EVALUATION OF THREE TYPES OF INOCULUM FOR BIOGAS PRODUCTION FROM BENCHTOP BIODIGESTERS

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ABSTRACT

This study delves into the crucial topic of energy renewal, mainly focusing on combating pollution and addressing climate change. Biogas emerges as a promising energy source, prompting the need to evaluate various inoculants to enhance biofuel production. Three distinct inoculants are examined: one based on brown sugar and rainwater, another on organic manure and stream water, and the third incorporating coffee grounds into the first. The substrate, mimicking organic household waste with pumpkin, cucumber, and mango components, undergoes assessment in low-cost biodigesters constructed using accessible technology. Maintaining a hydric retention time of 14 days and conducting tests in triplicate with controlled mesophilic temperatures, a substrate, water, and inoculum ratio of 1:0.25:0.75 is employed. Arduino sensors monitor crucial parameters like temperature, humidity, and pressure while measuring tapes and a gasometer quantify pH and biogas. By analyzing the data, the study aims to identify the most effective inoculant, optimizing biogas production in the biodigester. Biogas, recognized for its energy efficiency and production accessibility, stands out as a vital renewable energy source. Pursuing innovative microbial growth formulas contributes to energy yields and plays a crucial role in treating and managing agroforestry and urban waste.

Keywords: Organic waste, Biodigesters, Biofuels, Biogas, energy yield.

1 INTRODUCTION

Biogas/biomethane are promising biofuels in Brazil due to the large generation of waste that produces this biofuel. Biogas, when purified and refined by removing carbon dioxide (CO2), hydrogen sulfide (H2S), and moisture, enhances energy efficiency and calorific potential, transforming it into biomethane. Every 1 m³ of biogas is equivalent to 0.66 liters of diesel or 0.7 liters of gasoline, in addition to the possibility of being used directly as fuel or indirectly to generate thermal or electrical energy [1,2].

In the university restaurant (RU) at UFPA, about 1.3 tons of food is wasted in just one month of service[3]. In this scenario, biogas production could be one way to manage and treat these wasted resources. Biogas production in Brazil has increased by approximately 87% in the last 10 years, indicating the national market's interest in the sector. It is forecasted to grow around 574 million Nm³/year of biogas[4].

The choice of biogas production technology is crucial for process efficiency, considering factors such as resource availability, environmental conditions, and application spaces. Biodigesters, as the main systems utilizing anaerobic digestion of organic matter, come in various types, differing in their feeding method, shape, and inlet flow. Essential elements within the biodigester include the inoculum, an initial concentration of microorganisms to kickstart biofuel production; organic matter as an energy source for bacteria and the bacteria themselves, which play a crucial role in decomposing organic matter and in the efficient production of biogas [5,6].

The biochemical process in the biodigester involves four phases: hydrolysis, acidogenesis, acetogenesis, and methanogenesis[7]. Methanogenesis is the primary phase, converting acetic acid and hydrogen into methane and carbon dioxide[8]. The products obtained are biogas and digested in the biodigester, which can be used as biofertilizers.

Based on the above, this study aims to evaluate the influence of different types of inocula on substrate in biogas production in a low-cost laboratory biodigester[9].

MATERIAL & METHODS

The study began with data collection from the Superintendence of Student Assistance (SAEST) website between September and November 2022. Based on the results, three recurring foods were selected to compose the substrates for the experiments

The chosen biodigesters were of the adaptable type, allowing for continuous or batch processes. The construction involved 5-liter jerry cans, with holes for substrate input and biofertilizer output, and the utilization of hospital equipment for biogas collection.

Environmental parameters were measured using sensors and Arduino. Biodigester instrumentation included:

- DHT11 for temperature and humidity measurement.
- BMP280 for pressure measurement.
- Differential manometer.

- pH was measured using pH strips.

The chosen substrates were pumpkin, kale, and cucumber, locally sourced and underwent a two-stage grinding pretreatment to increase the surface area for bacteria. The inoculants were formulated with the aim of stimulating and enriching the microbial load in the biodigesters. Three distinct compositions were adopted for the inoculants.

