FRI-LCR-P-1-BFT(R)-05

BIOGAS FROM AGRICULTIRAL AND INDUSTRIAL ORGANIC WASTES

Ivan Konstantinov Angelov
Institute of Chemical Engineering,
Bulgarian Academy of Sciences, Bulgaria
E-mail: yeraodos@abv.bg

Prof. Venko Nikolaev Beschkov
Institute of Chemical Engineering,
Bulgarian Academy of Sciences, Bulgaria
E-mail: vbeschkov@yahoo.com

Abstract: *Th Biofuels are an important part of human efforts to reduce pollution, that comes as a result from human activity. There is a high diversity of biofuels, as the main ones are biodiesel, bioethanol and biogas. The last one is produced during anaerobic digestion of organic matter in special bioreactors. Different kinds of waste could be used as organic matter, such as household waste, municipality waste, agricultural and industrial waste. In the current paper, it was researched the possibility to obtain biogas, by utilizing stillage, which comes as a waste from alcohol production. The end product is biogas.*
Keywords: *Biogas, Stillage, Anaerobic digestion, Alternative fuels, Agricultural and Industrial wastes*

INTRODUCTION

With industrial development, human mankind changes the surrounding world by creating new machines and technologies or by updating (developing) the existing ones. Throughout the last three centuries mankind expanded in both economical and demographical way. The creation of steam machine and internal combustion engine, the discovery of electricity and oil has paved the way of the mankind to economic prosperity. All that technological achievements changed the way cities and societies look like. Today human population reached beyond 8 billion people. Today oil consumption reaches around 100 million barrels per day (https://www.worldometers.info/world-population/). The negative impact is, that such consumption creates an enormous pollution, which leads to the damage of the climate and the environment. It is possible to lower the pollution and keep the modern way of life, by using alternative energy sources, such as nuclear energy, solar and wind energy, hydro - energy, thermal energy, tidal energy and biomass. As all of them have their positive and negative sites, the best solution is to use a combination of all types of alternative sources. In the current paper, we will focus on biofuels as alternative fuels. Biofuels include biodiesel, bioethanol, biomethanol and biogas, etc.

The production of biogas by anaerobic digestion is widely used in modern days for treatment of various kinds of organic waste, such as waste from husbandry, agricultural, industrial waste. Anaerobic digestion is a standard technique for utilizing active sludge from wastewater purification systems and organic waste from food industry. The accumulated by anaerobic digestion biogas can be used in many applications. After corresponding treatment, biogas can substitute nature gas. The biomethane (obtained from biogas, after some treatment) could be directly injected into the national gas grid system, or used as a fuel in transport (cars, buses, trucks, tractors and ships), as well as a fuel for generating heat and electrical power (as cogeneration). That will lower the dependence of not only imported nature gas, but also oil and coals. Biogas plants would create also jobs for the local communities and therefore would contribute to the local economy.

The aim of this paper is to present data about biogas production from different substrates (manure, alcohol stillage, straw and combinations of them).

EXPOSITION

Experimental Details

For the purpose of the experiments, a pilot station was used. It consists of a bioreactor of 270 L volume and 1500 x 300 x 600 mm in size. It is separated into 8 interconnected chambers. A great advantage of the bioreactor is, that all the four processes are taking place simultaneously in different parts of the reactor vessel. The feeding material is injected from chamber 1, then it travels consequently through the chambers and exits the bioreactor at gate for exit material. The accumulated biogas is collected in a biogas holder. The holder is a glass cylinder submerged in basin, which is full of water. A thermal heating system is built for the bioreactor to maintain temperature of 35°C. The accumulated biogas is collected in biogas holder for further analysis. A sketch of the bioreactor is given in Fig 1. A picture of this equipment is shown in Fig. 2.

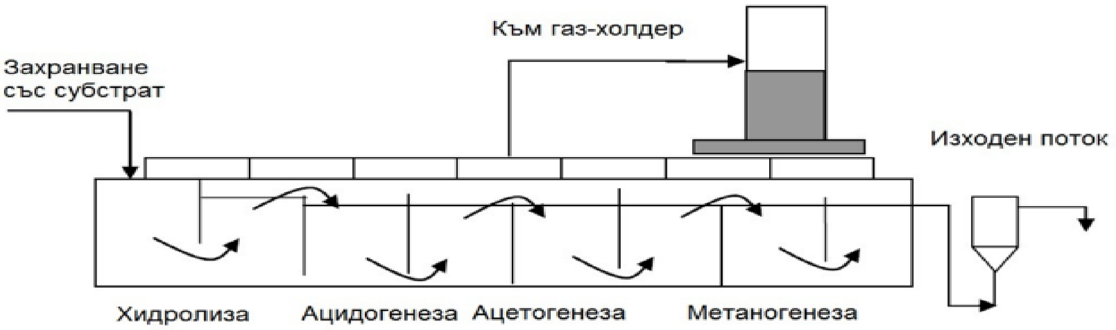

Fig.1. A schematic view of the bioreactor

Fig.2. Pilot bioreactor vessel

Another experimental work was continued on another four-step installation, which is shown below, cf. Figs 3 and 4.:

