

Conversion of Agricultural Wastes to Biogas using as Inoculum Cattle Manure and Activated Sludge

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Abstract

Agricultural wastes represent a large unexploited energy potential that could be converted into biogas by anaerobic digestion. In the present study there has been analysed the way in which agricultural wastes are converted into biogas by using as inoculum cattle manure as compared with activated sludge. To carry out this experiment on small scale there have been designed 5 batch bottles. For the batch process all substrate was put into the bottles at start. The biogas process was initiated after closing the bottles, and the biogas was collected during the process until the biogas production ended. During the 33 days of experiment the batch bottles were held at constant temperature (37⁰C) in a water bath. The biomass used in the experiment was wheat straw and corn stalks. Before being used in the experiment the biomass was milled using a kitchen mixer. After that the biomass was subjected to a combination of thermal and chemical pretreatments. The volume of biogas produces was measured every seven days during the experiment period. The biogas production measurements were done by using a BlueSens measuring equipment.

Keywords: agricultural wastes, biogas, corn stalks, pH, temperature, wheat straw.

1. Introduction

World energy crisis, the oil price which is more and more difficult to control and the current energy policies require finding new ways of obtaining fuel. Production of biogas through anaerobic digestion of organic materials provides a versatile carrier of renewable energy [1]. Methane production from energy crop could be an option for obtaining biofuel. But by using grain as raw material a major disadvantage occurs, that is the increase in price for food and feed grain. A solution for this problem is the second generation of biofuels, which means the use of non-food and non-feed materials in order not to interfere in the food price regulation [2]. An alternative to the use of grain as raw material could be the biodegradable agricultural wastes. By using biodegradable agricultural wastes in order to

produce biofuel following results could be obtained:

- an appropriate management of organic waste;
- grain price increase could be avoided: grains will be used only in human and animal nutrition;
- greenhouse gas emissions can be reduced [1];
- cheap waste recycling [3];
- organic waste disposal costs decrease [4];
- reducing odors and flies;
- reducing pathogens through sanitation.

2. Materials and methods

The main purpose of this experiment was to analyse in which way agricultural biomass agriculture is converted into biogas by using as inoculums: (i) *cattle manure* (obtained from the didactic dairy farm of our university), compared with (ii) *activated sludge* (obtained from the biogas plant belonging to a local brewery). As

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additional fermentation substrate we used in this experiment *wheat straw* and *corn stalks*. The experiment was carried out during 33 days

of anaerobic digestion. Five different batches in 2500 ml flasks (Figure 2) were performed as follows:

Table 1. Experiment organization scheme

Batch I	Batch II	Batch III	Batch IV	Batch V- Control
activated sludge + corn stalks	activated sludge + wheat straw	cattle manure + corn stalks	cattle manure + wheat straw	cattle manure

The wheat straw and the corn stalks were milled by using a kitchen mixer until the particle size were 1,0 – 2,0 mm. It was shown that smaller particles were better digested in biogas production, but size reduction would have been more efficient if combined with other pretreatments [5]. For that reason the milled biomass was subjected to a combination of thermal and chemical pretreatments: the biomass moistened with NaOH 2% was autoclaved 30 minutes at 2 bar and 121°C. After that, the biomass was neutralized with H₂SO₄ 10% and washed with water (the volume of water was 12 times the volume of biomass) in order to remove the inhibitors resulted during pretreatments. The pretreatment step (Figure 1) was done in order to depolymerise the lignocellulosic complex and increase the rate of degradation and the biogas potential of the substrates [2].

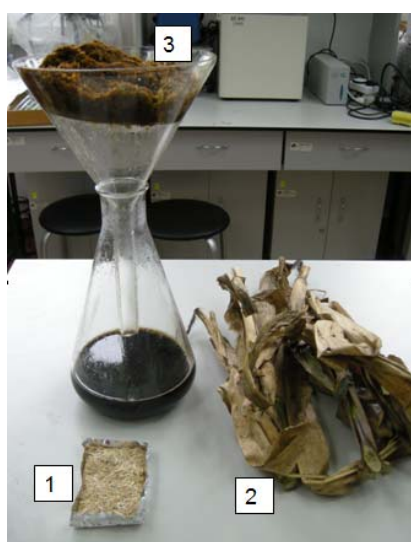


Figure 1. Biomass pretreatment (1-milled biomass; 2-corn stalks; 3-pretreated biomass;)

After pretreatment, the raw materials were mixed with inoculums (cow manure and activated sludge) and water, in particular ratios calculated to obtain 8% dry weight in all batches. The pH was adjusted to 7 [4].

The raw materials pretreated in the manner described above were introduced in 5 batch bottles (capacity 2.500 ml) according to the scheme presented in Table 1.

The raw material was well mixed and homogenized with water (to have 8% dry weight in all batches) and placed in bottles through a glass funnel.

The bottle caps have been fitted with two rubber flexible tubes:

- one of the tubes has one head free in the interior of the fermentation flask and is not in contact with the substrate, and the external end of the tube was connected to a balloon for storing the produced biogas;
- the second tube, immersed into the fermentation liquid, has the external end connected to a syringe through which the samples are harvested for pH measuring.

