BIODIGESTERS

Marcus Vinicius Rezende Júnior, Federal University of Uberlândia, School of Mechanical Engineering, marcus_aluno7@yahoo.com.br
Guy Monteil, Université Bourgogne Franche-Comté FEMTO-ST Institute CNRS/UFC/ENSMM/UTBM Department of Applied Mechanics, guy.monteil@univ-fcomte.fr

Abstract: *Intense agribusiness, potential carbon credits, and strongly polluted waterways led to a strong interest in biogas production in Brazil thirty years ago. Nevertheless, despite an ideal climate, biodigesters in Brazil have not been successful due to a lack of appropriate technical instruction and incentive. This paper aims to provide a better understanding of the biodigesters chemical reactions and present some different types/technologies of biodigesters.*

Keywords*: biodigester, environmentally friendly, renewable energy*

1. INTRODUCTION

A biodigester is like a mechanical stomach: organic material (e.g. manure, food scraps, and plant matter) is broken down (decomposed) by micro-organisms (bacteria) in an oxygen-free (anaerobic) environment to produce a renewable energy called biogas (methane and carbon dioxide) and other material that is mostly used as fertilizer. The produced biogas can be used directly as fuel, in combined heat and power gas engines or upgraded to natural gas-quality biomethane.

A model to develop the production of biogas was started by a Brazilian company that produces chilled and frozen foods. With program partners (swine and fish farms) and searching for running large-scale biodigesters for utmost value and profit, the model is a successful attempt to expand the knowledge and application of biodigesters in Brazil. Notwithstanding compared to another countries in the world, Brazilian production of biogas is still precarious.

Choosing a right biogas digester is important when constructing a biogas plant. From the point of view of structural strength and fluid dynamics, the best solution is possibly an egg-shaped vessel. Although, this type of construction is comparatively expensive and usually restricted to large-scale sewage treatment plants. The Chinese fixed-dome designs have similar shape to the egg-shaped one and it is less expensive.

The four key stages of anaerobic digestion are: hydrolysis, acidogenesis, acetogenesis and methanogenesis. Organic material such as glucose is biochemically digested into carbon dioxide (CO_2) and methane (CH_4) by the anaerobic microorganisms. The overall process that describes the chemical reaction can be written according to Eq. (1).

$$C_6H_{12}O_6 \rightarrow 3CO_2 + 3CH_4 \ (-393 \text{ kJ/mol glucose}) \tag{1}$$

1.1. Hydrolisis

Biomass is made up of large organic long chain molecules in most cases. For the bacteria in anaerobic digesters to access the energy potential of the material, these chains must first be broken down into smaller constituent parts (such as sugars) called monomers, to be available to other bacteria. This process of breaking the chains and dissolving the smaller molecules into solution is named hydrolysis. Therefore, hydrolysis of these high-molecular-weight polymeric components is the necessary first step in anaerobic digestion. Through this stage the complex organic molecules are broken down into fatty acids, simple sugars and amino acids. Acetate and hydrogen produced in the first stages can be used directly by methanogens. Other molecules, with a chain length greater than that of acetate such as volatile fatty acids, must first be catabolised into compounds directly used by methanogens.

1.2. Acidogenesis

Acidogenesis is a biological process that results in further breakdown of the remaining components by acidogenic (fermentative) bacteria. Volatile fatty acids are created along with ammonia, carbon dioxide, hydrogen sulfide and other byproducts. The process of acidogenesis is similar to the way milk sours.

1.3. Acetogenesis

The third step of anaerobic digestion is acetogenesis. Simple molecules created through the acidogenesis phase are further digested by acetogens to produce largely acetic acid, carbon dioxide and hydrogen.

1.4. Methanogenesis

The final stage of anaerobic digestion is the biological process of methanogenesis. The intermediate products of the preceding stages are used by methanogens and converted into methane, carbon dioxide and water. These components make up the majority of the biogas emitted from the system. This phase is sensitive to both high and low pHs and occurs between pH 6.5 and pH 8. The remaining and indigestible material not used by the microbes or any dead bacterial constitute the digestate which is the solid form of the waste.

2. INDUSTRIAL DIGESTER TYPES

In this section some typical biodigesters used in the industry are presented.

2.1. Batch plants

Batch plants are filled and completely emptied after a fixed retention time. They require high labor input. Each design and fermentation material is suitable for batch filling. Batch plants present a major disadvantage: the generated gas is not steady.

2.1.1. Continuous plant

Continuous plants are emptied and fed continuously. They empty automatically through the overflow whenever new material is filled in. The substrate must be fluid and homogeneous then. Because of the necessary work, continuous plants are appropriate for rural households. Gas production is constant and higher than in batch plants. Nearly all biogas plants are currently operating on a continuous mode.