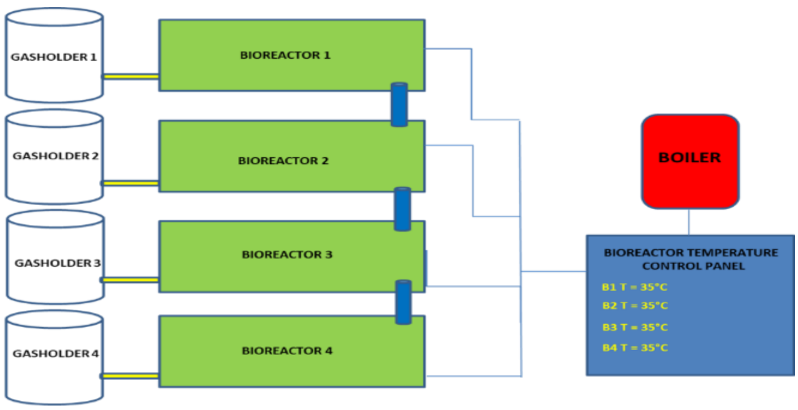

Fig. 3 A schematic view of the larger bioreactor installation

Fig. 4. Photograph of the large vertical bioreactors

It consists of 4 vertically placed bioreactors. Each one has 1 m^3 of volume. Each bioreactor is connected to a heating system through insulated pipelines. The system includes a boiler, which heats water, then through pipelines, the heated water goes into each reactor. The control panel controls the set temperature and the work schedule of the boiler. It allows individual temperature to be set for each of the 4 bioreactors. It is important to say, that the boiler reheats its own water, it works in so called “closed water system”. That leads to much lower energy consumption from the boiler heating system, hence makes the bioreactors more energy efficient.

RESULTS

1. Results from 8 chambered bioreactor

The 8 chamber bioreactor was fed by 2 substrates with different ratios between the feeding materials. Alcoholic stillage and cattle manure were used as feeding substrates. The results are shown in Table 1.

Table 1. Feeding schemes of the bioreactor

Type of feeding	Accumulated biogas volume, L	Work time, in days	Biogas production rate, L/day
500 g cattle manure + 1 L stillage	273	55	4.96
1000 g cattle manure + 1 L stillage	190	58	3.28
2000 g cattle manure + 1 L stillage	80	15	5.33
Total accumulated biogas	***543***	***128***	***4.52***

As it can be seen from the table, the best result was obtained during the first feeding. The reactor worked for 55 days and produced 273 L of biogas. All of the next feeding schemes showed less amount of working days and less amount of biogas, with the worst results in feeding 3. We believe that this feeding scheme was not appropriate and leads to organic overload of the process of anaerobic digestion.

The following Fig.5 shows the levels of pH measured in the bioreactor. Samples were taken from each chamber.

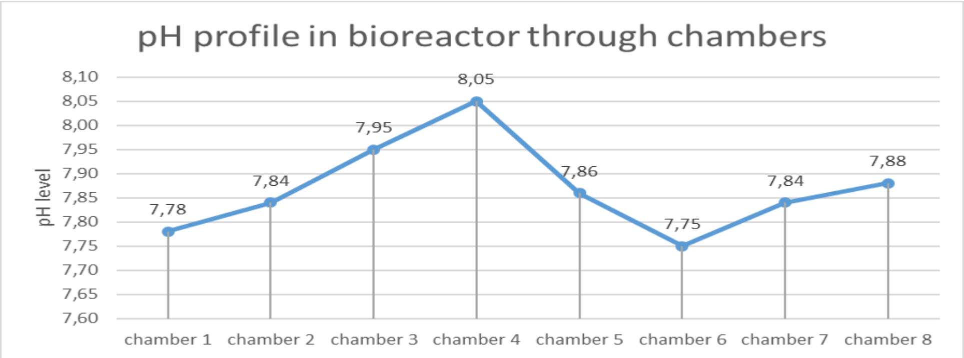

Fig.5. pH levels in bioreactor

As it can be seen from Fig.5, the pH profile remains relatively constant at around 7, i.e. 7.86 ± 0.1. There were slight fluctuations, which is a sign for a stable process.

