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Research Article

Batch Biodigester Prototype for Experimental Use

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Abstract: Currently there are different types of biodigesters, which dynamizes the knowledge about the handling and construction of these models. However, the adequacy of models that will be used in experimental scale for use in research laboratories that allow better planning, execution, data collection, analysis and interpretation of the results of experiments are of fundamental importance. The objective was to manufacture a batch biodigestor prototype on an experimental scale for sample use in research. The prototypes were supplied with substrate (water and manure mix) and inoculant (ruminal biomass) and filled to 80% of the total storage capacity. The variables biogas production and pressure were evaluated. The prototype of the batch biodigestor presented satisfactory performance, producing enough pressure to move the biogas to the manometer and the gasometer, making it possible to obtain these variables.
Keywords: Agroenergy, anaerobic biodigestion, biogas, greenhouse gases, methane, sustainable systems.

INTRODUCTION

The use of biodigesters more than 3000 years ago in ancient China. In 1859, in Bombay, India, the first biodigestion plant was built [1] and since then, this technology has been propagated mainly in low-income countries. In Brazil, only from the 70's, this technology was implemented, mainly due to the oil crisis.

Anaerobic digestion technology is a natural process of degradation of organic matter by microorganisms, in the absence of oxygen resulting in the formation of biogas. It should be noted that a lot of research has intensified in recent years around the world, because it is clean, renewable energy generation and collaborates to mitigate the negative effects of greenhouse gases.

There are reports in the scientific literature of the existence of different types of biodigestors, such as Indian, Chinese, Canadian etc., which makes the knowledge about the handling and the construction of models of biodigestors dynamic. However, the adequacy of models that will be used on an experimental scale, for use in research laboratory which make it possible to improve planning, execution, data collection, analysis and interpretation of the results of experiments are of fundamental importance. Thus, one of the models of biodigesters, batch type, is constituted of an airtight fermentation chamber, without contact with oxygen, that favors the digestion of the biomass by the anaerobic microorganisms, by single cycle, resulting in biogas, mainly methane and that after the fermentation process, results in biofertilizers, with several applications in agriculture. In addition, it is considered simple construction and handling, and for characterization of productive parameters for field deployment. Therefore, even on an experimental scale the equipment must be adequately suitable for the occurrence of microbial reactions and for biogas analysis and production, as well as the economic value to make it must be low cost and highly practical.

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Thus, the objective was to manufacture a batch biodigestor prototype on an experimental scale for sample use in research.

MATERIALS AND METHODS

Location of the experiment

The experiment was carried out at the Center of Agrarian and Environmental Sciences, Federal University of Maranhão (CCAA/UFMA), in Chapadinha, Maranhão/Brazil, in the period of October and November of 2018.

Material used to manufacture the biodigester prototype

The batch biodigestor prototype was built by a high-density polyethylene drum and molecular weight, with dimensions 32 x 39 x 56 cm (Width x Length x Height), blue color, fixed high sealing cap, with capacity of 30 liters, model NTF 15, with hydraulic connections: Male Straight Connector ½", Straight Connector (Male ½" x Female ¼") of copper, Female Tee ½", Ball Valve ½" threadable PVC, Ball Valve P13 brass ½" - external NPT x 5/8 UNC internal, through Male Thread Pipe Connector ½" NPT x Hose Barb $^{3/8}$" Bm brass and two sealing rings (adapted).

Procedure for manufacturing the biodigestor prototype

Initially, a circular aperture of 20 millimeters in diameter was made in the center of the outer surface at the top of the drum cover, with the aid of a cup saw and electric impact drill.

In the upper opening, a set of interconnected parts was coupled and the steps for its preparation had the following methodological procedures:

1st stage – The introduction of a male straight connector, together with sealing rings on the inner and outer upper part of the cap (1);
2nd stage – One of the 180° entries relative to another the female tee entry (2) was coupled to the upper part of the Straight Connector (1);
3rd stage – A male straight connector (3) was threaded into the 90° entry of the Tee (2);
4th stage – A female ball valve (4) was connected to the straight connector (3);
5th stage – A male straight connector (5) was threaded to the 180º free entrance of the Tee (2);
6th stage – A female Tee (6) was connected to the straight connector (5), which already had a male input ¼" of the straight connector (7) coupled to its of 90º;
7th stage – A digital manometer (8) was coupled to the female input ¼ of the straight connector (7);
8th stage – A male straight connector (9) was coupled into the free entrance of the Tee (6);
9th stage – A stainless steel ball valve (10) was threaded to the male connector (9) and
10th stage – A male thread pipe connector x hose barb (11), was coupled a ball valve (10).
These nine stages finalize the composition of the set of parts (figure 1).