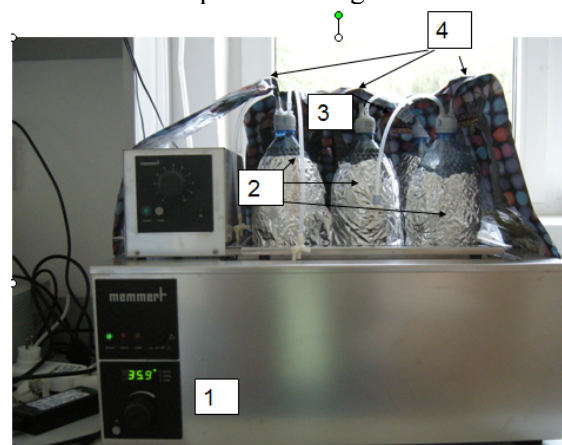


Figure 2. Fermentation batches placed in water bath at 37°C. (1- water bath; 2-batch bottles; 3-gas tubes; 4- balloons for biogas harvesting)

At the beginning of the experiment, in all 5 fermentation batches, pH was adjusted to 7. Consort C932 pH meter has been used in order to determine the pH value during the experimental period. The pH value was controlled and adjusted, if necessary, using 30% NH₄OH solution (Figure 7).

During the 33 days of experiment the anaerobic fermentation flasks obtained as described above were incubated at 37°C in a water bath. The fermentation flasks were subjected to stirring for 5 minutes/ 24 hours. Stirring of the bottles content reduces thermal stratification, disperses the

biosolids for a better contact with the microorganism, reduces scum build-up, dilutes level of inhibitors and retains inorganic material in suspension.

3. Results and discussion

During the 33 days of anaerobic fermentation, the pH value varied between 5.5 and 7.5 (Figure 3). The optimal pH value for methanogenic bacteria is between 7 and 7.5. When the pH value dropped below optimal value, pH correction was performed using 30% NH₄OH solution.

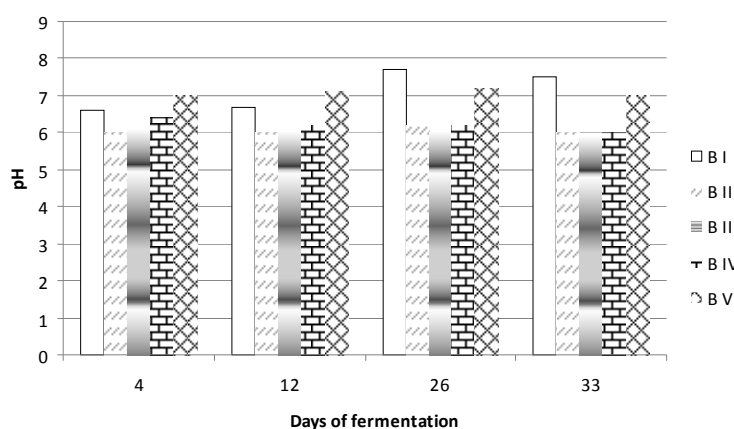


Figure 3. pH variation during anaerobic fermentation

The biogas production measurements were possible by using BlueSens fermentation equipment (Figure 4) provided with infrared CH₄ and CO₂ sensors, and gas counters. The CH₄ and CO₂ sensors have been installed to one separate BlueSens glass flask. This flask is filled with water in order to reduce the volume of air in the measuring chamber. We chose this technical solution to reduce to minimum the dilution of gas injected in the measuring chamber. The sensors will detect the CH₄ and CO₂ concentration in the measuring chamber (the free volume in the BlueSens glass flask) by infrared radiation reflected in the measuring cap. The biogas produced in each batch was collected in balloons and periodically harvested with a syringe (in

Figure 4 marked with *5-biogas syringe*). The biogas is immediately injected in the BlueSens flask fitted with sensors. All tube ends are fitted with closing faucets to prevent gas loss. After the concentration of CH₄ and CO₂ is measured, the injected gas is transported through a tube to a gas counter. This device measures the volume of the biogas produced in the experiment. From gas counter, the gas is collected into a measuring cylinder, filled with water, placed upside down into a larger glass cylinder. Data generated by gas sensors and gas counter are processed in function box (in figure 4 marked with *9 and 10*), where a .dat file is generated and transferred into the computer, where on-line measurements are stored by BACVis software (Figure 5; Figure 6).

