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BIOGAS PRODUCTION IN DAIRY CATTLE SYSTEMS, USING BATCH DIGESTERS WITH AND WITHOUT SOLIDS SEPARATION IN THE SUBSTRATES

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ABSTRACT: This research aimed to evaluate the biogas production during the anaerobic biodigestion process of dairy cattle manure, with and without solids separation. Sixteen biodigesters of the batch type were used, each one with 2L of capacity, supplied with manure in four different conditions: (1) pure manure, after washing the floors of the free stall system; (2) manure after the solids separator; (3) manure after the solids separator and sand decanter and (4) manure with the solid retained in separator solids, dissolved in water. The hydraulic retention time was of 196 days. The highest reductions of volatile solids (VS) were obtained for the biodigesters supplied with manure that went through some process of solids separation. The highest potential of methane production(CH_4) obtained was of 0.2686 m^3 CH_4 kg^{-1} of added VS, supplied to digesters with manure after solids separator. The best potential for biogas and methane production was observed when there was a reduction of the solids concentration in the manure and, in this case, the hydraulic retention time can be reduced, which reduces the volume of the biodigester and the cost of implementation and maintenance, but the highest biogas production occurred in the biodigesters without solids separation.

KEYWORDS: biogas, biodigester, manure, dairy cattle, solid separation.

INTRODUCTION

Brazil presents as a major cattle producer and in 2012, it had a herd of more than 212 million cattle and, according to the IBGE (2012), the total number of milked cows accounted for approximately 10.9% of the actual cattle, with approximately 23 million cows being milked.

The increased demand for animal products causes the intensive exploitation of animals, which are grouped in large numbers, producing large volumes of manure in small areas, generating problems both for their treatment and disposal, as well as for environmental pollution.The possibility of biogas recovery in the treatment of manure has highlighted Bovine farming as one of the main activities for producing large amounts of manure.

In practice, biogas recovery is possible with the use of biodigesters and, according to BARBOSA & LANGER (2011); the biodigester represents an excellent alternative for the treatment of generated manure, since it is the producer responsibility, who must provide an appropriate destination to them.Batch type biodigesters are loaded at one time, fermenting for a suitable period, and the material is discharged after the end of the actual biogas production period (BONTURI & VAN DIJK, 2012).

The manure, when collected to enter the biodigester, may contain fractions that may be considered non-biodegradable or slowly biodegradable, arising from food parts not degraded by the animal, such as fibers, or from the washing process as sand, for example.These fractions can affect the process of anaerobic digestion and some authors recommend that the separation of this fraction occurs so that the process becomes more efficient (greater production of biogas / kg of solid), fast (less hydraulic retention time) and more economical because it requires reactors with smaller size for the same number of animals (MOLLER et al., 2004).

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In this sense, the objective was to evaluate the biogas production in batch biodigestors, with and without the separation of solids in the substrates with manure from dairy cattle, evaluating the biogas and methane production potentials and the reductions of volatile solids contents to obtain biogas production parameters.

MATERIAL AND METHODS

The experiments were carried out at the Faculty of Agrarian and Veterinary Sciences (FCAV) of the Universidade Estadual Paulista (UNESP) - Jaboticabal Campus - SP, with the collection of field and manure data for the samples and composition of biodigester substrates carried out on a farm with tradition in the production of milk located in the municipality of São Pedro, SP.

Sixteen biodigesters were used that had a useful fermentation capacity of 2 liters of substrate each; the model scheme used can be seen in Figure 1.

