

Comparative Determination of Cofermentation Using Residual Waters for Biogas Production at Small Scale

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The present paper underlines the necessity of valorification for residual waters in the context of using them as source for biogas production inside anaerobic fermentation processes. Relative to this aspect, there will be presented a comparative approach for two types of residual waters from Timisoara city (residual water from the treatment plant and from beer factory), both in combination with residual dehydrated sludge and cow whey. Conclusions will be traced relative to the used materials in terms of general properties (physical and chemical), anaerobic fermentation process and quantity and quality for the produced biogas.

Keywords: residual waters, biogas, anaerobic fermentation

The rapid development of human society increased the energy demands, which will led to the depletion of conventional energy sources [1].

Residual biomass as: organic domestic, garden and agro-industrial wastes, crop residues, manure, wastewater sludges, offers a huge potential for the production of renewable energy [2-4]. Anaerobic digestion of residual biomass has attracted much interest in recent years. This technology offers great potential for rapid disintegration of organic matter to produce biogas and save fossil energy [5-8].

The biogas produced by digestion is a clean and environmentally friendly fuel, with a CH₄ content of about 55-65%. Other constituents include 30-40% of CO₂, fractions of water vapour, traces of H₂S and H₂, and possibly other contaminants (e.g. siloxanes).

Anaerobic digestion was first considered as an inefficient and unreliable treatment process applicable to a limited number of substrates, but now it has received increased attention during the last few years [9]. Management of the organic fraction of urban solid waste using anaerobic procedures will contribute to the reduction of greenhouse gas emissions, and using biogas, which is a carbon neutral energy, to generate electrical energy will eventually help in reducing the combustion of fossil fuels.

The methane content of biogas varies between 50 - 70% depending on feedstock. It has an energy content equivalent to about two-third of that of natural gas and can be burnt in stationary engines or turbines to generate heat and electricity; in many cases the methane drives an engine and Combined Heat and Power (CHP) plants generates electricity and heat as by-product.

Biogas can be compressed and stored, and its quality can be improved by removing CO₂ using chemical methods.

The production of biogas through anaerobic digestion offers significant advantages over other forms of waste treatment, including [5]:

- less biomass sludge is produced in comparison to aerobic treatment technologies;
- successful in treating wet wastes of less than 40% dry matter;
- more effective pathogen removal – this is especially true for multi-stage digesters or if a pasteurization step is

included in the process;

- minimal odor emissions as 99% of volatile compounds are oxidatively decomposed upon combustion, e.g. H₂S forms SO₂;

- high degree of compliance with many national waste strategies implemented to reduce the amount of biodegradable waste entering landfill;

- the slurry produced (digestate) is an improved fertilizer in terms of both its availability to plants and its rheology;

- a source of carbon neutral energy is produced in the form of biogas.

The composition of these wastewaters depends on the source and its characteristics, but the main constituents are: organic matter, nutrients (nitrogen, phosphorus and potassium), inorganic matter (dissolved minerals), toxic chemicals and pathogens [10]. Releasing of an untreated wastewater effluent into environment can have negative impact on ecosystem and human health. Now, there are varieties of strategies used to treat the wastewaters [11-14].

Experimental part

Substrate choices and general information regarding the used materials

The base materials used were mixtures composed by the following:

- first glass vessel: residual water from the treatment plant, 4% dehydrated sludge from treatment plant and 5% cow whey;

- second glass vessel: residual water from the beer factory, 4% dehydrated sludge from treatment plant and 5% cow whey.

The general properties of the two materials are presented below. The determinations were made according to standard methods [15-20].

The fermentation process was held between 40 and 50 days in order to observe the pH and gas quantities and composition in terms of CH₄ and CO₂ percentages maintaining a constant temperature between 36 and 37 °C.

In order to correct the pH values during the process, it was used a solution of NH₃, 20% concentration.

The general overview of the small-scale installation is

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No.	Material	Hygroscopic moisture content [%]	Ash content (dry basis) [%]	Mean calorific value (dry basis) [MJ/kg]
1.	Residual water from the treatment plant, 4% dehydrated sludge from treatment plant and 5% cow whey	6.5	38.4	14.7
2.	Residual water from the beer factory, 4% dehydrated sludge from treatment plant and 5% cow whey	5	27.9	17.1

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

No.	Material	Carbon content [%]	Sulphur content [%]	Chlorine content [mg/kg]	Volatile content (dry basis) [%]
1.	Residual water from the treatment plant, 4% dehydrated sludge from treatment plant and 5% cow whey	34.5	5.2	0.9	39.5
2.	Residual water from the beer factory, 4% dehydrated sludge from treatment plant and 5% cow whey	37.3	4	2.2	40.2

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

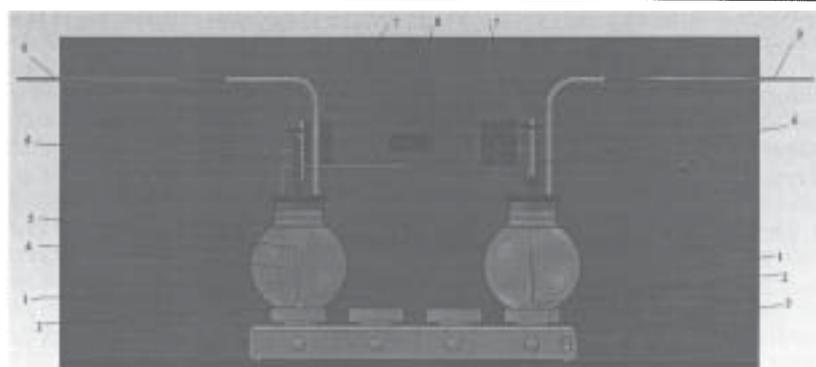


Fig. 1. Overall view of the small-scale installation

presented in figure 1.

