Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 17, Issue 1, 2017
PRINT ISSN 2284-7995, E-ISSN 2285-3952

STUDY ON THE PROCESS OF ANAEROBE DIGESTION OF BIOGAS IN A BIOGAS PLANT

Mariana DUMITRU

Lucian Blaga University of Sibiu, 10 Victoriei Boulevard, 550024, Sibiu, Romania, Phone/Fax: +40-(269) 21.60.62, E-mail: mariana.dumitru@ulbsibiu.ro

Corresponding author: mariana.dumitru@ulbsibiu.ro

Abstract

The biomass resources existing all over the world can give us an idea of the global potential of biogas production, which is still not exploited to its full capacity, especially in our country. Biogas has proven in many countries its big potential as an alternative source of energy, being used on a large scale. In this study, we analysed the biochemical process of anaerobe digestion of biogas, because it is one of the most important processes which take place in a biogas plant. Agricultural biogas production provides agricultural, economic and environmental benefits and for this reason, the promoters of the biogas development in Europe, especially after the oil crisis, were the organic farmers, interested in anaerobe digestion, not only for renewable energy generation, but as a way to improve fertiliser quality of their animal manure.

Key words: *biogas, anaerobe digestion, anaerobe digestion parameters, digestate*

INTRODUCTION

In our days, using of alternative fuels is more and more a constant preoccupation of researchers all over the world, and within this trend, biogas proves that it is a reliable source of energy [11]. In Table 1 is presented the present and future ponder of alternative fuels in the world.

Table 1. Planned ponderance of alternative fuels

	2010	2015	2020
Biofuels	6 %	7 %	8 %
Natural gas	2 %	5 %	7 %
Hydrogen	0 %	2 %	5 %
TOTAL	8 %	14 %	20 %

Source: [7]

In a biogas plant, a very important process is that of anaerobe digestion, which is a microbiological process of decomposition of organic matter in absence of oxygen. The main products of this process are biogas and digestate. Biogas is a combustible gas, consisting mainly of methane and carbon dioxide. Digestate is the decomposed substrate, resulted from the production of biogas [5].
During anaerobe digestion, very little heat is generated in contrast to aerobic decomposition, in presence of oxygen, like it is the case of composting. The energy, which is chemically bounded in the substrate, remains mainly in the produced biogas, in form of methane.
The process of biogas formation is a result of linked process steps, in which the initial material is continuously broken down into smaller units. Specific groups of micro-organisms are involved in each individual step [3]. These organisms successively decompose the products of the previous steps.

MATERIALS AND METHODS

In this study, we analysed the biochemical process of anaerobe digestion of biogas in a biogas plant, observing the characteristics of all the main steps of this process.
The simplified diagram of the anaerobe digestion process, highlights the four main process steps: hydrolysis, acido-genesis, aceto-genesis, and methane-genesis [3]. The process steps quoted in Figure 1, run parallel in time and space, in the digester tank. The speed of the total decomposition process is determined by the slowest reaction of the chain. In the case of biogas plants, processing vegetable substrates containing cellulose,

hemi-cellulose and lignin, hydrolysis is the speed determining process. During hydrolysis, relatively small amounts of biogas are produced. Biogas production reaches its peak during methane –genesis [1].

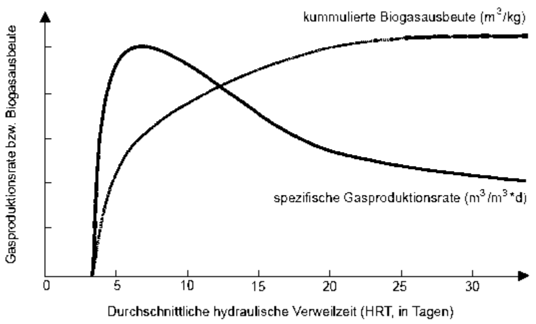

Fig. 1. Biogas production after addition of substrate – batch test
Source: [8]

Hydrolysis

Hydrolysis is the first step of anaerobe digestion, during which the complex organic matter is decomposed into smaller parts. During hydrolysis, polymers like carbohydrates, lipids, nucleic acids and proteins are converted into glucose, glycerol, purines and pyridines [4].

A variety of microorganisms is involved in hydrolysis, which is carried out by exo-enzymes, produced by those microorganisms which decompose the undissolved particulate material. The products resulted from hydrolysis are further decomposed by the microorganisms involved and used for their own metabolic processes.

Acidogenesis

During acidogenesis, the products of hydrolysis are converted by acidogenic (fermentative) bacteria into methanogenic substrates. Simple sugars, amino acids and fatty acids are digestioned into acetate, carbon dioxide and hydrogen (70%) as well as into volatile fatty acids) and alcohols (30%).

