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ENHANCING THE ANALYTICAL CAPACITY FOR BIOGAS DEVELOPMENT IN BRAZIL: ASSESSMENT OF AN ORIGINAL MEASUREMENT SYSTEM FOR LOW BIOGAS FLOW RATES OUT OF AGRICULTURAL BIOMASS RESIDUES

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ABSTRACT: This study presents a comparison of two systems for measuring low-flow biogas production rates. Grass silage was used as substrate in the experiment. Measurements were made by using (a) manual readings and (b) an automated system. The automated system proved to be efficient as it allowed readings of the biogas flow rates in real time. Results were stored in a computerized system with a safe access interface to download the recorded data at any desired moment. Furthermore, the systems also minimized the error rate in comparison to the manual method.

KEYWORDS: automation, biogas, biogas meter, biogas volume.

INTRODUCTION

Internationally, biogas has gained great interest over the last years as it may be used as a renewable energy source for the generation of heat and power and also for the generation of fuel (biomethane) (LEÓN & MARTÍN, 2016; LANTZ, 2012). Particularly for Brazil, the development in bioenergy structure can be seen as a strategic step, especially for rural communities, due to the potential self-provision of energy as well as the commercialization of the excess energy in the national system (ARAÚJO et al., 2014). The regulation of the electricity sector allows injecting the surplus of generated electricity in the distribution grid in the evolution of Brazil energetic sector (DA SILVA et al., 2016).

Facing this, in studies by KONRAD et al., (2014 a), KONRAD et al., (2014 b) and LUMI et al., (2015), the authors show that it is possible to use anaerobic digestion technology to treat waste from agriculture of animal or vegetable origin, which to be converted into biogas, i.e. energy, they become useful resources for society.

In studies by PEREIRA et al., (2013), to assess the prospects for expansion of renewable energy sources in Brazil, it was assumed that by the year 2030 will generate 8,500 MW of energy from biomass, which is compared to the current situation (2015), an increase of approximately 76.5%. For this analysis, the authors considered a scenario without expansion of fossil fuels, which would represent share of biomass in about 3% of total energy projected for 2030.

However, in order to support the development of biogas infrastructure, it will be needed to count with analytical capacities that can help technology companies and the local communities to test the potential substrates in the early development stages, and to monitor the implementation and operation of biogas projects in the subsequent project phases.

The cornerstone for this analytical capacity will be the implementation of appropriate laboratory scale test facilities. However, a major drawback in this laboratory phase is that the use of small-scale anaerobic reactors (normally with a total capacity lower than 3 L) implies a very low biogas generation rate during the initialization period of the anaerobic digestion (i.e. the first 2 to 5

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days). This complicates biogas flow measurements, since commercial meters usually do not measure such low flows (LIU et al., 2004; SIBAJA et al., 2011).

Currently there are different methods used to measure biogas volume flows for small-scale laboratories, being the most relevant (a) the eudiometer tube, (b) the gas pressure measurement instrument, (c) the gas sampling tubes, (d) the gas-collecting bags, (e) the Hohenheim fermentation test (syringe sampler) and (f) the micro gas meter (Bergedorf fermentation test/Milligascounter) (VDI, 2006; MARTÍNEZ SIBAJA et al., 2011). These systems are characterized by their high overall costs, mainly due to the working hours associated to their conduction. Therefore, for the Brazilian case, there is still a need for precise, but at the same time low-cost measurement systems.

In this regard, the liquid displacement has proven to be a simple and reliable method for measuring flow rates of gases in a laboratory scale, as with this method it is also possible to follow the dynamics of the generation of biogas (CADENA et al., 2010). For this reason, an automated measurement system for low biogas flows has been developed in the Laboratory of Bioreactors of UNIVATES in the state of Rio Grande do Sul, Brazil. It is based on the system earlier described by VEIGA et al., (1990) who presented some important features to consider in a measurement system for low biogas flows.

The newly developed system comprises several modifications to the original methodology, including the replacement of the electrodes for event counting by optical emission and reception sensors sensible to infrared light and triggered by obstruction of the light path by a polystyrene sphere.

