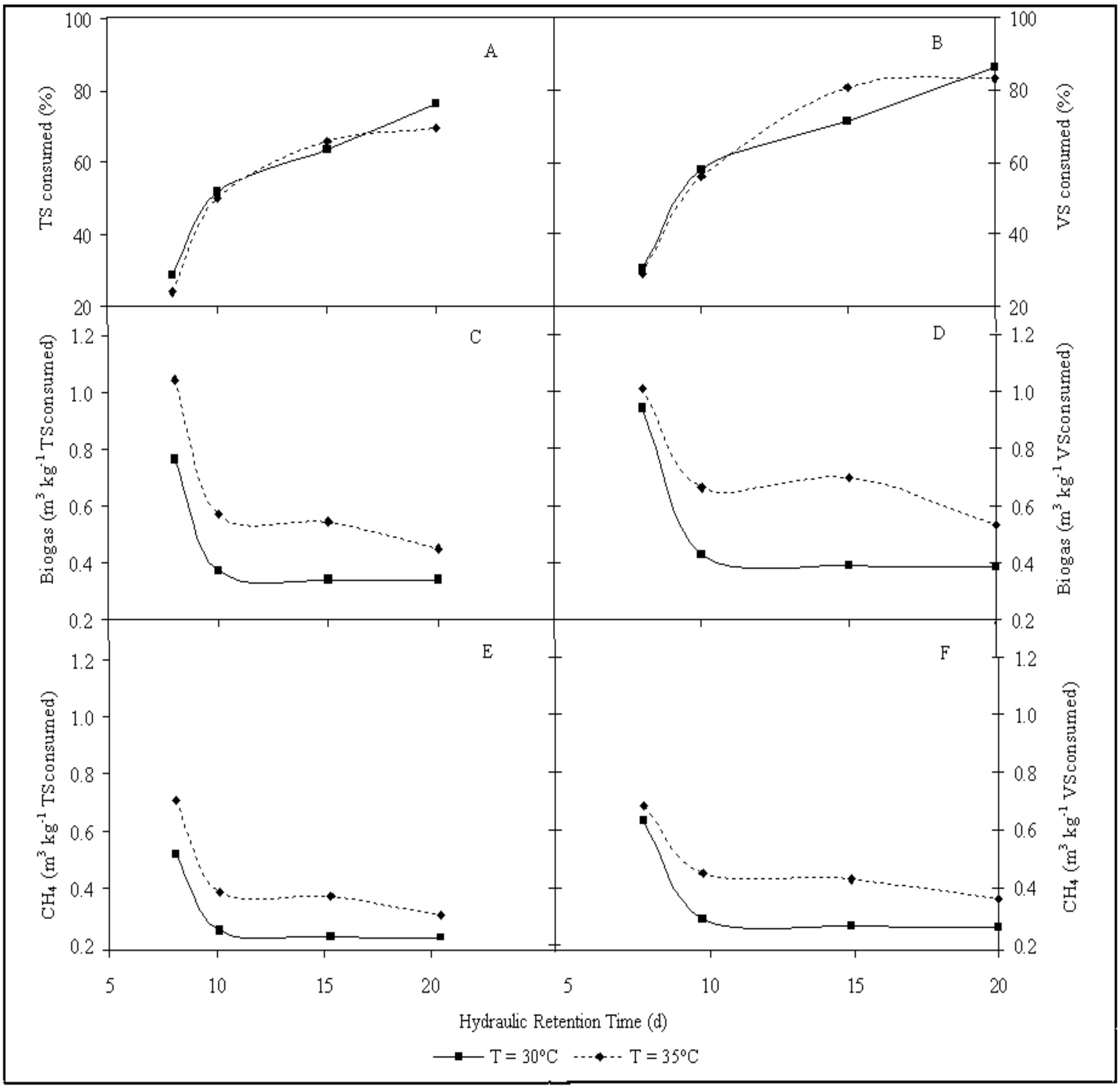

FIGURE 1 **Average performance of TS and VS removals, and biogas production: (A) means of TS removal; (B) means of VS removal; (C) volume of biogas in relation to TS removed; (D) volume of biogas in relation to VS removed; (E) volume of CH_4 in relation to TS removed; (F) volume of CH_4 in relation to VS removed.**

The maximum productions of 1.05 m^3 of biogas per kg of TS removed, and of 1.01 m^3 of biogas per kg of VS removed follow the results found by Castro (1998) and Amorin et al. (2004), i.e., the increase of the load resulted in increased biogas production and increased CH_4 content held at the gaseous mixture in the treatment with anaerobic reactors.

The increase on the organic load, through reduction of the HRT, increased the volumetric production of biogas in relation to the TS and VS removed from the system. These values are in accordance with those of Castro (1998) and Souza et al. (2005), who verified that the increase in the temperature also increases the volumetric production of biogas.

The highest production of biogas were 1.013 m^3 and 0.700 m^3 of biogas per kg of VS removed, at the HRT of 8 and 15 days, respectively, at a temperature of 35 ºC. At a HRT of 20 days, also at a temperature of 35 ºC, the biogas production was 0.533 m^3 of biogas per kg of VS removed. These results surpass those reported by Amaral et al. (2004), who obtained 0.487 m^3 of biogas per kg of VS removed in an Indian continuous bioreactor, loaded with bovine manure, at a HRT of 20 days.

The productions of CH_4 followed the profile of the priorly cited biogas productions, reaching maximum values of 0.705 m^3 of CH_4 per kg of TS and of 0.683 m^3 of CH_4 per kg of VS, removed at a HRT of 8 days. The results were higher than those values obtained by Karapaju (2008), who found a production of 0.41 m^3 of CH_4 in relation to the volatile solids.

These results, however, were lower than those obtained by Souza et al. (2005), who registered values of 1.400 m^3 of CH_4 per m^3 of reactor, at HRT of 10 days. Knowing that the useful volume of the reactors in this experiment was 9.6 L and that the highest production was achieved at HRT of 8 days, a production of 1.140 m^3 of CH_4 per m^3 of reactor may be computed.

The purpose of the treatment will define the reactor dimensions, as a function of the affluent load. If the objective is to produce methane, the option for smaller reactors with large production of gas is defined. If the objective is to improve the quality of the effluent, however, bigger bioreactors that retain the substrate for larger periods of time will be than necessary.

4 CONCLUSIONS

The anaerobic treatment of residuary water emanating from facilities used for dairy cattle rearing under permanent confinement, performed in continuous flow tubular anaerobic bioreactors for biogas production was efficient.

The best results for volumetric production of biogas in relation to the solids removed were 1.046 m^3 and 1.013 m^3 of biogas per kg of Total Solids and Volatile Solids removed, respectively, with a HRT of 8 days and substrate temperature of 35 ºC.

In relation to reduction of the Total Solids and Volatile Solids present in the wastewater, the best results were achieved with HRT of 20 days, and at 30 ºC temperature, with the removal of 76.16% and 86.23% of TS and VS, respectively.

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