Experimental Approach in Biogas Production from Agricultural Substrates

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Abstract: The use of renewable energy is one of the most important issues which are to be solved nowadays in the general context of increasing energy demand. A possible solution to this problem is using residual materials to produce biogas, a biofuel commonly used in firing processes to produce heat and energy. The present paper presents a small scale comparative experiment designed to show the potential of municipal wastewaters and agricultural residual material in terms of biogas quality and quantity. The small scale installation used for testing is located at the Mechanical Engineering Faculty, Politehnica University Timisoara. Conclusions will be traced relative to the obtained results in order to determine the possible applications of the produced biogas.

Keywords: agricultural biomass, wastewater, biogas, anaerobic digestion.

1. Introduction

Anaerobic digestion is a technology that allows the conversion of wastes into energy. The end product is called biogas – a mixture of CH4 (55 – 75% vol.), CO2 (25 – 45% vol.) and traces of H2S, NH3, N2, etc [1-3].

Biogas produced from anaerobic digestion of organic materials is used to generate heat, electric power or biofuel [4, 5].

Another final product of anaerobic digestion is the digestate – a material rich in nutrients as: nitrogen, phosphorus, potassium, magnesium, sulphur – frequently used in agriculture as fertilizer [6, 7].

Different sorts of organic wastes are suitable for anaerobic digestion: agricultural biomass, municipal solid wastes, industrial wastes, etc..

One of the byproducts in waste treatment process is sludge. The techniques used to improve biogas production by anaerobic digestion of this substrate are ultrasonic treatment, ozone oxidation, acid treatment, alkaline treatment and heating process [8 -15].

Another way to increase the efficiency of the process is to make the simultaneous digestion of two or more substrates. Agricultural biomass, like crop residues or degraded agricultural plants, is very appropriate as co-substrate [16-18].

Therefore, the aim of this study is to investigate the performance of anaerobic co-digestion of different degraded cereals and wastewater from a treatment plant located in Timisoara city, Romania. The experiments were performed in batch conditions.

2. Experimental

2.1. Substrate choices and general information regarding the used materials

The materials used were:
- substrate 1: 400 – 500 gr two row barley inserted in 5L of residual water from Timisoara treatment plant;
- substrate 2: 400 – 500 gr cereal mixture composed by 40% wheat, 40% corn and 20% sunflower husks inserted in 5L of residual water from Timisoara treatment plant.

During the anaerobic digestion process there were not used any inoculums, catalysts or other enzymes for increasing the quality or quantity of the produced biogas.

The following characteristics of each substrate were measured: the hygroscopic moisture content, the ash content, the mean calorific value, the carbon, nitrogen and volatile content. The determinations were made according to the following standard methods:
- EN 14774 – Solid biofuels – Determination of moisture content – Oven dry method (parts 2 and 3) [19];
- EN 14775 - Solid biofuels - Determination of ash content [20];
- EN 14918 - Solid biofuels – Determination of calorific value [21];
- EN 15290 – Solid biofuels – Determination of major elements [22];
- EN 15104 – Solid biofuels – Determination of total content of carbon, hydrogen and nitrogen – Instrumental methods [23];
- EN 15148 – Solid biofuels – Determination of the content of volatile matter [24].

All analyses were performed in duplicate.

2.2. Experimental set-up

The fermentation process was held for 30 days, at a constant temperature (between 35 and 37 °C), in order to observe the pH evolution, the quantity of biogas produced and its composition in terms of CH_4 and CO_2 percentages.

During the process a solution of 20% NH_3 was used in order to correct the pH values.

The pilot plant used for producing biogas from biomass through anaerobic digestion is presented in figure 1.

The components of the small-scale installation are: 1 – thermal glass reactors with a total volume of 6 L used for dark fermentation; 2 – magnets positioned at the bottom of the glass vessels used for magnetic stirring of the used material suspensions; this system allows also the manual stirring / agitation; 3 – device used for heating the suspension inside the reactors; 4 – thermocouple used for temperature control; 5 – system for sampling and pH correction of the suspensions; 6 – syringe used for sampling and pH correction system; 7 - pH controllers connected to pH sensors placed inside the reactors in order to determine in real time the pH value of the suspension; 8 – temperature controller connected with the thermocouples; 9 – gas bags with a total volume of 2 L dedicated for sampling the obtained biogas from the fermentation process.

The gas analyzer used to analyze the biogas was a DELTA 1600 S IV type, which allows the determination of methane and carbon dioxide composition up to 100% by volume.

3. Results and Discussion

Before starting the anaerobic digestion experiments, the two agricultural materials and the residual water were characterized from a physical and chemical point of view: moisture content, ash content, gross and net calorific value, volatile matter content, carbon content, nitrogen content, and hydrogen content. The corresponding values are presented in table 1.