Acetogenesis

Products from acidogenesis, which can not be directly converted to methane by thanogenic bacteria, are converted into methanogenic substrates during acetogenesis. Volatile fatty acids and alcohols are oxidised into methanogenic substrates like acetate, hydrogen and carbon dioxide. Volatile fatty acids, with carbon chains longer than two units and alcohols, with carbon chains longer than one unit, are oxidized into acetate and hydrogen [3]. The production of hydrogen increases the hydrogen partial pressure. This can be regarded as a „waste product“ of acetogenesis and inhibits the metabolism of the acetogenic bacteria. During methanogenesis, hydrogen is converted into methane. Acetogenesis and methanogenesis usually run parallel, as symbiosis of two groups of organisms.

Methanogenesis

The production of methane and carbon dioxide from intermediate products is carried out by methanogenic bacteria. 70% of the formed methane originates from acetate, while the remaining 30% is produced from conversion of hydrogen (H) and carbon dioxide (CO_2), according to the following equations [3]:

Acetic acid $\longrightarrow$ Methane+ CO_2
H + CO_2 $\longrightarrow$ Methane + Water

Methanogenesis is a critical step in the entire anaerobic digestion process, as it is the slowest biochemical reaction of the process. Methanogenesis is much influenced by operation conditions. For example, composition of feedstock, feeding rate, temperature, and pH are factors influencing the methanogenesis process. Also, factors as digester overloading, temperature changes or large entry of oxygen can result in termination of methane production.

RESULTS AND DISCUSSIONS

Anaerobe digestion parameters

The efficiency of anaerobe digestion is influenced by some critical parameters, thus it is very important that appropriate conditions for anaerobic microorganisms are provided. The growth and activity of anaerobic microorganisms is significantly influenced by conditions such as exclusion of oxygen, constant temperature, pH-value, nutrient supply, stirring intensity as well as presence and amount of inhibitors (e.g. ammonia). The methane bacteria are fastidious anaerobes, so that the presence of oxygen into the digestion process must be strictly avoided.

Temperature

One of the most important parameter in the anaerobe digestion process is temperature, that is why measuring the temperature values in the different stages of the process is essential. The anaerobe digestion process can take place at different temperatures, divided into three temperature ranges: psychrophilic (below 25^0 C), mesophilic (25^0C –45^0C), and thermophilic (45^0C – 70^0 C). There is a direct relation between the process temperature and the Hydraulic retention time (Table 2).

Table 2. Thermal stage and typical retention times

Thermal stage	Process temperatures	Minimum retention time
Psychrophilic	< 25 °C	70 to 80 days
Mesophilic	30 to 42 °C	30 to 40 days
Thermophilic	43 to 55 °C	15 to 20 days

Source:[2]

The temperature stability is decisive for anaerobe digestion. In practice, the operation temperature is chosen with consideration to the feedstock used and the necessary process temperature is usually provided by floor or wall heating systems, inside the digester. Figure 2 shows the rates of relative biogas yields, depending on 2 factors: temperature and retention time.

Many modern biogas plants operate at thermophilic process temperatures , as the thermophilic process provides many advantages, compared to mesophilic and psychrophilic processes, such as:

-effective destruction of pathogens

-higher grow rate of methanogenic bacteria at higher temperature

-reduced retention time, making the process faster and more efficient

-improved digestibility and availability of substrates

-better degradation of solid substrates and better substrate utilisation

-better possibility for separating liquid and solid fractions.

The thermophilic process has also some disadvantages:

-larger degree of imbalance

-larger energy comsumption, due to high temperature

-higher risk of ammonia inhibition

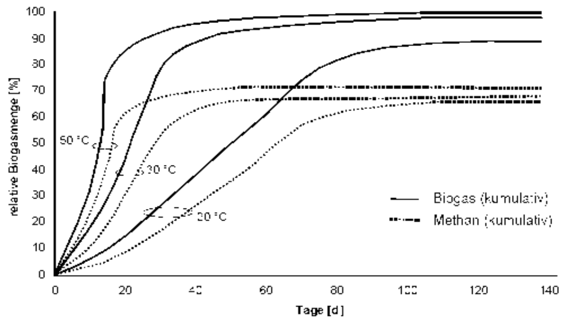

Fig. 2.Relative biogas yields, depending on temperature and retention time

Source: [8]

Table 3. Parameters for evaluation of a biogas plant

Parameter	Unit	Symbol	Determination
Temperature	T	°C	Measurement during operation
Operational pressure	P	mbar	Measurement during operation
Capacity, throughput	V	m3/d; t/d	Measurement
Reactor volume	VR	M^3	Determined by construction
Gas quantity	V per day/ year	m3/d; m3/a	Measurement during operation and conversion to Nm3
Retention time (hydraulic, minimum guaranteed)	HRT MG RT	d	Calculation from operating data
Organic anaerobe digestion		kg oTS / (m3 * d)	Calculation from operating data
Methane concentration in biogas	CH4	%	Measurement during operation
Specific biogas yield		%	Calculation from operating data
Specific biogas production		m3 / m3	Calculation from operating data
Plant efficiency	η	%	Net energy drawn from gross energy
Specific treatment costs		€/m3 Input; €/GV	Calculation

