Biogas production on lab-scale: utilization of wastewater from Hunedoara treatment plant

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Abstract. In the present work, the potential of wastewater procured from a local treatment plant situated in Hunedoara in order to produce biogas was assessed in anaerobic co-digestion process. Finding appropriate combinations of feedstocks involved in the process represents a key factor in obtaining high biogas amounts and also high quality of biogas. Therefore, a case study was carried out in a lab-scale installation for biogas production using a suspension consisting of wastewater, animal (cow and chicken) slurry and degraded corn. The wastewater and animal slurry were selected as the main feedstock providing for the microbial community required in the anaerobic digestion, in a volume ratio of 3:1 animal slurry to wastewater. Moreover, the feedstocks were subjected to several characterization methods: determination of total content of carbon, hydrogen and nitrogen and the content of volatile matter using European Standards. The process was performed in thermophilic conditions and controlled mixing of the suspension for a period of 24 days. The performances were appreciated by monitoring the amount of the produced biogas and the main gaseous components of the biogas: CH₄, CO₂ and H₂S.

1. Introduction

The utilization of biomass and different types of wastes as energy sources has become a usual and required practice due to the environmental concerns such as the greenhouse gases emissions, waste handling, water pollution and also due to the necessity of replacing the fossil fuel resources with renewable resources for production of energy [1], [2].

Biogas production by anaerobic digestion represents one of the main technologies that convert biomass into energy. As the process was developed over the years, mono-substrates were replaced with mixtures of substrates and moreover, various types of waste were used as the main feedstocks for biogas production or in combination with biomass (energy crops). Based on the literature, among the organic waste involved in the anaerobic co-digestion, there may be mentioned municipal organic waste, agricultural waste (resulted in animal farms and agricultural crops), forest residues, sewage sludge and wastewaters [1-5].

Wastewaters are abundant and locally available resources providing for nutrients and microorganism that break down the complex organic molecules mediating the decomposition process.
Wastewaters are resulted in different domains such as industry, farms and municipal treatment plants. Common industries that produce wastewaters exploited as feedstock for biogas production are food (e.g. cheese whey and dairy, edible oils, slaughterhouses and meat processing, fruit and vegetable processing, fish, coffee processing, etc.) and beverage industries [2], [6-9].

Important research has been focused on the improvement of biogas production by anaerobic co-digestion for which finding appropriate mixtures of feedstocks may represent a challenge in order to obtain good performances of the process [1].

The aim of the present study was to investigate the production of biogas from a mixture consisting of wastewater from Hunedoara treatment plant, animal slurry and degraded corn seeds in a lab-scale experimental plant.

2. Experimental part

2.1. Experimental installation

The biogas production by anaerobic co-digestion process was performed in a lab-scale installation. It consists of a 5 liters capacity reactor made of stainless steel that allows automatic control of the suspension temperature and mixing. In Figure 1, photos of the plant are illustrated, wherein the main parts of the plant configuration are indicated.

![Figure 1. Photos of lab-scale experimental plant for biogas production (1-agitator with two blades; 2- heating source; 3 – biogas output; 4 - sample output; 5 – display for temperature and mixing control)](image)

As the biogas is produced, it is collected at the top of the reactor (through biogas output - point 3) in gas sampling bags. Apart from biogas output, another output (point 4) was designed to extract samples of the involved feedstock during the anaerobic co-digestion in order to be subjected for further analyses. In this case, small volumes of the suspension were regularly collected using a syringe for pH measurement during the entire experiment. Biogas composition was analyzed using a portable biogas analyzer (Biogas 5000 Gas Analyzer provided by Geotech).
2.2. Feedstock and experimental operating parameters

In the present case study, the biogas was produced by anaerobic co-digestion process. The feedstock mixture involved in the process consists of wastewater from Hunedoara treatment plant (1 liter), animal slurry (3 liters) and degraded corn seeds (150 mg). The animal slurry comes from cows and chickens provided from an animal farm situated in Timis county.

Additionally, each type of feedstock was characterized using European Standards (EN 15104, EN15148) in order to determine some of the critical constituent elements such as carbon, hydrogen and nitrogen and also the content of the volatile matter (dry basis) of the feedstock (Table 1). Of particular interest may represent the content of carbon and respectively nitrogen, as the ratio C/N is one of the main factors that influence the biogas production by anaerobic digestion process. Optimum C/N ratio values reported in the literature range between 20 and 30 [1].

Content of the volatile matter is a measure used to appreciate the potential of the feedstock for biogas production and provides information about the fraction of feedstock solid matter that may be converted into the biogas [10].