The values listed in table 1 suggested that the properties of two row barley and cereal mix substrates are closer one to each other. In light of the fact that the properties of raw materials influence the effectiveness of anaerobic digestion, we can expect to similar biogas production.

The time variation for pH is presented in table 2. It can be observed that during the process, the batches started with a relatively high pH value and, with the help of pH corrections, they were maintained in the range 7 – 8 during the fermentation period.

During the tests, the produced biogas was measured both in terms of quality and quantity.

TABLE 1. Main parameters of substrates used in the anaerobic digestion process

Biomass	Two Row Barley	Cereal mix	Residual water from Timisoara treatment plant
Moisture content (db) [%]	10.7	10.7	5.85
Ash content (db) [%]	2.22	1.53	36.2
Net calorific value (db)[J/g]	16763	16820	14000
Carbon content[%]	40.1	40.7	32
Nitrogen content [%]	1.38	1.16	5
Volatile matter content (db) [%]	82.4	84.9	37.9

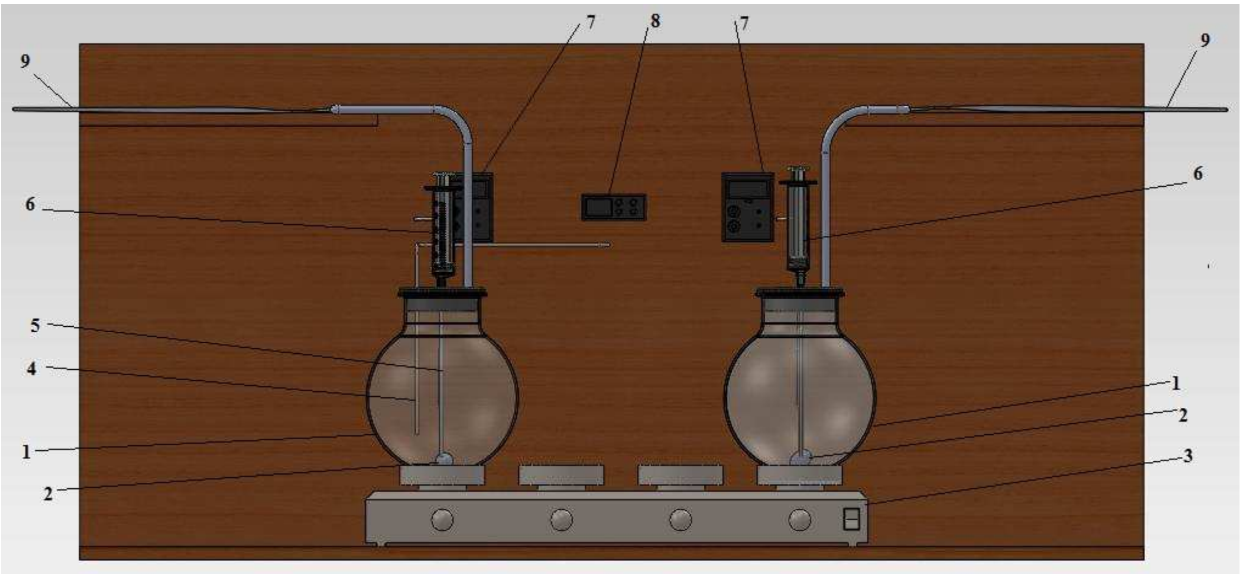

Figure 1. Overall view of the small-scale installation

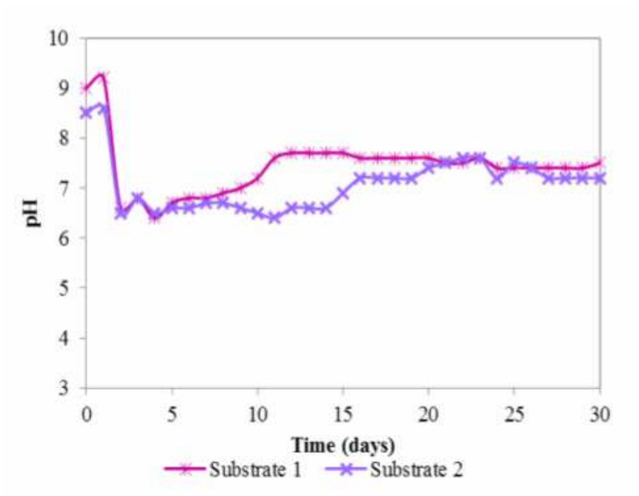

Figure 2. pH variation

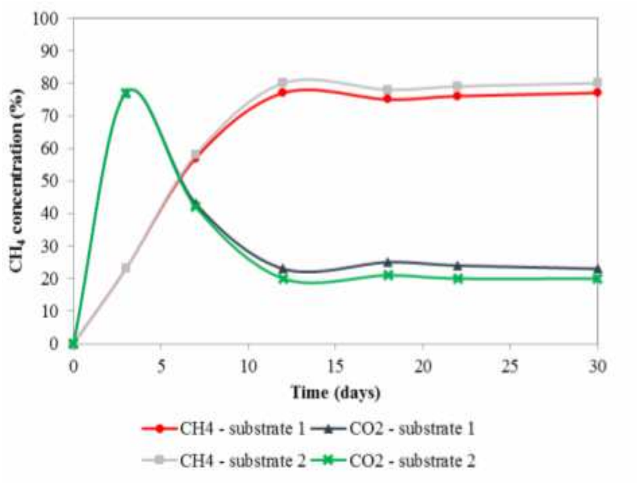

Figure 3. CH_4 and CO_2 concentrations for the first and second vessels

The quantities of biogas produced were about 20 L for substrate 1 and about 18 L for substrate 2. Compared to the initial material volume used (5 L), the biogas quantities are large, which is a good indicator for further studies and analysis for process optimization. Also, the methane content is high for both batches, having in mind that no dedicated enzymes or catalysts were used.

4. Conclusions

Both batches of materials presented good results in terms of biogas production and methane concentration during the process. The two row barley batch (substrate 1) had a better indicator in biogas quantity and methane concentration, implying further testing in order to better understand the way in which the process can be optimized.

One of the main ideas which can be extracted from the present work is that the residual water from the treatment plant has a good potential relative to further usage at larger scale with possible applications for biogas production with usage in firing processes.

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REFERENCES