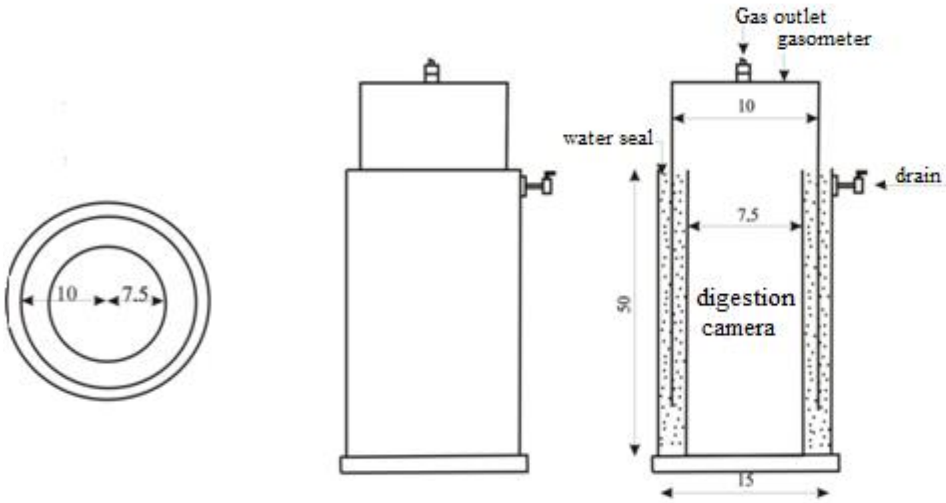


FIGURE 1. Model of Batch Digestersschematic diagram (cm).

Initially, the manurewere collected by scraping and, in a receiving tank, homogenized.After homogenization, the manure passed through a 0.75 - 0.90 mm mesh solids separator, where the solid fraction was separated.Then, the liquid fraction has passed through a sequence of 3 decantation boxesto remove finer solids such as sand. The simplified scheme can be seen in Figure 2.

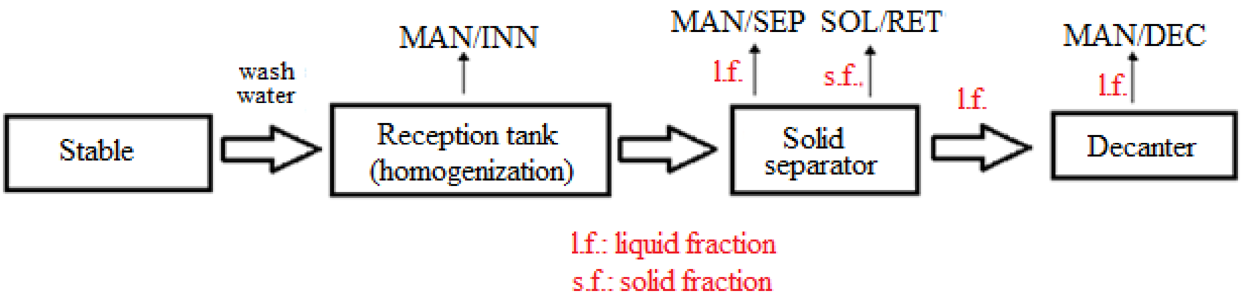


FIGURE 2. Flowchart of the collecting process and separation of solid manure used in the experiment.

The characterization and biodigestion of the manure obtained in the stable *in natura*(manure, urine and floor washing water) were carried out, right after the homogenization of the solid fraction (MAN/INN) retained in the separator mixed with 20% of water (SOL-RET), the liquid fraction obtained after passage after separator (MAN-SEP) and the liquid fraction after the separator and decanters (MAN-DEC), adopting 4 repetitions.

The manure characterization analyzes were carried out in the Biomass and Anaerobic Biodigestion Laboratory, belonging to the Department of Rural Engineering of Unesp / Jaboticabal (SP). The TS (total solids) and VS (volatile solids) contents were determined according to the methodology described by APHA (2005).

The biogas productions were calculated based on the displacement of the gasometers, measured with a ruler. The number obtained in the reading was multiplied by the area of the inner cross section of the gasometers, equal to 0.00785 m³.After each reading, the gasometers were zeroed using the biogas discharge record. The correction of the biogas volume, for the conditions of 1atm and 20 ºC, was carried out based on the study of CAETANO (1985).

The biogas and methane production potentials were calculated using the total biogas production data of each biodigester and the quantities of manure, TS and VS added in the biodigester and the VS reduced during the process. The values were expressed in m³ of biogas and of methane per kg of manure, added TS, VS added and VS reduced.

The quality of the produced biogas was made weekly to determine the levels of methane (CH_4) and carbon dioxide (CO_2), analyzed by FINNINGAN GC-2001 gas chromatograph.

For the anaerobic biodigestion test, a general linear model with 4 replicates was used. The assumptions for variance analysis were checked and the means were compared by the Tukey test at the 5% probability level in the SAS (Statistical Analysis System) program.

RESULTS AND DISCUSSION

Table 1 shows the values for the mean values of total solids (TS), volatile solids (VS) and the reductions obtained in the volatile solids contents of the substrates obtained after washing the stable floors (MAN-INN) as well as of the fractions obtained after the solids separator (MAN-SEP and SOL-RET) and following the sand decanter tank (MAN-DEC).