Table 1. Physical and chemical properties of the feedstock involved in the process assessed in terms of total content of C, H and N and the content of volatile matter

| Feedstock                        | Content of carbon [%] | Content of hydrogen [%] | Content of nitrogen [%] | Content of volatile matter (dry basis) |
|----------------------------------|-----------------------|-------------------------|-------------------------|----------------------------------------|
| Corn seeds                       | 40.35                 | 6.5                     | 1.29                    | 85.5                                   |
| Wastewater from Hunedoara treatment plant | 24.1                  | 3.65                    | 3.359                   | 41.63                                  |
| Animal slurry (cow, chicken)     | 38.3                  | 5.2                     | 2.59                    | 60.2                                   |

Thermophillic condition was selected for the process, hence the operating temperature was around 44-45°C. Moreover, a constant mixing of the suspension was implied during the entire process. The process was operated for a period of 24 days. The pH measurements were carried out at certain days and carefully monitored because the pH is an important parameter that affects the overall behaviour of the process. Adjustments of the pH were accomplished by addition of small volumes of glacial acetic acid inside the reactor.

In order to evaluate the efficiency of the anaerobic co-digestion process, the biogas amount and the main gaseous compounds of the biogas (CH₄, CO₂ and H₂S) were investigated for the entire period of process operation.

3. Results and discussion

The experimental investigation regarding the exploitation of the wastewater treatment plant mixed with animal slurry and corn seeds in order to produce biogas was carried out by analysing the variation of pH, the amount of the produced biogas and the composition of the biogas (in terms of CH₄, CO₂ and H₂S) over time.

Figure 3 illustrates the amounts of the collected biogas at certain days. By analysing the trend of the biogas production in the first 14 days, it could be noticed that the highest amount of biogas was collected in day 6 and in day 8, after which the biogas production started to decrease. After 6 days only 0.5 L biogas was produced meaning that the process of anaerobic co-digestion was inhibited.
The trend of the biogas production may be closely correlated with the variation of the pH represented in Figure 2. A significant increase of the pH could be noticed after only three days of the process, so that the pH value reached 8.07 in day 4. In the following four days, pH remained almost constant, around the value of 8.13. After day 8, as the amount of biogas started to decrease, the pH of the suspension started to increase again reaching a value of 8.24 in day 14.

Taking into consideration both the variation of the pH and the biogas, the inhibition of biogas production may be explained by the increase of the pH. For this reason, in order to control the increase of the feedstock mixture pH, 10 ml of acetic acid was added to the suspension in day 14. This resulted in a prominent boost of the biogas production, within the same day. After day 14, the amount of
produced biogas continued to increase so that during the following next 3 days the production of biogas was around 1L per day, followed by slight decrease. Two more liters of biogas were produced, 1 L in day 19 and finally, 1 L after 5 days (day 24) indicating the anaerobic co-digestion process slowed down.

Moreover, with regard to the pH values (Figure 2), a plateau region could be noticed between day 14 and day 24 suggesting that the addition of the acid led to the stabilization of the suspension pH.

Figure 4. Variation of CH$_4$ and respectively CO$_2$ concentration over time

The quality of the biogas is another very important factor used to evaluate the efficiency of anaerobic co-digestion process and the possibility for further utilization of the obtained biogas as energy source. Figure 4 shows the variation of CH$_4$ and respectively CO$_2$, the main constituent gases of the biogas. Similarly to the variation of the biogas amount, during the first 14 days, the percent of CH$_4$ reached a maximum value (around 65%) in day 6, after which it started to decrease below 30%.

As well, as the CH$_4$ percent increased the CO$_2$ percent decreased. The increase of CO$_2$ in day 14 emphasize more strongly that the process was inhibited, as it was concluded from the interpretation of the figure 2 and figure 3. After the addition of the acid in the reactor suspension, the biogas composition was improved and the CH$_4$ percent was maintained above 50% reaching the highest value (~70%) in day 17. Furthermore, the CO$_2$ was maintained below 30%. Figure 5 illustrates the variation of H$_2$S quantity (expressed in ppm) over time.

The overall amount of biogas produced after 24 days of anaerobic co-digestion is 7.9 L of which 52.9% is represented by CH$_4$, 32.4% is CO$_2$ and the concentration of H$_2$S is 820 ppm. The fraction of CH$_4$ and H$_2$S correspond to the typical composition of biogas, as reported in the literature. Still, additional investigation would be needed to identify the other compounds of the biogas which represents approximately 14% of the total amount of biogas. The concentration of H$_2$S (820 ppm) is below the limit of 1000 ppm H$_2$S required for using the biogas as an energy source for heating application (boilers) [11], [12].
4. Conclusion
The present study revealed the potential of the wastewater provided from Hunedoara treatment plant mixed with animal slurry and corn seeds to produce biogas by anaerobic co-digestion process. The process was significantly affected by the pH variation which required the addition of the acetic acid in the suspension. After the pH control, the biogas production was substantially improved and the concentration of CH$_4$ increased. As well, the amount of the H$_2$S was below 0.1% of the total biogas. The present investigation was approached as a case study, which may serve to improve the utilization of the wastewater for biogas production in further research.

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