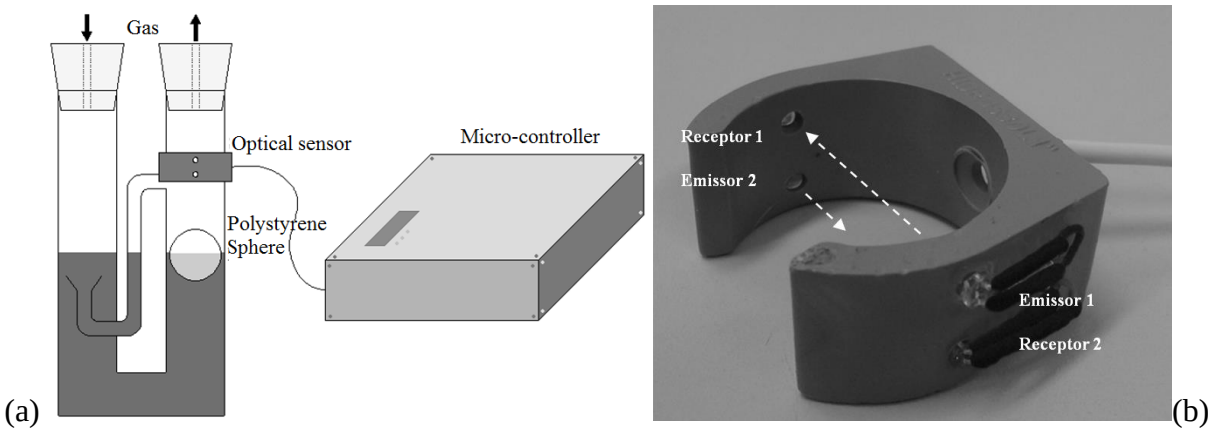
The aim of this study was to evaluate a new method of semi-continuous, automated low flow rate biogas measurements against a system with manual readings, in order to assess its appropriateness to support the development of the biogas analytical capacity in Brazil.

MATERIAL AND METHODS

Description of the automated flow measurements for low biogas flows

The proposed system (Figure 1) uses liquid displacement (in this case water) as the measuring principle. The methane is analysed by the specific sensor *Advanced Gasmitter*, produced by PRONOVA Analysentechnik GmbH & Co. The increasing gas pressure displaces the water on the gas inlet side of a U-shaped tube. At a threshold pressure, the gas is released via the hydraulic valve. Such displacement forces the water level to rise on the side of the gas meter open to the atmosphere. The polystyrene sphere swimming on the water surface is rising accordingly and at some point obstructs the passage of light between the two sensors. This triggers an event, which is recorded in a control unit, which is schematically represented in Figure 2. The optical sensor is mounted on the outlet side of the gas meter. Each sensor consists of two infrared transmitter and receiver sets (Figure 1b). An event is registered by the control unit when the light is obstructed by the polystyrene sphere. The two sets of transmitter and receiver are separated at a distance of 10 mm vertically, to allow a hysteresis analysis.

This means that an event is registered only when there is a complete blockage of light in the two receivers followed by complete clearance in both receivers, thus preventing undue counts caused by potential water level fluctuations.



(a) (b)

FIGURE 1. (a) Schematical representation of the measurement system for low biogas flows, (b) Detail of the optical sensor used for measuring events.

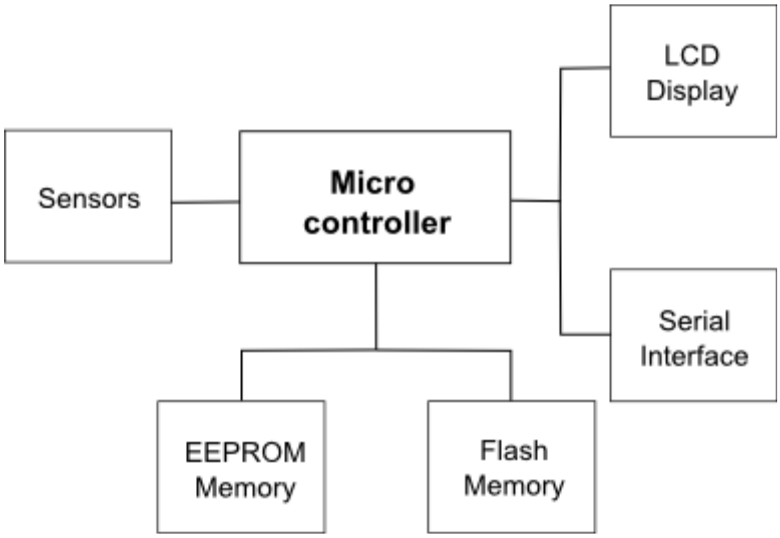


FIGURE 2. Flow diagram of the incorporated electronic circuit, including user interface and data logging.