TABLE 1. Average contents of total solids (TS), volatiles solids (VS) and VS reduction, in%, for biodigesters with MAN-INN, MAN-SEP, MAN-DEC and SOL-RET.

	AFFLUENT		EFFLUENT		VS REDUCTION
	TS(%)	VS (%)	TS (%)	VS (%)	(%)
MAN-INN[1]	7.05	5.94	4.59	3.85	35.17ab
MAN-SEP[2]	2.43	1.97	1.55	1.23	37.75 a
MAN-DEC[3]	2.32	1.85	1.46	1.15	37.84 a
SOL-RET[4]	3.54	2.99	2.39	2.00	33.09 b
P Values					0.0012
F Values					10.33
CV %					3.98

P-probability; F-significance; CV- coefficient of variation;
Averages in the column with distinct letters differ by the Tukey test (P<0.05)
[1]manure*in natura*; [2]manure after solid separator; [3]manure after decanters; [4] solids retained in the solids separator.

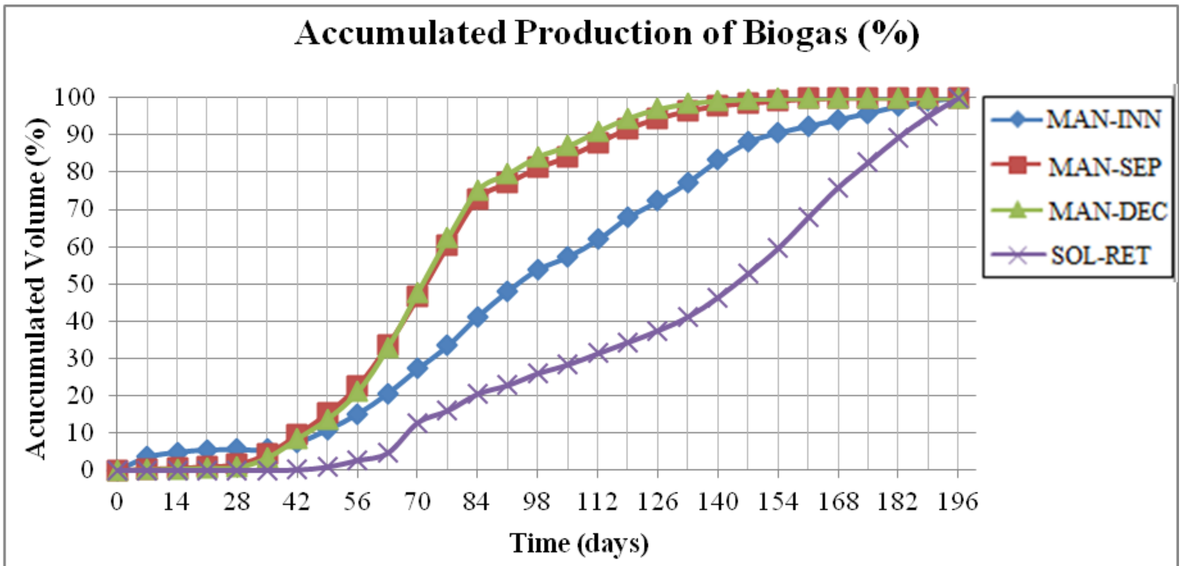
The results refer to the manure that was used to supply the biodigesters (affluent) and to the biofertilizer obtained after the process (effluent). On the day of the biodigesters supply the MAN-INN presented with 7.05% of TS, the MAN-SEP with 2.43%, the MAN-DEC with 2.32% and the SOL-RET with 21.26% that after dilution of 0.300 kg in water resulted in substrate with 3.54% of TS.

The reductions of volatile solids during the anaerobic biodigestion process ranged from 33.09 to 37.84%, being the highest values for MAN-SEP (37.75%) and MAN-DEC (37.84%), which showed no significant differences (P> 0.05) with the manure*in natura* (MAN-INN).

It was observed that the solids retained in the sieve, which were diluted in water to supply the biodigesters (SOL-RET), showed the lowest reduction of volatile solids, 33.09%.

XAVIER & LUCAS JÚNIOR(2010) using manure from dairy cattle with and without inoculumobtained reductions between 22.41 and 50.72%, being the highest level of reduction obtained using inoculum and AMARAL et al. (2004), working with manure from dairy cattle submitted to different hydraulic retention times, obtained reductions of 26.08% to 40.36%.