Source: [7]

CONCLUSIONS

After observations made on the anaerobe process which take place in biogas plant, we can conclude, among other, that operation temperature influences the toxicity of ammonia. Ammonia toxicity increases with increasing temperature, and can be relieved by decreasing the process temperature. However, when decreasing the temperature to 50°C or below, the growth rate of the thermophilic microorganisms will drop drastically, and a risk of washout of the microbial population can occur, due to a growth rate lower than the actual hydraulic retention time. This means that a well functioning thermophilic digester can be loaded to a higher degree or operated at a lower Hydraulic retention time than an mesophilic one, because of the growth rates of thermophilic organisms (Fig. 3).

Experiences shows that at high loading or at low Hydraulic retention time, a thermophilic operated digester has higher gas yield and higher conversion rates than a mesophilic digester.

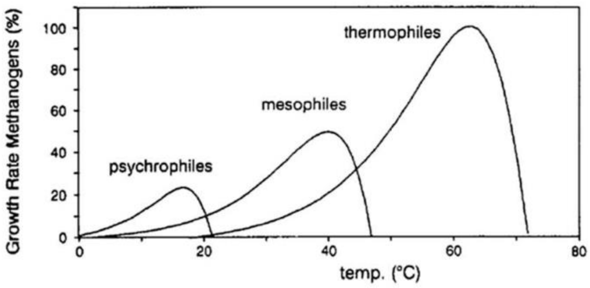

Fig. 3. Relative growth rates of methanogens
Source:[2]

Also, we may conclude that the viscosity of the anaerobe digestion substrate is inversely proportional to temperature. This means that the substrate is more liquid at high temperatures and the diffusion of dissolved material is thus facilitated. Thermophilic operation temperature results in faster chemical reaction rates, thus better efficiency of methane production, higher solubility and lower viscosity.

The higher demand for energy in the thermophilic process is justified by the higher biogas yield. It is important to keep a constant temperature during the digestion process, as temperature changes or fluctuations will affect the biogas production negatively. Thermophilic bacteria are more sensitive to temperature fluctuation of +/-1°C and require longer time to anaerobe digestion apt to a new temperature, in order to reach the maximum methane production. Mesophilic bacteria are less sensitive. Temperature fluctuations of +/-3°C are tolerated, without significant reductions in methane production.

These considerations are also usefull in waste management [9], which it is known to be an important source from which biogas results.

REFERENCES

[1] Agrinz, G., 2006, BiG East Biogas Study Tour – Austria

[2]Angelidaki, I. *et al.,* 2004, Environmental Biotechnology. Anaerobe digestion – Biogas Production. Environment & Resources DTU, Technical University of Denmark.

[3]Al Seadi, T., Rutz, D., Prassl,H., Tobias M., Janssen, R., 2008, Biogas handbook, University of Southern Denmark Esbjerg, Denmark

[4]Al, Seadi, T., 2001, Good practice in quality management of anaerobe digestion residues from biogas production. Report made for the International Energy Agency, Task 24- Energy from Biological Conversion of Organic Waste. Published by IEA Bioenergy and AEA Technology Environment, Oxfordshire, United Kingdom

[5]Al Seadi, T., Holm Nielsen J., 2004, Utilisation of waste from food and agriculture: Solid waste: Assessment, Monitoring and Remediation; Waste management series 4; Elsevier; ISBN 0080443214, 735-754.

[6] Dumitru, M., 2015, Study on the feeding system of a biogas plant, Scientific Papers Series "Management, Economic Engineering in Agriculture and Rural Development", Vol. 15, Issue 4.

[7] Dumitru, M., 2015, Development trends of biogas**,** Scientific Papers Series "Management, Economic Engineering in Agriculture and Rural Development", Vol. 15, Issue 1.

[8]LfU, 2007,Biogashandbuch Bayern - Materialband. - Bayerisches Landesamt für Umwelt, Augsburg, Germany.

[9]Neagu, C., 2013, Waste management generated from agriculture in Călăraşi county. Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", Vol. 13, Issue 3.

[10]Rutz, D., Janssen, R., *et al*., 2008, The Biogas Market in Southern and Eastern Europe: Promoting Biogas by Non-technical Activities. - Proceedings of the 16th European Biomass Conference and Exhibition; Valencia, Spain; ISBN 978-88-89407-58-1

[11]Víquez, C. S., 2013, Biogas as an alternative energy source to promote indigenous communities development, Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development", Vol. 13, Issue 1.