INVESTIGATING BIOCHEMICAL BIOGAS POTENTIAL FROM CO-DIGESTION OF BOVINE MANURE AND ACTIVATED SLUDGE WASTE

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ABSTRACT

Global population growth increases food and sewage treatment demand, highlighting the need for sustainable practices. This study investigates the anaerobic co-digestion of cattle manure and sewage sludge for biogas production, testing different mixing ratios. Experiments reveal that co-digestion improves the production of biogas from sludge with a significant gain in efficiency, up to 53.07%. The Biochemical Biogas Potential of manure as the only substrate is the highest, and the increase in potential in the tested mixtures occurs with the increase in its percentage in the compost. These findings promote the viability of co-digestion as a sustainable solution for waste and energy management.

Keywords: Anaerobic Co-digestion 1. Wastewater 2. Livestock waste 3. Biogas 4. Resource Recovery 5.

1 INTRODUCTION

Constant population growth intensifies several global emergencies, including greater demand for food and greater production of sanitary sewage. One option to intensify the food supply is the production of dairy cattle in a confined and semi-confined manner, which is extremely relevant in the southern region of Brazil but generates concentrated effluents, which can cause problems such as air pollution, groundwater contamination, eutrophication, among others.[1] In parallel, sanitary sewage also increases as the population increases. A biological method widely used in Wastewater Treatment Plants (WWTPs) is the activated sludge system. However, this process produces large quantities of activated sludge waste (ASW), which must be discarded to avoid secondary environmental pollution. The cost of transporting and disposing of ASW in landfills in the Catarinense Company of Water and Sanitation (CASAN) metropolitan region exceeded 5.5 million BRL in one year.[2]

In this context, anaerobic digestion (AD) has been recognized as one of the most technically mature methods for treating various types of organic waste, offering a high degree of stabilization, reducing the volume of waste, and transforming organic products into energy biogas and biofertilizers. Anaerobic co-digestion (AnCoD) stands out for processing different types of waste simultaneously and balancing essential parameters to enhance the efficient production of biogas. Therefore, this study aims to investigate the Biochemical Biogas Potential (BBP) from the AnCoD of BM from intensive livestock farming and ASW from CASAN's WWTPs, analyzing different mixture fractions of the substrates to obtain the best proportion of the compound. This research will serve as a basis for future investigations and applications of AnCoD systems for waste recovery and obtaining biogas.

2 MATERIAL & METHODS

BM was obtained from a dairy farm located in Vacaria, Brazil. In the same location, inoculum was also collected from an anaerobic lagoon system from a dairy industry that had already been adapted to degrade BM. The ASW from an aerobic secondary treatment was supplied by Casan's WWTPs in Florianópolis, Brazil, together with the inoculum from the anaerobic digester of the same WWTPs. The inoculum used in the AnCoD experiments is composed of a mixture of the two aforementioned inocula. The samples and respective inocula were characterized immediately upon arrival for volatile solids (VS)[3] and pH.

The experimental apparatus used to measure BBP was based on the VDI Standard – 4630[4] and is shown in Figure 1. The substrate-to-inoculum ratio followed the same standard, where the quotient of substrate VS to inoculum VS should be lower than or equal to 0.5 in order to ensure no inhibition due to excess substrate. The system was maintained at 37°C ± 2°C (mesophilic conditions), and gas readings were taken daily. The tests were carried out with substrates in different mixture fractions: 0/100%, 20/80%, 40/60%, 60/40%, 80/20%, and 100/0% of ASW and BM (VS, VS), respectively, in triplicate and followed by the blank (inoculum only), and were terminated when the daily gas production was <1% of the total cumulative generation. The observed values were converted to standard temperature and pressure conditions (273 K and 1013 mbar) to eliminate systematic errors related to the quantification of gas production. Water vapor pressure based on tabulated data from the literature [4] was also considered.

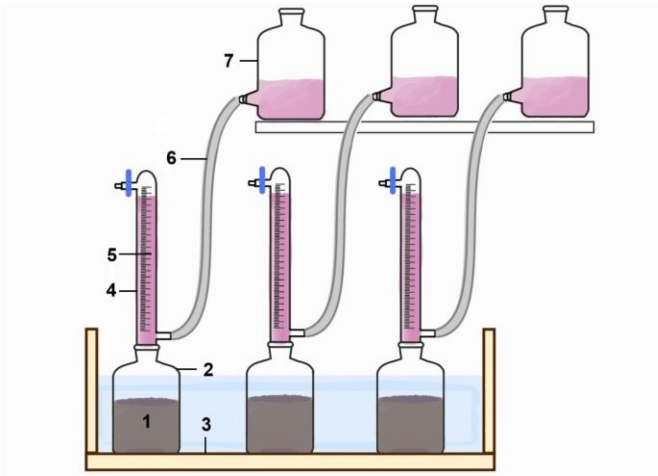

Figure 1 Experimental apparatus of the eudiometer system (1 - substrate + inoculum, 2 - reactionary flask, 3 - termosthatized bath, 4 - eudiometer, 5 - sealing solution, 6 - connection, 7 - Mariotte flask)

The BBP of the compounds was calculated using Equation (1).

$$BBP = \frac{(VN(Cumulative\ Yield)Substrate - (VN(Cumulative\ Yield)Blank)}{VS.mSample} \quad (1)$$

The BBP ($mL_{N(Biogas)}.g.SV^{-1}$) represents the relationship between the volume of biogas produced ($V_{N(Cumulative\ Yield)Substrate}$), minus the volume produced by the blank (inoculum) ($V_{N(Cumulative\ Yield)Blank}$), divided by the product of the mass of VS ($g_{SV}.kg_{Sample}^{-1}$) the mass of the substrate (m_{sample}) added to the reaction flask. The Gain Percentage (GP) value was calculated using the additional value of experimental BBP obtained in relation to the calculated theoretical BBP. The latter was calculated for the mixture fractions based on the experimental BBP results of the individually digested substrates (0/100% and 100/0% ASW/BM VS, VS).