1. De Mes T.Z.D., Stams A.J.M. and Zeeman G., in: Reith J.H., Wijffels R.H., Barten H. (Eds): Biomethane and Biohydrogen. Status and perspectives of biological methane and hydrogen production, **2003**, 58-94.
2. Linville J.L., Shen Y., Wu M.M. and Urgun-Demirtas M., *Curr. Sustainable Renewable Energy Rep.,* 2(4), **2015**, 136-144.
3. Al Seadi Biosantech T., Rutz D., Janssen R. and B. Drosg, in: Wellinger A., Patrick Murphy J. and Baxter D. (Eds.), The Biogas Handbook, **2013**, 19-51.
4. Demirbas A., *Energy Sources Part A*, 30, **2008**, 101–109.
5. Ruane J, Sonnino A. and Agostini A., *Biomass Bioenergy*, 34, **2010**, 1427–1439.
6. Nkoa R., *Agron. Sustain. Dev.*, 34, 2014, 473-492.
7. Abubaker J., Risberg K. and Pell M., *Appl. Energ.*, 99, **2012**, 126 -134.
8. Dewil R., Baeyens J. and Goutvrind R., *Environ. Prog.*, 25(2), **2006**, 121–128.
9. Appels L., Dewil R., Baeyens J. and Degrève J., *Int. J. Sustainable Energy*, 1(2), **2008**, 94–104.
10. Bougrier C., Albasi C., Delgenès J.P. and Carrère H., *Chem. Eng. Process.*, 45, **2006**, 711–718.
11. Erden G., Demir O. and Filibeli A., *Bioresour.Technol.*, 101, **2010**, 8093–8098.
12. Neyens E., Baeyens J. and Weemaes M., *J. Hazard Mater.*, 98, **2003**, 275–293.
13. Appels L., Van Assche A. and Willems K., *Bioresour. Technol.*, 102(5), **2011**, 4124–4130.
14. Lin J.G., Chang C.N. and Chang S.C., *Bioresour. Technol.*, 62, **1997**, 85–90.
15. Neyens E. and Baeyens J., *J. Hazard Mater. B*, 98, **2003**, 51–67.
16. Svensson L.M., Christensson K. and Bjornsson L., *Bioprocess Biosyst Eng.*, 29, **2006**, 137–142.
17. Karellas S., Boukis I. and Kontopoulos G., *Renewable and Sustainable Energy Reviews*, 14, **2010**, 1273-1282.
18. Fantozzi F. and Buratti C., *Bioresource Technology*, 100, **2009**, 5783-5789.
19. Solid biofuels – Determination of moisture content – Oven dry method, European Standard EN 14774, **2009**.
20. Solid biofuels - Determination of ash content, European Standard EN 14775, **2009**.
21. Solid biofuels – Determination of calorific value, European Standard EN 14918, **2010**.
22. Solid biofuels – Determination of major elements, European Standard EN 15290, **2011**.
23. Solid biofuels – Determination of total content of carbon, hydrogen and nitrogen – Instrumental methods, European Standard EN 15104, **2011**.
24. Solid biofuels – Determination of the content of volatile matter, European Standard EN 15148, **2010**.

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