The bioreactor worked for total 128 days and produced total of 543 L of biogas with average daily biogas production of 4.52 L per day. We believe that, the higher volume of stillage shifts the bacteria metabolism to produce more H_2S than CH_4. Probably that was the reason for the lower CH_4 content in second and third loading.

2. Results from Large scale reactor with a different substrate - straw

The straw was milled with grain grinder to make the substrate more easily absorbable by the bacteria in the bioreactor. The milled substrate was then mixed with manure and water. The bioreactor was then sealed and the heating system was set at temperature at 35 °C. There were 3 loadings of the reactor: a) initial feeding - 10 kg of straw + 10 L of cattle manure + 380 L of water; b) addition of 14 kg of straw and c) addition of 50 L cattle manure.

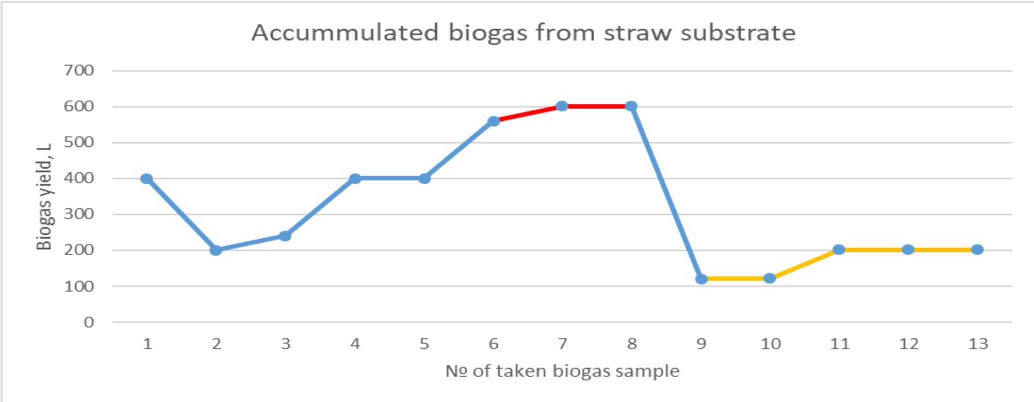

Fig.6. Biogas yield for the large installation (245 days)

The bioreactor produced total of 4240 L of biogas for 245 days. The total burning biogas was 2080 L and the % relation burning/non – burning biogas was 49,06%. That means, almost half of the obtained biogas was combustible. The red line on the graphic shows the part of biogas, which is not combustible, because it consists mainly of CO_2 and the yellow line shows the biogas with lowest combustibility (bus still combustible). We anticipate that at some moment, microorganisms shift their metabolism and produce more CO_2 then CH_4, after that conditions changed and microorganisms continued to produce more methane.

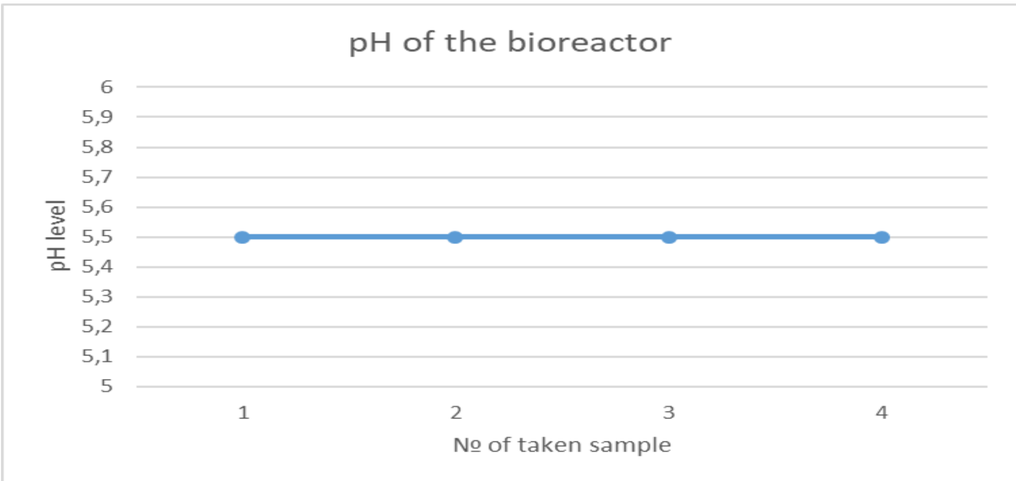

Fig.7. pH profile of large bioreactors

Samples for pH were taken from different time moments of the experiment. One in the beginning of the experiment, two in the middle and another one at the end of the experiment. As Fig.7 shows, the pH levels remain constant in the bioreactor, but lower than the optimum values for methane production.