3 RESULTS & DISCUSSION

The sample characterization results are presented in Table 1. The two residues and the inoculum presented neutral pH values, which is favorable in the AD process and similar to other studies. The concentration of VS in the studied BM was 67.88 ± 0.09 $g.kg^{-1}$, higher than the value found in the literature[2], 19.40 $g.kg^{-1}$, possibly due to the presence of forage. While the concentration of VS in the ASW was 9.09 ± 0.07 $g.kg^{-1}$, below the reference from other studies, which reached 25 ± 2 $g.kg^{-1}$, due to the residue coming from the secondary treatment.

Table 1 Characterization of substrates and inoculum.

Parameter	BM	ASW	Mixed Inoculum
pH	7.22	6.05	7.38
Total Solids ($g.kg^{-1}$)	82.83 ± 0.20	12.03 ± 0.05	32.96 ± 0.38
Volatile Solids ($g.kg^{-1}$)	67.88 ± 0.09	9.09 ± 0.07	23.17 ± 0.17

Figure 2 shows the biogas curves accumulated over the test days for the six proportions analyzed. The blank tests were used to disregard the contribution of biogas production related to inoculum degradation and have already been discounted from the curves shown in the figure. The average BBP and GP values are shown in Table 2.

Table 2 Average BBP and GP values of the mixture fractions.

Assay (ASW/BM%, VS/VS)	BBP ($mL_{N(Biogas)}.g.SV^{-1}$)	BBP Theoretical ($mL_{N(Biogas)}.g.SV^{-1}$)	GP (%)
100/0	124.79 ± 28.47	-	-
80/20	260.97 ± 23.37	170.50	53.07
60/40	263.70 ± 19.96	216.20	21.97
40/60	291.67 ± 24.32	261.91	11.36
20/80	336.98 ± 14.33	307.61	9.55
0/100	353.32 ± 12.92	-	-

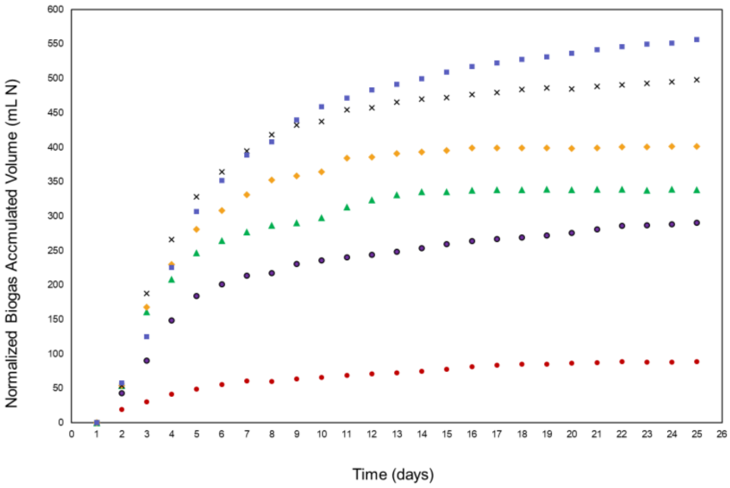

Figure 2 BBP of mixtures 100/0% (●), 80/20% (●), 60/40% (▲), 40/60% (◆), 20/80% (×) and 0/100% (■) of ASW/BM (VS, VS).

The AD of pure BM presented the highest BBP of the experiments, with 353.32 ± 12.92 ($mL_{N(Biogas)}.g.SV^{-1}$), which is expected due to the higher concentration of VS in the substrate. It is possible to observe that there is an increase in the BBP as the amount of BM increases. However, it should be noticed that the BBP is a measurement of the maximum biogas production capacity, and this value is not observed in semi-continuous systems, as the daily feeding of the system does not allow the complete degradation of the substrate.

The AnCoD of the mixture has an apparent synergistic effect that benefits the circumstance of lower concentration of nutrients and lower content of biodegradable organic matter in the ASW, improving its biodegradation. This result can be attributed to the increase in the production of volatile fatty acids from the reaction with the insertion of BM, causing the subsequent increase in readily available biodegradable organic matter for use by microorganisms.[5] From this perspective, 20% of the BM (VS) in the compound has already proven to be sufficient to make such organic matter available, with the highest GP, of 53.07%. Other authors demonstrate that AnCoD increases the solubilization of recalcitrant organic compounds, which may have improved the biodegradability and biogas production of ASW.[6] This result is very positive as the high percentage of gain benefits the use of anaerobic co-digestion as an alternative for treating sanitary sludge, which is a problem that currently demands considerable financial resources for CASAN.

4 CONCLUSION

The best result observed among the mixtures was the 20/80% (ASW/BM, VS/VS) fraction with BBP of 336.98 ± 14.33 ($mL_{N(Biogas)}.g.SV^{-1}$). However, the biggest GP with the AnCoD process was the 80/20% (ASW/BM, VS/VS) fraction, probably favored by the biodegradable organic matter available. These results establish the basis for future research into applying an AnCoD system as a sustainable and low-energy-cost solution for waste management, supply of the energy matrix for WWTPs, and stabilization/sanitation of sewage sludge.

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