The control unit is equipped with a temperature sensor (ΔT_{min}=0.0625°C and an atmospheric pressure sensor (ΔP_{min}=0.24 hPa). These high resolutions contribute to minimizing potential errors of the calculated gas volume under normal conditions (temperature and atmospheric pressure). Data from the temperature and air pressure sensors are stored in an EEPROM (Electrically-Erasable Programmable Read-Only Memory) within the control unit. The sensors are connected to the control unit through flexible cables, allowing close placement to the point where the volume measurements take place. This results in more consistent readings as when the sensors are installed inside the casing of the control unit.

Calibration of the biogas volume represented by one counting event must be made individually for each gas meter, due to small differences in the handmade glass tubes. This volume was around 40 ml at normal conditions in this system. For calibration, this volume as well as the ambient temperature and air pressure were measured simultaneously, in each calibration. The atmospheric pressure sensor is calibrated against a reference atmospheric pressure.

The control unit manages the entire measurement system by registering counts from the gas meters and the temperature and pressure sensor. At each discrete counting event, the number of the gas meter, date, time, temperature, pressure and volume of biogas produced are recorded. This information is stored in a FLASH memory (non-volatile) system in the control unit. The data can then be downloaded to a computer, using customized software that automatically generates Excel spreadsheets for easy information handling.

On the LCD display of the control unit, the total number of recorded events, the occupancy rate of the memory, time, and current temperature and pressure are shown.

For connecting the device with an external computer, the control unit has a serial communication interface. When connected, the user can download the data stored in the memory, set the date and time settings of the device or delete the data in the non volatile memory. The automated measurement system records each counting event together with a time stamp and the correlated ambient temperature and air pressure. This recorded data were downloaded to a computer daily, but can be accessed at any time during or after the experiment.

ComparativeComparatives **analysis**

A comparative experiment was designed, in which the developed measurement system was evaluated against gas volume measurement with gas sampling tubes, a standard laboratory procedure in Germany. In this standard system, the reactors were connected to reception flasks with a variable volume of up to 2.6 L, as presented in Figure 3. The measurements occurred manually when the desired gas volume inside the reception flasks were reached.