Figure 3 shows the variations in accumulated production, in % of biogas.



MAN-INN-manure *in natura*; MAN-SEP-manure after solid separator; MAN-DEC- manure after decanter; SOL-RET-solids retained in the separator;

FIGURE 3. Accumulated production of biogas (%) in batch digesters with manure of dairy cows obtained after washing the stable floors (MAN-INN) and of the fractions obtained after the solid separator (MAN-SEP and SOL-RET) and after the sand decanter (MAN-DEC).

Figure 3 shows that with approximately 120 days, more than 90% of the biogas production was reached for the MAN-SEP and MAN-DEC biodigesters, indicating a faster stabilization of the manure,while the MAN-INN biodigestors reached about 70% of its production and SOL-RET biodigester reached about 35% of the production, which indicates that lower stabilization of the manure until that period, reaching 90% of biogas production by the biodigester SOL-RET, after 182 days from the beginning of the experiment.Figure 4 shows the average daily production of methane.

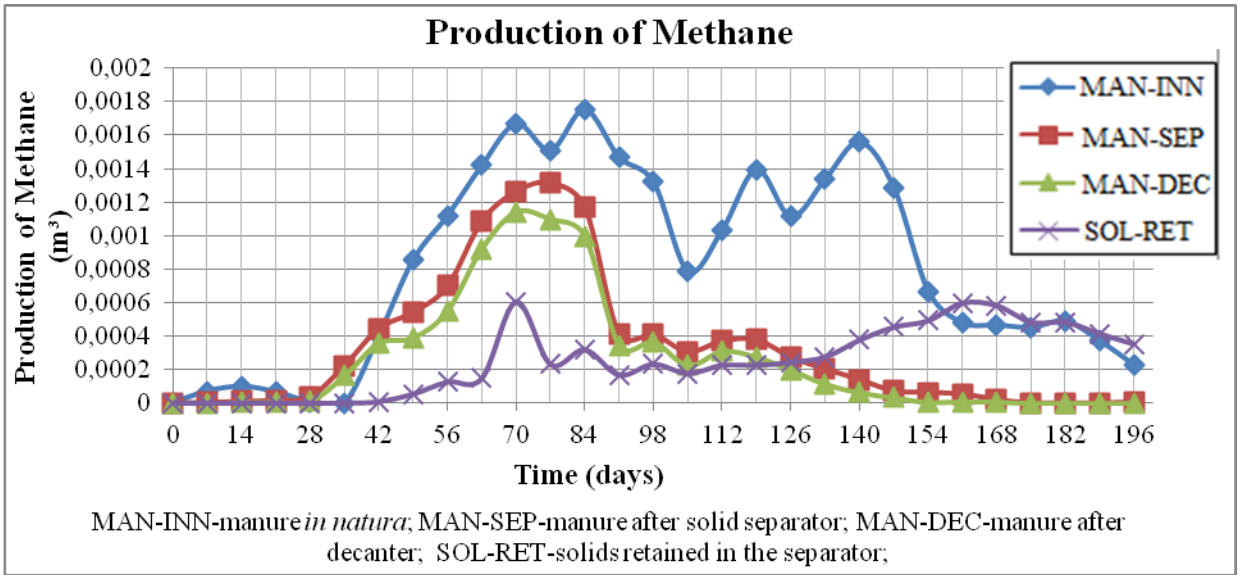


FIGURE 4.Average daily production of methane in batch digesters operated with manure of dairy cows obtained after washing the stable floors (MAN-INN) and of the fractions obtained after the solid separator (MAN-SEP and SOL-RET) and after the sand decanter (MAN-DEC).

The average daily production of methane for the MAN-SEP and MAN-DEC digesters are similar and intensify from approximately 30 days of the beginning of the experiment reducing its production after approximately 80 days. The methane production for the SOL-RET biodigester presents a peak at 70 days of the experiment and intensifies after 130 days, which justifies the low accumulated biogas production in the previous period.The presence of only one methane peak at the beginning of the experiment for the MAN-SEP and MAN-DEC biodigesters indicates that there was separation of a more difficult biodegradation material and this is explicit by the presence of methane peak production in the end of the experiment by the SOL-RET biodigester, constituted with the separated solids.The highest methane content present in the biogas was 92.1% for the MAN-SEP biodigester and the lowest was 82.3% for the MAN-INN biodigester, which were higher than those found by GALBIATTI et al. (2010) that worked, among other substrates, with bovine manure and the highest average methane content was 81.48%.