The components of the small-scale installation are:

1 - thermal glass vessels with a total volume of 6L 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 glass vessels;

4 - thermocouple used for temperature control inside the fermentation vessels;

5 - system for sampling and pH correction of the suspensions inside the vessels;

6 - syringe used for sampling and pH correction system;

7 - pH controllers connected to pH sensors inside the glass vessels in order to determine in real time the pH value of the suspension;

8 - temperature controller connected with the thermocouple inside the glass vessel for temperature control to a determined range;

9 - gas bags with a total volume of 2L dedicated for sampling the obtained biogas from the fermentation process.

Results and discussion

The tested batch of material consisted, as described above, in parallel measurement for a mixture composed from 91% residual water from the treatment plant, 4% dehydrated sludge from treatment plant and 5% cow whey

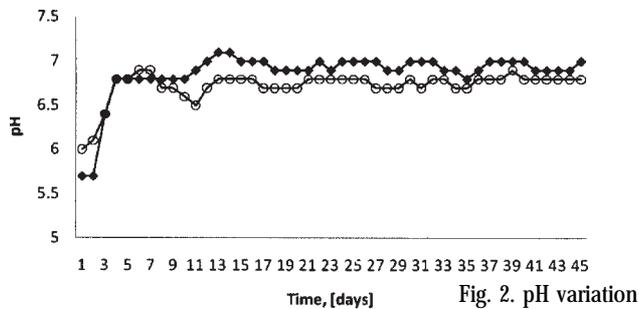


Fig. 2. pH variation

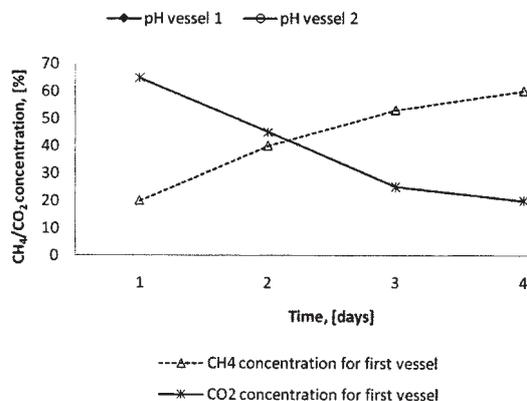


Fig. 3. CH_4 and CO_2 concentrations for the first vessel (residual water from the treatment plant, 4% dehydrated sludge from treatment plant and 5% cow whey)

for the first vessel and 91% residual water from the beer factory, 4% dehydrated sludge from treatment plant and 5% cow whey for the second glass vessel.

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 time variation for pH is presented in figure 2.

It can be observed that during the process, the batches presented a relatively high pH value which made the use of the NH_3 suspension to be made just at the beginning of the process when the starting pH was not neutral.

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

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

The CH_4 and CO_2 concentrations are presented in figure 3, 4.

It is mentioned that the four values for the first reactor and the five values considered for the second reactor are corresponding to the mean value read over 10 days of process, and because of this reason the measurement was divided in four periods of 10 days each. For the second reactor there were made two readings in the last period of measurements.

The produced quantities were about 4 L of gas for the mixture with 91% residual water from the treatment plant, 4% dehydrated sludge from treatment plant and 5% cow whey and about 5 L for the batch composed by 91% residual water from beer factory, 4% dehydrated sludge from treatment plant and 5% cow whey.

Conclusions

Even if both batches produced biogas, the main composition of the produced gas until the end of process was about 60 - 61% CH_4 and 38 - 40% CO_2 for both batches of material.

From the determinations it can be observed that the batch composed by 91% residual water from beer factory, 4% dehydrated sludge from treatment plant and 5% cow

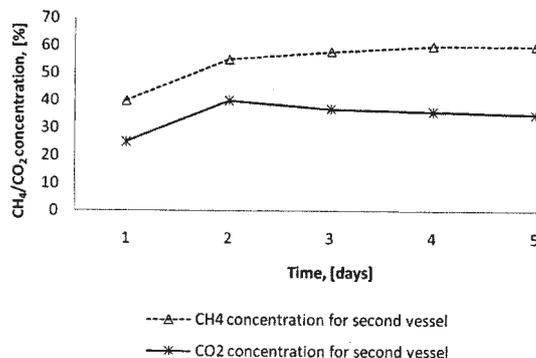


Fig. 4. CH_4 and CO_2 concentrations for the second vessel (residual water from beer factory, 4% dehydrated sludge from treatment plant and 5% cow whey)

whey has a slightly higher biogas quantity produced during the process, while the first batch composed from 91% residual water from the treatment plant, 4% dehydrated sludge from treatment plant and 5% cow whey and about 5 L.

Both biogas quality and quantity depend on the organic concentration inside the used material, this being a good indicator that the residual water from beer factory has a higher concentration in biodegradable materials.

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