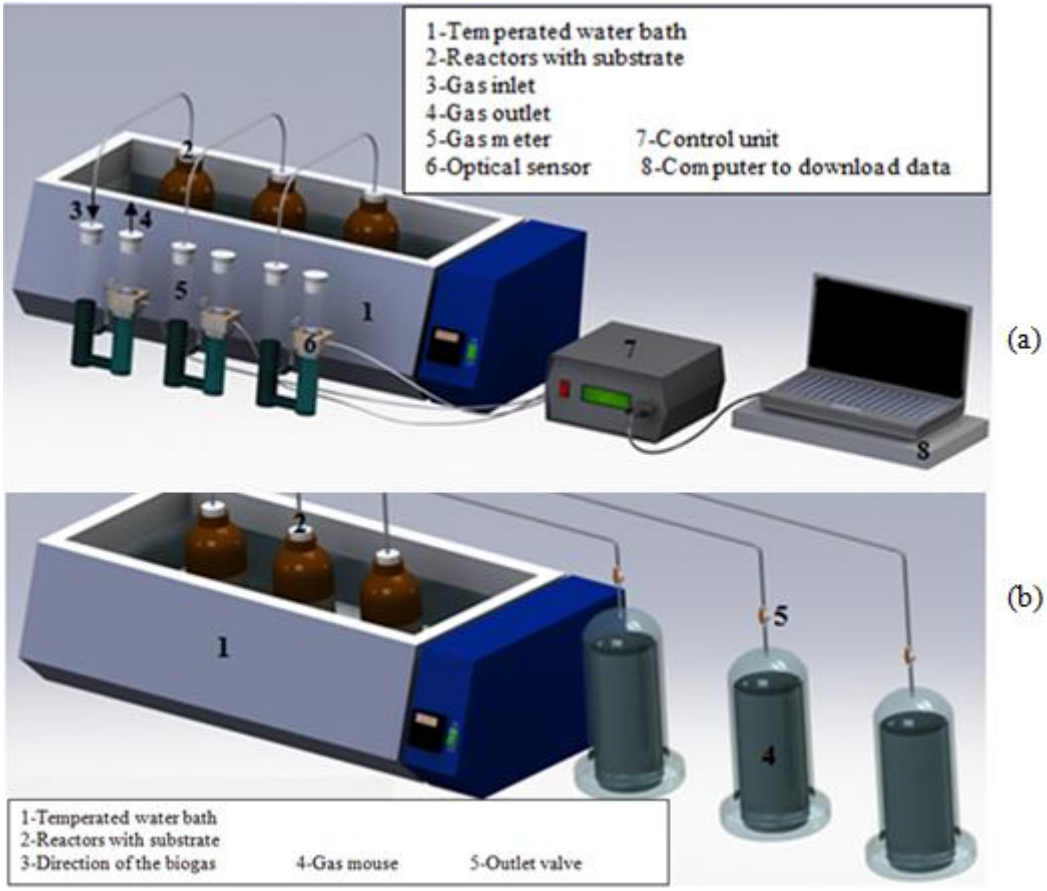


FIGURE 3. Experimental setup of (a) the automated gas flow measurement system and (b) the manual system.

Three laboratory reactors (Erlenmeyer flasks with 2L substrate capacity) were placed in a constant temperature water bath, set at 37°C. Grass silage was used as substrate, and the comparative measurements were carried out for a period of 30 days (Figure 3). The grass silage was chosen as it is widely used in bio-digestion in Germany.

The manual measuring system, the determination was set to every time the accumulated volume added up to 800 mL. After determination of the accumulated gas volume, the biogas was released from the cylinder by means of the outlet valves depicted in Figure 3b. Atmospheric pressure and ambient temperature at the time of measurement were recorded together with the

actual biogas volume. The statistical analysis was performed through T-Student test for independent samples, using the program v SPS. 6.0.

RESULTS AND DISCUSSION

The two methods of gas flow measurement were compared in terms of data reliability. Figure 4 shows the measured gas volumes as average of the three replicates for each system. In the manual gas flow, measurement system 16 measurements were made over the period of 30 days. In the automated gas flow measurement system readings (each event = 40 mL) were made daily until the end of the experiment, a total of 30 measurements. It is emphasized that the measurements in the manual system were only performed after reaching volumes of 800 mL.

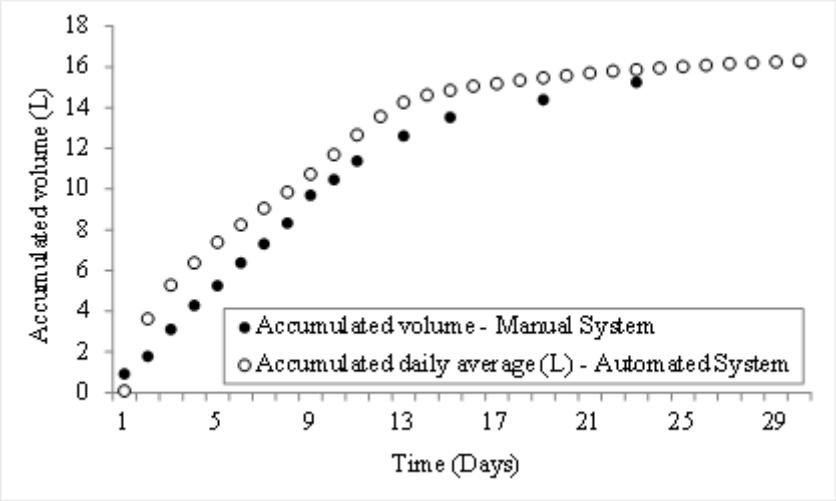


FIGURE 4. Accumulated biogas production in the two measurement systems. Symbols show (●) accumulated biogas volumes from daily readings in the manual system and (○) calculated accumulated biogas volumes in the automated system. Each symbol represents an average of three replicates.

