Small Scale Determinations for Biogas Production Using Anaerobic Fermentation - 2L Batch Scenarios

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Nowadays demand for clean energy and new solutions for renewable energy carriers makes it a challenge to find new substrates that can be used for production of biofuels. In this context the present paper aims to present possible solutions of substrate mixtures using materials that exist in abundance at least in the western part of Romania. Conclusions will be traced relative to material potential at small scale in terms of producing biogas.

Keywords: anaerobic fermentation, biogas, residual materials

Wastewater treatment is facing serious problems worldwide due to environment concerns regarding resource shortage. Moreover, the economic world is pressured by the environment researchers to find new sustainable solutions for green energy production [1]. As a result, a keen interest is being devoted to renewable feed stocks based on organic/inorganic used materials which can be turned into (bio)fuels [2].

Anaerobic digestion process has been identified as a low energy consumption technology for efficient recovery of wastewater (with/without organic substrate) as biogas [3-5]. Anaerobic digestion is a promising technology applied to treat different types of organic wastes and to reduce their biodegradability while recovering bio-energy [6,7]. By anaerobic digestion, organic carbon is converted by redox reactions into its most oxidized state (CO_2) and its most reduced state (CH_4) [8]. It is a complex process consisting of several stages: hydrolysis, acidification, acetate synthesis and methanogenesis [9]. Hydrolysis is considered the rate determining step involved in this process and it can be controlled by suitable adjustment of the organic substrate particle size, temperature, pH, homogeneity, etc [10]. The acidification bacteria then turn soluble organic material into organic acids, carbon dioxide and hydrogen during the acidification step. The organic acids are decomposed into acetic acid/esters, formic acid/esters which are transformed into methane by methanogenic microorganisms [11]. Moreover, the digestate, meaning the effluent coming out of the anaerobic process can be reused in agriculture as nutrient for plants because of its high N, P, K content together with humic substances [12].

This multi-step complex process can be successful only in the presence of the right bacteria consortia, temperature and pH control and organic matter able to produce significant amounts of methane. The anaerobic fermentation can occur in mesophilic and thermophilic environment. Compared to the mesophilic temperature, the thermophilic process has the advantage of the greater methane yield, lower retention time but it has the draw-back of inhibition substances accumulation which terminates the methanogenesis [13].

The substrate of the anaerobic digestion is also a determining performance item. Usually for the improvement of the methane yields, co-digestion in anaerobic conditions of a main basic feedstock (e.g. animal manure, waste water, sewage sludge, etc.) mixed with a secondary feedstock (e.g. crop residue, food or silage wastes) is fed into the digestion reactor with or without an incoculum (bacteria) [14].

Our research group has focused on the anaerobic digestion of mixed substrate, waste water and cereal wastes, in mesophilic conditions following a batch reactor approach at pilot-scale [15-18]. The environmental impact of using waste water as co-substrate for anaerobic digestion through which a useful resource is produced represents a promising alternative for future economic development [18-24].

The papers will present small scale determinations of different substrates in order to determine the suitable ones for further testing at larger scale.

Experimental part

Experimental setup

For experimental purposes, it was used a thermostatic bath and batches of 1.5 L inside of plastic vessels with a total volume of 2 L. The work principle of the small scale testing rig is presented below.

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Fig. 1. Overall view of the test rig

The components are described as follows:

1 – thermostatic bath with multiple places for heating up the used materials for the anaerobic fermentation process (the temperature is controlled with the help of the thermocouple and can be checked with the help of a thermometer inserted into the bath);

2 – plastic bottles with a total volume of 2 L, filled up to about 1.5 L with the materials used for determinations;

3 – the corks of the plastic bottles were modified in order to allow both sampling for pH checking, homogenization by means of plastic syringes, and gas transfer from the bottles into the gas bags. Also, because of the light sensibility of the anaerobic bacteria, the bottles were covered with aluminum foil;

4 – hose orifice for syringe insertion, used for sampling and homogenization;

5 – connection (small diameter hose) between the plastic bottle and the gas bag for biogas storage;

6 – gas bag for biogas storage.

Substrate choices and general informations regarding the used materials.

The general properties of the used materials for the batches at 2L are presented below. The determinations were made according to standard methods [26-30].