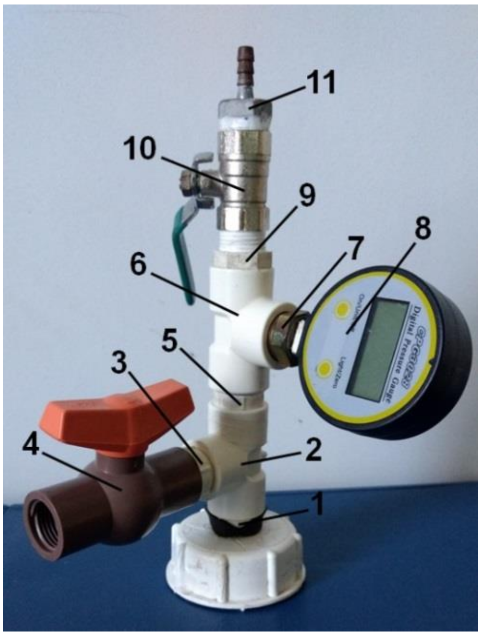

Fig-1: Set of interconnected parts

In order to avoid possible biogas leaks, all materials used in the prototype of the batch biodigestor were sealed with the help of tapes of 18 mm x 50 m screw thread and type key for pipes, to adjust and complete the structure of the prototype according to figure 2.

Fig-2: Batch biodigestor prototype

After being filled, the biodigestor prototypes were monitored to verify possible leaks and stirred in circular movements daily, in order to favor the necessary conditions for the anaerobic fermentation in the fermentation chamber.

Effluent preparation and Biomass

Cattle manure was used as an organic substrate, previously diluted in water, in a ratio of 1:1, the mixture being homogenized using a polyethylene water box, and the mixture kept at rest for 12 hours. After this period, the biodigesters prototypes were supplied in batch, ie, the substrate (water and cattle manure mix) and the inoculant (ruminal biomass), denominated as effluent, were placed in the biodigester at the beginning of the experiment and filled up to 80% of the total storage capacity.

Measurements and data collection

The biogas pressure was obtained using digital manometer (pressure – bar), and the amount of biogas produced by treatment was obtained through the gasometer LPG/CNG - LAO G 0.6, both readings always obtained in the 48-hour interval, during the period of 15 days.

STATISTICAL ANALYSIS

For the analysis of the data, the descriptive statistics were applied. The statistical tests proposed were performed using statistical software SISVAR version 5.6 [2].

RESULTS AND DISCUSSION

The descriptive analysis of the data for the biogas production and pressure variables obtained with the prototype of the experimental biodigesters are presented in table 1.

Table-1: Results of the variabes, maximum production (MP), minimum production (MiP), average (Av), variance (V), standard deviation (SD) and coeficiente of variation

Variables	MP	MiP	Av	V	SD	CV (%)
Biogas of production (m^3/day)	3.0	0.0	0.44	1.27	1.12	253.47
Gas pressure (bar)	1.28	0.47	0.79	0.03	0.17	22.15

Initially prototype experimental biodigesters were supervised daily to check for possible leaks and manual adjustments of the parts that constituted it.

It was observed external changes of the biodigester from the third day after the supply with the biomass, causing deformation in its dimension, however, deformations did not lead to biogas leaks in the prototypes, nor did they cause significant damages that could cause oxygen entry and the death of the anaerobic bacteria, making the experiment impossible. Probably, what happened was the internal pressure generated by the biogas production, which culminated in the highest observed means of biogas production and pressure, which were 3.0m^3 and 1.28 bar, respectively.

In the collection of the variables, the management of the prototypes became effective. The practicality in the handling did not present any difficulty that would lead to prejudice the collection and obtaining of the data. Thus, anaerobic conditions were favored, and the sealing system and prototype of the biodigester presented good performance implying that the different stages of biogas production were considered normal at all stages (hydrolysis, acidogenesis, acetogenesis and methanogenesis).

When analyzing two biodigesters operated on a pilot scale from bovine manure for 29 days [3], observed average production of 3.8 m^3. [4] highlight that in relation to the same fermentation conditions between the continuous and discontinuous process, there are differences in the production of biogas, where the authors observed a 42% increase in biogas production for the continuous process.

The data obtained for both biogas production and pressure were practically stable, with few variations, however from the 14th day, was observed a decrease in the values of the analyzed variables and ending the experimental observation period at 15 days after supplying the biodigestor prototype. It should be noted that over time there is a decrease in the production of biogas, explained by the death of naturally occurring anaerobic bacteria, as well as due to the experimental prototype of the biodigestor being operated in a non-continuous (batch) way, with single charge, without renewal of biomass and the metabolic processes of anaerobic digestion.

When analyzing the pressure of the biogas obtained in the 15 days of experiment an average pressure of 0.77 bar, for the average of 0.44 m^3/day of biogas produced occupying a space of 0.01 m^3, 20% of the volume of the biodigester. According to [5], who submitted a biogas reservoir to a room temperature for 3 days, the gas produced equivalent to 0.0021 m^3, reached a pressure of 1 bar occupying a space of 0.0013872 m^3. Usually the biogas pressure generated in the biodigester has low pressure which requires some adaptations in equipment to be used as an energy source. It should be noted that several factors influence the process of anaerobic biodigestion, influencing the efficiency of this process.

Conclusion

The batch biodigester prototype presented satisfactory performance, producing sufficient pressure to displace the biogas to the manometer and gasometer, making it possible to obtain these variables.

Therefore, this study demonstrates the efficiency of the biodigester and confirms the feasibility of this technique both in the sustainable aspect, making it an alternative for implantation in scientific studies and small rural properties. In addition, more research is needed to optimize the system, to increase the number of variables to be analyzed and to simplify its collection methods.

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