As it can be seen, the automated method of measuring biogas allows to evaluate the behaviour of the anaerobic digestion process with a good precision of the ratio between the generated biogas volumes at each time interval and also to compare the efficiency of biogas generation in days when there are changes in the climatic conditions (temperature and pressure differences). The precision of the system has been evaluated using the methodology suggested by VEIGA et al., (1990).

In the automated reading system, it was possible to evaluate the generation of biogas in the course of the day. Figure 5 shows how the calibrated gas volume represented by each count is influenced by the change in atmospheric pressure and temperature for a period of 24 hours randomly chosen from the course of the experiment. In this period, 23 counting events occurred at approximately hourly intervals. These were recorded, amounting to 1012.19 mL biogas generated during this period. The volume of biogas represented by each event is influenced by the ambient atmospheric pressure and temperature.

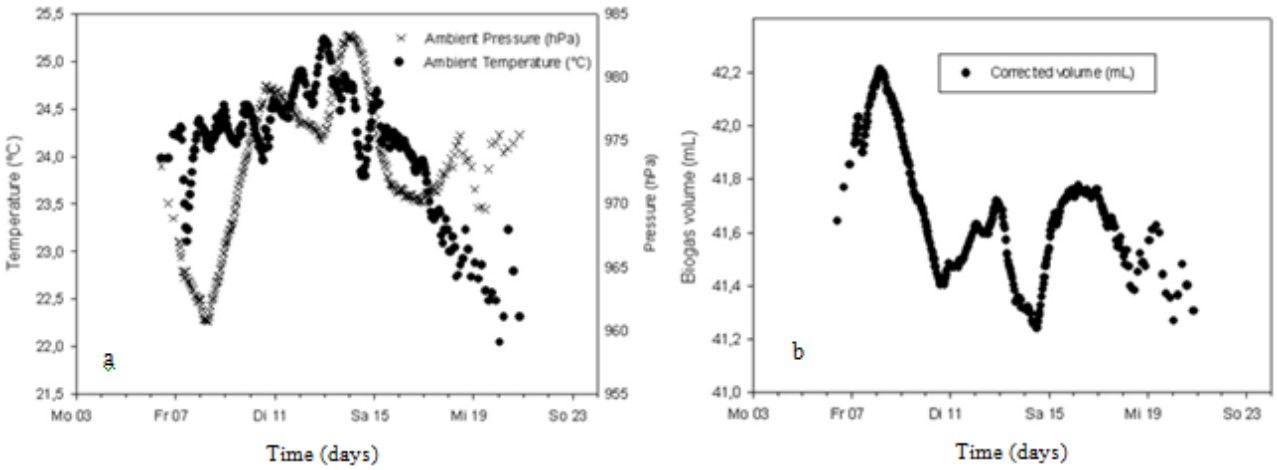


FIGURE 5. (a) Actual corrected volume measurements during the experimental trial, and (b) ambient temperature and pressure for sample volume corrections in the automated reading system.

The total accumulated biogas volume in the manual method was 16,238.33 mL (measured daily average = 1,014.90±179.27) while in the automated was 16,296.28 mL (measured daily average = 543.21±717.94). No statistical difference was observed between the measuring methods ($P>0.05$), which shows non-inferiority of any of the methods.

CONCLUSIONS

The difference between the automated system for measurement of laboratory biogas production and the manual measuring system was very small (only 0.36%). However, this study also showed that the automated system had a faster reading of biogas volume, and also showed comfortable and reliable data acquisition and processing. The advantages of the automated measurement system are automated data acquisition in real time, easiness of data access, compact design and easy installation and handling. The automated system is especially convenient when monitoring a significant number of experiments simultaneously.

It has been therefore demonstrated that this methodology could support the implementation of potential analysis throughout Brazil.

At no time this study attempted to discredit the manual reading system presently used in different laboratories. The manual methodology has been used for a long time and is an accepted methodology in scientific circles. Our goal was to contribute with an improved methodology, which may reduce the possibility of human error in the readings of laboratory scale biogas production, and at the same time to reduce the potential costs associated to the measurements.

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