- The first inoculum was based on rainwater and brown sugar, aiming to provide a rich source of microorganisms and substrate.
- The second inoculum incorporated coffee grounds into the mixture, exploring its potential impact on biogas production.
- The third inoculum introduced the use of organic fertilizer derived from composting.

Each inoculum underwent a retention period of seven days to increase the microbial load before being mixed with the substrates, thus simulating realistic conditions of food organic waste in the biodigesters.

After preparing the components, the biodigesters were assembled, sealed, and painted black to optimize energy absorption. Sensor programming was carried out using the ARDUINO IDE *software*. The next step involved the acquisition and pretreatment of vegetables, followed by the production and mixing of the inoculants with the substrates. The dynamics of biogas production are monitored daily over a 14-day hydraulic retention time (HRT). This period was chosen to evaluate the initial dynamics of biogas synthesis, providing data on the influence of the process on environmental parameters.

The final objective of this experiment is to determine the volume of biogas produced in each biodigester to evaluate the efficiency of each inoculant. To do this, it is necessary to calculate the volume of biogas using the following equation 1[10]:

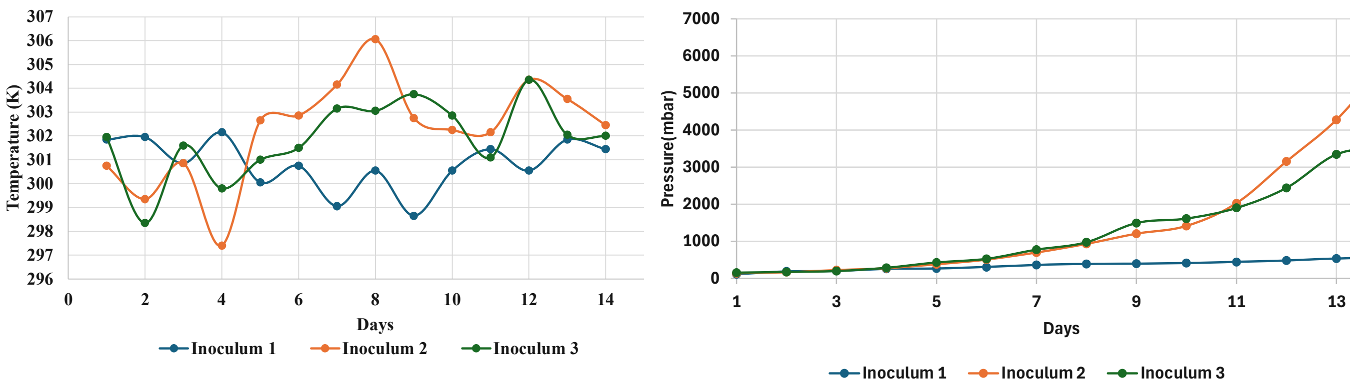
$$Vxday = \frac{P*Vu*22.41}{83.14*T}$$

Where: P $(mbar)$ is the pressure of the biodigester in millibars, Vu (L) is the useful volume of the biodigester in liters, T (K) is the temperature of the biodigester in Kelvin, and Vx day is the volume of biogas produced in milliliters over the 14-day period.

2 RESULTS & DISCUSSION

The results of temperature and humidity measurements for the first inoculum (rainwater + brown sugar) were obtained using the DHT11 sensor. Initially, the pressure would be evaluated using the BMP280 sensor; however, environmental factors such as humidity and acidity caused its oxidation, damaging the sensors. Because of this, a manometer was used to perform pressure analyses. This adaptation was necessary to overcome the challenges caused by adverse environmental conditions.