Table 1
GENERAL CHARACTERISTICS OF THE USED MATERIALS (PART 1)

No.	MATERIAL	Higroscopic Moisture content [%]	Ash content (dry basis) [%]	Mean calorific value (dry basis) [MJ/kg]
1.	DBZ5 (digestate, cow manure and 5% cow whey)	13	25	14.2
2.	DBZ10 (digestate, cow manure and 10% cow whey)	14.3	25.1	14
3.	UEN5Z5(waste water from treatment plant, 5% stabilized sludge from treatment plant, 5% cow whey	5.8	38.1	14.8
4.	UEN4Z5(waste water from treatment plant, 4% stabilized sludge from treatment plant, 5% cow whey)	5.9	38	14.7
5.	FBN5Z5(waste water from beer factory, 5% stabilized sludge from treatment plant, 5% cow whey)	5.4	28	17
6.	FBN4Z5 (waste water from beer factory, 4% stabilized sludge from treatment plant, 5% cow whey)	5.5	28.2	17.5

Table 2
GENERAL CHARACTERISTICS OF THE USED MATERIALS (PART 2)

No.	MATERIAL	Carbon content [%]	Sulphur content [%]	Volatile content (dry basis) [%]
1.	DBZ5 (digestate, cow manure and 5% cow whey)	29.5	0.5	43
2.	DBZ10 (digestate, cow manure and 10% cow whey)	29	0.6	48.5
3.	UEN5Z5(waste water from treatment plant, 5% stabilized sludge from treatment plant, 5% cow whey	33.7	5.2	38.6
4.	UEN4Z5(waste water from treatment plant, 4% stabilized sludge from treatment plant, 5% cow whey)	33	4.8	38.2
5.	FBN5Z5(waste water from beer factory, 5% stabilized sludge from treatment plant, 5% cow whey)	36.1	3.9	40.6
6.	FBN4Z5 (waste water from beer factory, 4% stabilized sludge from treatment plant, 5% cow whey)	36	4	40.4

From the tables above it can be observed that the ash content is high making the materials unsuitable for firing processes as standalone fuel, while the calorific value is relatively high, indicating a good energetic potential for the chosen batches. The sulphur content is high for the last 3 batches, being a potential problem for the firing chamber in case of firing processes.

Results and discussions

The pH of the suspension was corrected with a solution of NH_3 20% concentration and the temperature regime was held inside the domain of 36 – 37 °C. The experiment lasted for 45 days of continuous measurements.

The time variation for pH is presented below.

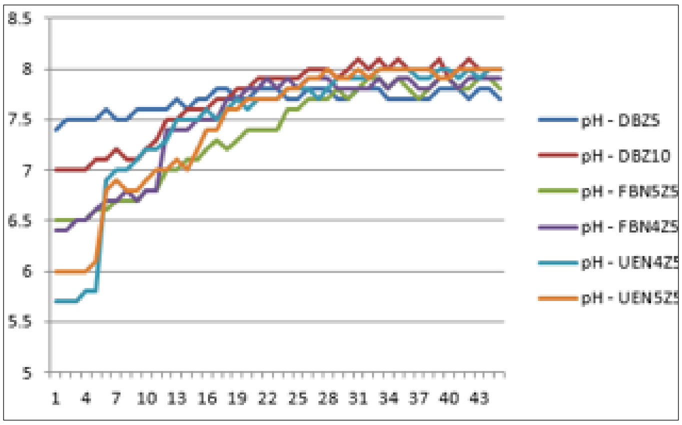

Fig. 2. *p*H variation for the studied batches of material

It can be observed that during the process, the starting pH values are relatively high, about 5.7 – 6, and the general correcting operations were reduced to a minimum because of the buffer capacity for the tested batches of material. The final pH values at the end of the process are 7.5 – 8, suitable for the anaerobic fermentation conditions.

For gas analyzing there was used the DELTA 1600 S IV gas analyzer, which allows determination of methane and carbon dioxide composition up to 100% by volume.

All the six batches produced biogas, and the final measured composition is:

For DBZ5 batch – CH_4 conc. = 57%
CO_2 conc. = 41%

For DBZ10 batch – CH_4 conc. = 53%
CO_2 conc. = 42%

For FBN5Z5 batch – CH_4 conc. = 68%
CO_2 conc. = 27%

For FBN4Z5 batch – CH_4 conc. = 69%
CO_2 conc. = 30%

Unfortunately, the other two batches (UEN5Z5 and UEN4Z5) did not produce any biogas, proving to be not suited for anaerobic fermentation processes at first tests.

The produced quantities were about 9.5 L of gas for the DBZ5, 11L for DBZ10, 8L for FBN5Z5 and 3.5 for FBN4Z5 batch.

Conclusions

The present paper aimed to present a small scale approach in terms of biogas production using different material combinations and evaluated partially the biogas quantity and quality.

From the obtained results it can be deduced that the most suitable materials, at leat in the presented scenario, were the batched containing waste water from beer factory, 5% stabilized sludge from treatment plant, 5% cow whey and waste water from beer factory, 4% stabilized sludge from treatment plant, 5% cow whey.

It seems that the waste water from beer factory proves to be a more reliable substrate than the one from the treatment plant because of its general composition and bacteria existing in it.

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