CONCLUSION

Based on the obtained results, major conclusions are as follows:

1. The possibility to produce biogas from stillage and cattle manure was tested. It is possible to produce biogas, but attention should be paid to feeding schemes.
2. It was observed that different ratios give different results for biogas production. In a case of organic overload, biogas production is limited or not possible.
3. The possibility to produce biogas by utilizing an organic waste, such as straw, was tested. Results showed, that while it is possible to produce biogas from straw, it is very important to optimize the ratio between straw, cattle manure and water in order to obtain biogas with higher CH_4 content.
4. Both sets of experiments were successful, but more work is required to optimize performance of the anaerobic digestion in different bioreactors with combustible reach of methane biogas production. In some of the experiments, substrate pretreatment was required.

REFERENCES

European Union. Article 1, Directive 1999/31/EC from April 1999 on the landfill of waste.

De Baere, L. (2001). *"The Right Forces - Producing Power from Recycled Organics."* Biocycle. Department of Energy. (2001). Emissions of Greenhouse Gases in the United States.

Co., B.A.G. (2004). *Waste to Biogas and Compost*. 2004. Danish Ministry of Environment and Energy, Copenhagen, Environment News, 61. 2001.

C. Giolli, A. Scrivani, G. Rizzi, F. Borgioli, G. Bolelli, and L. Lusvarghi, *"Failure mechanism for thermal fatigue of thermal barrier coating systems"*, Journal of Thermal Spray Technology, vol.18, pp. 223–230, 2009.

C. Zhou, Q. Zhang, and Y. Li, *"Thermal shock behavior of nanostructured and microstructured thermal barrier coatings on a Fe-based alloy"*, Surface & Coatings Technology, vol.217, pp. 70–75, 2013.

Daniel W Parker, *"Thermal barrier coatings for gas turbines, automotive engines and diesel equipment"*, Materials & Design, Vol. 13, no. 6, pp. 345-351, 1992.

E. Buyukkaya, *"Thermal analysis of functionally graded coating Al-Si alloy and steel pistons"*, Surface and Coatings Technology, vol. 202, pp. 3856-3865, 2008.

E. Esfahanian, A. Javaheri, and M. Ghaffarpour, *"Thermal analysis of an SI engine piston using different combustion boundary condition treatments"*, Applied Thermal Engineering,vol. 26, pp. 277-287, 2006., pp. 398-402, 2007.

H. Jamali, R. Mozafarinia, R. Shoja Razavi, and R. Ahmadi-Pidani, *"Fabrication and Evaluation of Plasma-Sprayed Nanostructured and Conventional YSZ Thermal Barrier Coatings"*, Ceramic International, vol. 38, pp. 6805-6712, 2012.

M. Cerit, V. Ayhan, A. Parlak, and H. Yasar, *"Thermal analysis of a partially ceramic coated piston: Effect on cold start HC emission in a spark ignition engine"*, Applied Thermal Engineering,vol. 31, no. 2 –3, pp. 336-341, 2011.

Michael Anderson Marr, *"An Investigation of Metal and Ceramic Thermal Barrier Coatings in a Spark-Ignition Engine"*, M.S thesis, Mechanical and Industrial Engineering, University of Toronto, 2009.

Muhammet Cerit, *"Thermo mechanical analysis of a partially ceramic coated piston used in an SI engine"*, Surface & Coatings Technology, vol. 205, pp. 3499-3505, 2011.

R. Ahmadi-Pidani, R. Shoja-Razavi, R. Mozafarinia, and H. Jamali, *"Improving the thermal shock resistance of plasma sprayed CYSZ thermal barrier coatings by laser surface modification"*, Optics and Lasers in Engineering, vol. 50, pp. 780–786, 2012.

T. Hejwowski, and A. Weronski, *"The effect of thermal barrier coatings on diesel engine performance"*, Vacuum, vol. 65, pp. 427-432, 2002.

V. Esfahanian, A. Javaheri, and M. Ghaffarpour, *"Thermal analysis of an SI engine piston using different combustion boundary condition treatments"*, Applied Thermal Engineering, vol. 26, pp. 277-287, 2006.