2.1.2. Semi-batch basis

A semi-batch basis is used to digest straw and dung together. The slowly digested straw-type material is fed in about twice a year as a batch load. The dung is added and removed regularly.

3. SMALL-SCALE DIGESTERS

In this section the small-scale digesters are presented.

3.1. Fixed dome biogas plants

A fixed-dome plant consists of a closed, dome-shaped digester with an immovable, rigid gas-holder and a displacement pit (or compensation tank). In the upper part of the digester there is the gas storage. When gas production starts, the slurry is displaced into the compensating tank. Gas pressure increases with the volume of gas stored, i.e. with the height difference between the two slurry levels. If there is little gas in the gas-holder, the gas pressure is low.

3.2. Floating drum plants

Floating-drum plants comprises of an underground digester and a moving gas-holder. The gas-holder floats either straight on the fermentation slurry or in a water jacket of its own. The gas is gathered in the gas drum, which rises or moves down, according to the quantity of gas stored.

3.3. Earth-pit plants

Masonry digesters are not necessary in stable soil since it is sufficient to line the pit with a thin layer of cement (wire-mesh fixed to the pit wall and plastered) with the view to prevent seepage. The edge of the pit is strengthened with a ring of masonry that also works as anchorage for the gas-holder. The gas-holder can be made of metal or plastic sheeting. If plastic sheeting is used, it must be linked to a quadratic wooden frame that extends down into the slurry and is anchored in place to counteract its buoyancy. The requisite gas pressure is reached by placing weights on the gas-holder. An overflow point in the peripheral wall carries out as the slurry outlet.

3.4. Ferro-cement plants

They can be applied either as an earth-pit lining or a self-supporting shell. The vessel is commonly cylindrical. Very small plants (volume under 6 m^3) can be prefabricated. As in the case of a fixed-dome plant, the ferro-cement gasholder demands special sealing measures (proven reliability with cemented-on aluminium foil).

4. BIOGAS PRODUCTION

Most of the biogas is produced during the middle of the digestion, after the bacterial population has grown, and tapers off as the putrescible material is exhausted. On top of digester there is generally gas storage in an inflatable gas bubble. It can always be extracted and stored close to the facility in a gas holder.

The methane in biogas can be incinerated to produce heat and electricity, generally with a reciprocating engine or microturbine in a cogeneration arrangement. In this system the waste heat and electricity generated are used to heat the digesters, to dry plants or wood or to warm buildings. Suppliers can buy excess electricity or it can be placed into the local grid. Electricity produced by anaerobic digesters is reputable to be renewable energy and may attract subsidies. Since the gas is not released straight into the atmosphere and the carbon dioxide comes from an organic source with a short carbon cycle, biogas does not contribute to increasing atmospheric carbon dioxide concentrations.

For Brazil it could be a very promising way to produce electricity or gas as the biomass from agriculture is abundant.

5. REFERENCES

AMARATUNGA, M.: Structural Behaviour and Stress Conditions of Fixed Dome Type of Biogas Units. Elhalwagi, M.M. (Ed.): Biogas Technology, Transfer and Diffusion, London & New York, pp. 295-301, 1986.

FULFORD, D.: Fixed Concrete Dome Design. Biogas - Challenges and Experience from Nepal. Vol I. United Mission to Nepal, 1985, pp.3.1-3.10.

REZENDE JÚNIOR, M. V., POULAIN, A., MONTEIL, G. Le biodigesteur. Projet de troisième année, ETE. ENSMM, 2015.

RINGKAMP, M. – FH Hildesheim Holzminden/Faculty of Civil Engineering Holzminden (Germany): Regional Biogas Extension Programme GCR - Final Report on Statistical and Structural Examination of Caribbean Biogas Plants. 1989, 60 p.

SASSE, L. - GATE, Bremer Arbeitsgemeinschaft für Überseeforschung Entwicklung (BORDA): Biogas Plants - Design and Details of Simple Biogas Plants. 2nd edition, 1988, 85 p.

VAN BUREN, A.; CROOK, M. A Chinese Biogas Manual – Popularizing Technology in the Countryside. Intermediate Technology Publications Ltd. London (UK), 1979, sixth impression 1985, 135 p.

WERNER, U., STOH, U., HEES, N. - GATE: Biogas Plants in Animal Husbandry - A Practical Guide. Friedr. Vieweg & Sohn, Braunschweig/Wiesbaden (Germany), 1989; 153 p.

6. RESPONSIBILITY NOTICE