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STABILIZATION OF CONTINUOUS ANAEROBIC DIGESTION REACTORS ON LABORATORY SCALE

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ABSTRACT:

Since the industrial revolution, sewage and effluents containing emerging pollutants have become a threat to the environment and water cycle on Earth. Anaerobic digestion (AD) emerged as the important method to mitigate the impact pollutants by consuming it and generating methane and carbon dioxide as substrates. Stabilization of anaerobic digestion reactors stands as a pivotal aspect in optimizing biogas production and ensuring operational efficiency. This process involves the establishment and maintenance of favorable conditions for the bacterial community metabolism aiming at their maximum efficiency and methane production. In this experiment, two reactors were assembled equally with 800 mL of working volume, an expected pH of 7-7,5, and Volatiles Suspended Solids (VSS) 10 g/L. The volume of biogas produced, pH, SSV, and chemical oxygen demand were accompanied and led to stabilization. Although differences had appeared between the reactors, by the addition of sodium bicarbonate as a control of the acidification process and constant and regulated feed, after approximately 100 days, the expected environmental and efficiency conditions were achieved.

Keywords: Continuous anaerobic reactor, anaerobic digestion, stabilization protocol.

1 INTRODUCTION

Due to industrialization advancements, increasing population, and pollution taxes on earth, environmental pollution has become a major concern. Thus, in a world where structured human cities cohabitate with ecosystems, emerging pollutants, and wastewater become a threat to the environment (Gavrilescu et al., 2015). Mitigating the impact of emerging pollutants is directly aligned with United Nations Sustainable Development Goals 6 and 11, aiming to preserve life below water and sustainable use of natural resources (*THE 17 GOALS | Sustainable Development*, n.d.).

Anaerobic digestion (AD) has been a consolidated technology for wastewater and sewage treatment removing organic pollutants and producing methane as a subproduct (Mata-Alvarez et al., 2000). However, this technology has limitations when it comes to degrading some pollutants, especially recalcitrant and emerging pollutants such as pharmaceutical drugs and pesticides (J. L. Chen et al., 2014).

In this sense, developing laboratory scale reactors is critical to improve studies in the field, such as adding zero valent iron particles to remove recalcitrant pollutants. Furthermore, AD reactor standardization is still a challenge due to the system complexity and variability in the microbial community. Lastly, the development of AD reactor in laboratory scale could help to improve AD processes in an industrial scale. Thus, this study aims to analyze anaerobic reactor conditions until stabilization.

2 MATERIAL & METHODS

INOCULUM

The inoculum chosen was a blend between 1400 mL of a previous sludge from a local sewage treatment station, CASAN, (Florianópolis, Brazil), and 1100 mL from a food additives industry AD system. Both sludges were mixed in a previous reactor, with volumes equal to 2500 mL. From this setup, the bacterial community was fed twice a week with an organic load of cellulose, soluble amid, and yeast extract until biogas production stabilization, as described below.

REACTORS ASSEMBLY

It was chosen as a duplicate system with identical reactors (B1 and B2) with 1000 mL each (800 mL of working volume and 200 mL of headspace) and 10 g/L SSV. The two reactors were assembled with 707.3 mL (11,31g/L SSV) from the previous reactor, added micronutrients, and completed until 800 mL with saline solution (0.5 g/L NaCl).

OPERATIONAL CONDITIONS

Both reactors were started and allocated in an incubator at 37°C and connected to a system to measure biogas volume (DIN 38.414-8) (Figure 1). Moreover, reactors were operated in a continuous regime with intermittent (three times a week). The exchange volume was 100mL, resulting in an HRT of 18.67 days. The feed solution was composed of 0.5g/L NaCl, 6.3 g/L soluble starch, 5.7 g/L microcrystalline cellulose, 2.0 g/L yeast extract, and 0.1 mL of the micronutrient solution corresponding to a weight ratio between substrate to inoculum of 0.5 and between carbon to nitrogen of 25.

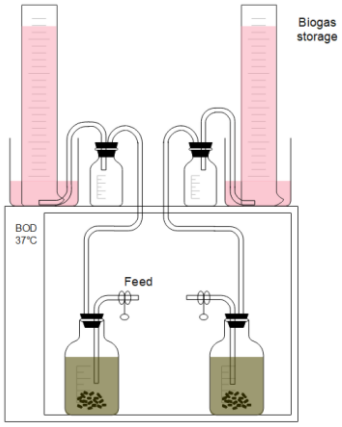

Figure 1 B1 e B2 setup scheme

Data such as temperature, atmospheric pressure, produced biogas volume, and pH of both reactors were registered at each feed. Moreover, analyses such as Chemical Oxygen Demand (COD) and Total Suspended Solids (TSS), Volatile Suspended Solids (VSS), and Fixes Suspended Solids (FSS) were regularly made to follow the reactor stabilization process.