Table 2 shows the biogas production potential values expressed in m^3 of biogas per kg of manure, per kg of total solids added, per kg of volatile solids added and per kg of reduced volatile solids.

TABLE 2. Average potential of biogas production, expressed in m^3 of biogas per kg of manure, per kg of total solids (TS) and volatile solids (VS) added per kg of reduced VS.

MANURE	BIOGAS PRODUCTION			
	m^3/kg Manure	**m^3/kg TS add**	**m^3/kg VS add**	**m^3/kg VS red**
MAN-INN[1]	0.0180 b	0.2551 a	0.3027 a	0.8605 a
MAN-SEP[2]	0.0062 c	0.2555 a	0.3151 a	0.8403 a
MAN-DEC[3]	0.0049 c	0.2104 a	0.2639 a	0.6927 ab
SOL-RET[4]	0.0313 a	0.1475 b	0.1747 b	0.5263 b
P Values	<0.0001	0.0005	0.0004	0.0011
F Values	34.47	12.58	13.01	10.56
CV(%)	26.67	13.24	13.33	12.98

P-probability; F-significance; CV- coefficient of variation;
Averages in the column with distinct letters differ by the Tukey test (P<0.05)
[1]manure*in natura*; [2]manure after solid separator; [3]manure after decanters;
[4]solids retained in the solids separator.

The average biogas production per kg of manure in the biodigesters with MAN-INN and SOL-RET (0.018 and 0.031 m³ respectively) is similar to that found by AMARAL et al. (2004), who obtained on average 0.025 m³ of biogas per kg of manure and by XAVIER & LUCAS JÚNIOR (2010) obtained values ranging from 0.0163 to 0.0267 m³ of biogas per kg of manure.The values obtained for the biodigesters supplied with MAN-SEP and MAN-DEC were lower (0.0062 and 0.0049 m³ of biogas per kg of manure, respectively) and, compared to the production by MAN-INN, there was a reduction of 65,5% and 72.8%, respectively, in total biogas production.These values are compatible with those found by MACHADO (2011), who, working with manure from dairy cattle submitted to different air exposure times, obtained values ranging from 0.0026 m³ to 0.0080 m³ of biogas per kg of substrate.

Considering the biogas production per kg of total solids added, an important factor to eliminate the interference of the water content present in the biomass, it is observed that they ranged from 0.1475 to 0.2551 m³, values higher than those found by AMARAL et al. (2004), which ranged from 0.10 and 0.12 m³ per kg of TS added.The values found in this study are close to values found by XAVIER & LUCAS JÚNIOR (2010), ranging from 0.1924 to 0.3101 m³ and those found by MACHADO (2011) ranged from 0.0970 to 0.2478 m³ of biogas per Kg TS added.

Biogas production potentials for reduced volatile solids were higher for biodigesters fed with MAN-INN and MAN-SEP with values of 0.8605 and 0.8403 m³ of biogas per kg of reduced VS, respectively, and are within the range of values observed by XAVIER & LUCAS JÚNIOR (2010), ranging from 0.7243 to 1.082 m³ of biogas per kg of reduced VS.

The biogas production, in m³ per kg of manure, in the MAN-INN and SOL-RET biodigesters, differed statistically from the other biodigesters ($P < 0.05$), and the biodigesters with MAN-SEP and MAN-DEC were statistically the same ($P > 0.05$). For the other parameters (m³ of biogas by TS added, VS added and VS reduced) only the biodigestor with SOL-RET showed significant statistical differences ($P < 0.05$).

CONCLUSIONS

The results showed that, with the separation of solids, the biodigesters supplied with MAN-SEP and MAN-DEC obtained a reduction in total biogas production of up to 72.8% when compared to the biodigestor supplied with the *in nature*manure (MAN-INN).However, the MAN-SEP and MAN-DEC biodigesters presented faster stabilization and biogas with higher methane content. With the solids separation the hydraulic retention times can be reduced, which will reduce the volume of the biodigesters and the costs of implantation and maintenance due to clogging.

If the choice is made for the separation of solids, the pollutant potential of the separated solids must be considered and an adequate disposal of the same as the composting should be done.

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