Figure 1 Temperature and Pressure Profiles in the Biodigester



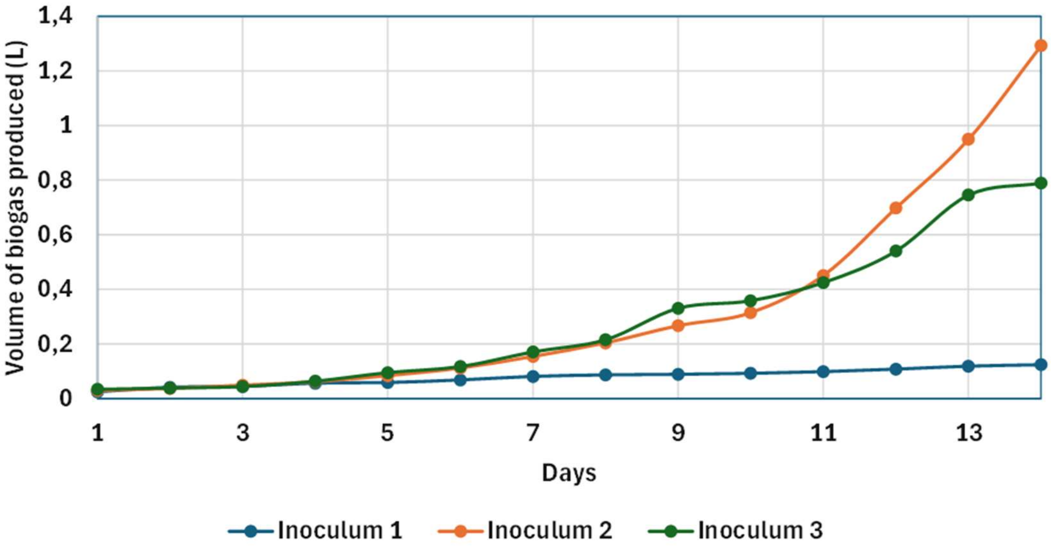
Description: Inoculum 1, rainwater and brown sugar; Inoculum 2, composite of Inoculum 1 and coffee grounds; Inoculum 3, composite of Inoculum 2 and organic fertilizer.

During the hydraulic retention period, the biodigesters were influenced by daily temperature variations, impacting biogas production. Exposure to external elements, especially during the night, caused a reduction in local temperature, affecting the ideal range for microbial growth, which is between 30 and 40 °C (mesophilic range). This condition resulted in some average temperatures around 25 °C, explaining the variations in the dynamics of biogas production. However, when temperatures stabilized, notable microbial growth and increased biogas production were observed.

Upon analyzing the different pressure curves, the second inoculum exhibited the highest pressure and, consequently, the highest biogas production, followed by the first inoculum and the third inoculum. Utilizing a microbial source with a substantial amount of methanogenic bacteria and coffee grounds rich in minerals in the second inoculum contributed to microbial growth, explaining its higher production. For the first inoculum, the collection of rainwater mixed with brown sugar resulted in lower bacterial growth than the second inoculum. In the case of the third inoculum, other microorganisms in the organic fertilizer competed for substrate, potentially inhibiting the initial growth of anaerobic digestion bacteria, especially when anaerobic conditions were not fully achieved.

All pH values of the inoculum-substrate mixtures were within the ideal range of 6 to 7 for the growth and development of bacteria responsible for anaerobic digestion.

Figure 2: Volume of biogas produced



Description: Inoculum 1, rainwater and brown sugar; Inoculum 2, composite of Inoculum 1 and coffee grounds; Inoculum 3, composite of Inoculum 2 and organic fertilizer

3 CONCLUSION

Based on the assessment of the potential of different inoculants in an anaerobic digestion process, it is concluded that inoculant 2, consisting of coffee grounds, rainwater, and brown sugar, achieved the highest volume of biogas produced. The addition of coffee grounds promoted a significant improvement in anaerobic digestion, reflected by an increase in biogas production. The volume of biogas produced with the addition of coffee grounds was 1.29 L, while the first inoculant produced 0.12 L and the third generated 0.78 L. This represents an increase of approximately 975% compared to the first inoculant and 65% compared to the third. This is likely due to the nutritional properties, especially minerals, and the reduced particle size, allowing for a larger contact area and more efficient interactions with bacteria. Therefore, considering these findings, inoculant 2 is a more promising choice for enhancing biogas production in biodigesters and could be applied on a larger scale.

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