3 RESULTS & DISCUSSION

Both reactors presented variations in values of biogas production, pH, COD, and solids concentration (Figure 2). Initially, they had an inconstant biogas production. However, after 50 days, they presented a constant biogas production of approximately 70 mL a day (Figure 2-A). As shown in Figure 2-B, pH was between 6 and 6.5 at the beginning, not being the ideal pH for AD. Based on this, sodium bicarbonate was added to each feed to maintain the pH between 7 and 7.5, the optimal pH for anaerobic digestion (Kunz et al., 2019). Reduction in pH could be explained as an accumulation of volatile fatty acids (VFAs) from the acidogenesis phase (Ahring et al., 1995).

Changes in pH can directly affect bacteria metabolism. When AD stages are unbalanced, metabolic pathways could be disrupted and changes in efficiency can be observed (Demirel & Scherer, 2008). In that regard, methanogenesis, the slowest stage of AD, is affected by the acid environment, and methane production is reduced. As shown in Figure 2-B, decreases in pH lead to a proportional reduction in biogas production (Latif et al., 2017).

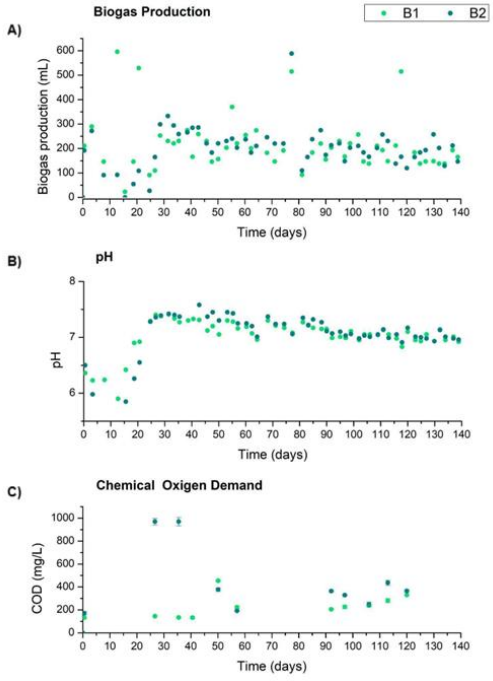

Figure 2 B1 e B2 A) biogas production, B) pH, and C) COD values.

By observing Table 1, reactor B2 had a VSS closer to expected (10g/L). In contrast, reactor B1 showed a lower value equal to 7.09 g/L. After 70 days, we can see that B1 and B2 were leaning toward an equal FSS concentration and a VSS closer to 10 g/L, as expected.

Table 1 Reactors B1 and B2: Total Suspended Solids (g/L), Fixes Suspended Solids (g/L), Volatiles Suspended Solids (g//L)

	TSS (g/L)		FSS (g/L)		VSS (g/L)	
Time	B1	B2	B1	B2	B1	B2
39 days	10.56 (±0.18)	15.05 (±0.02)	3.47 (±0.06)	5.57 (±0.07)	7.09 (±0.12)	9.48 (±0.09)
95 days	13.11 (±0.49)	14.40 (±0.10)	3.85 (±0.15)	4.25 (±0.04)	9.27 (±0.34)	10.15 (±0.06)
109 days	11.84 (±0.14)	14.60 (±0.12)	3.08 (±0.02)	3.72 (±0.03)	8.76 (±0.15)	10.88 (±0.15)

Furthermore, the COD of the output effluent from the two reactors (Figure 2-C) became closer over time, which may indicate a similarity between their efficiency.

4 CONCLUSION

AD is a complex system where each step is crucial in terms of efficiency and acidification. Moreover, remaining organic load and solids concentration can affect its efficiency. Biogas production of both reactors presented variations, especially at the beginning. However, the decision to regulate pH with sodium bicarbonate led to a regular production of biogas.

To summarize, although the two reactors were theoretically set up equally, the bacterial community complexity and experimental errors involved, and differences in their composition and efficiency were observed. Passing working time, both reactors led until stabilization and can be considered stabilized after 90 days of operation.

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