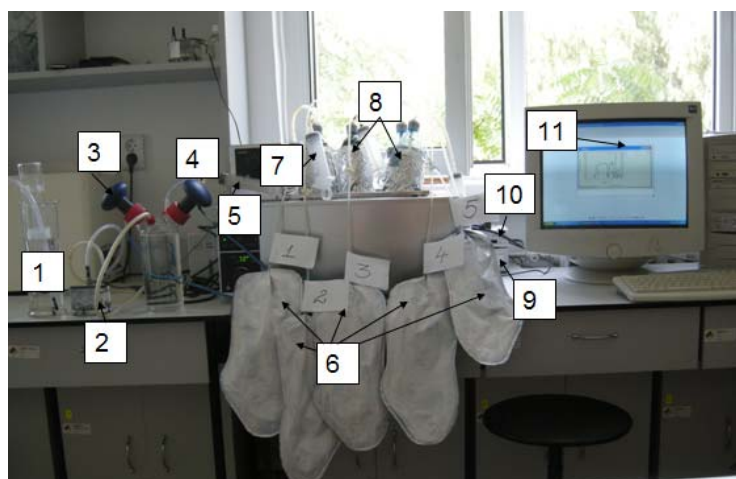


Figure 4. Data recording with BlueSens equipment (1-cylinder; 2-gas counters; 3-CH₄ sensor; 4-CO₂ sensor; 5-syringe for gas harvest; 6- gas harvesting balloons ;7-syringe for liquid probes harvest; 8-batch flasks; 9-function box for gas counter; 10-function box for gas sensors; 11-data acquiring computer)

The CH₄ and CO₂ concentration obtained in the 5 batches during the first 4 days of fermentation are shown in Figure 5. The CH₄ and CO₂

concentrations obtained in the 5 batches during the period of maximum of methane production (after 26 days of fermentation) are shown in Figure 6.

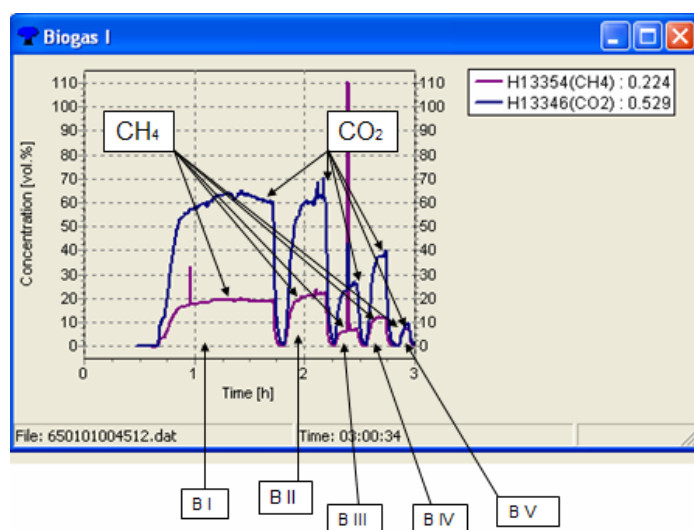


Figure 5. Concentration of CH₄ and CO₂ for the 5 batches: B I, B II, B III, B IV, B V during the first 4 days of fermentation

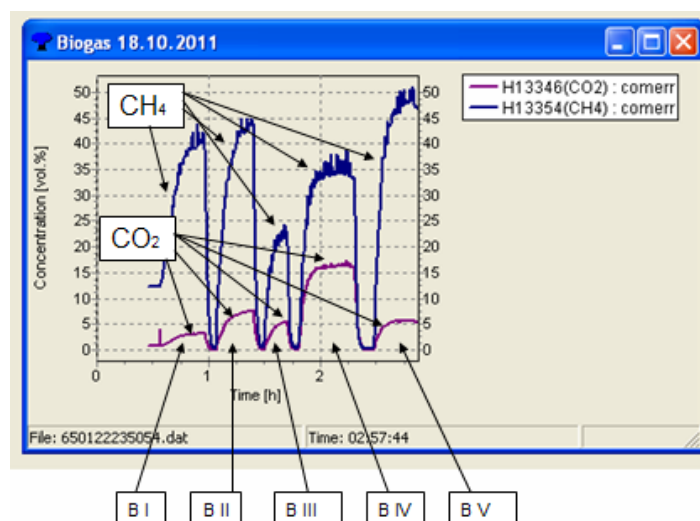


Figure 6. Concentration of CH₄ and CO₂ for the 5 batches: B I, B II, B III, B IV, B V

Each pick represents the maximum concentration of CO₂ and CH₄ (indicated in Figures 5 and 6) obtained by injecting the biogas collected from the fermentation balloons with a syringe. The five picks represent each of them the concentrations of the gases measured by the sensors of the five fermentation flasks (B I, B II, B III, B IV, B V). By consideration of space, we will not insert in this work all graphs generated by the BACVis program during the 33 days of experiment. The graph in Figure 5 represents the gas concentrations at the beginning of the experiment, and Figure 6 represents the maximum concentrations of methane obtained in this study. Analyzing the maximum concentrations of CO₂ and CH₄

(indicated in Figures 5 and 6), we see that by summing the concentrations of the two gases measured by infrared sensors, an important amount of air remains into the measuring chamber. For example, in Figure 5, the highest concentration of CH₄ is indicated around 50%, and the concentrations of CO₂ in around 5%. The sum of the two concentrations is around 55%, this means that the difference until 100% should be other gases from air left into the measuring chamber (N₂ and O₂). Anyway, a concentration of methane tenfold higher than carbon dioxide indicates a top quality biogas (a good biogas contains a mixture of CH₄ and CO₂ in a ratio of around 1.5 to 1).

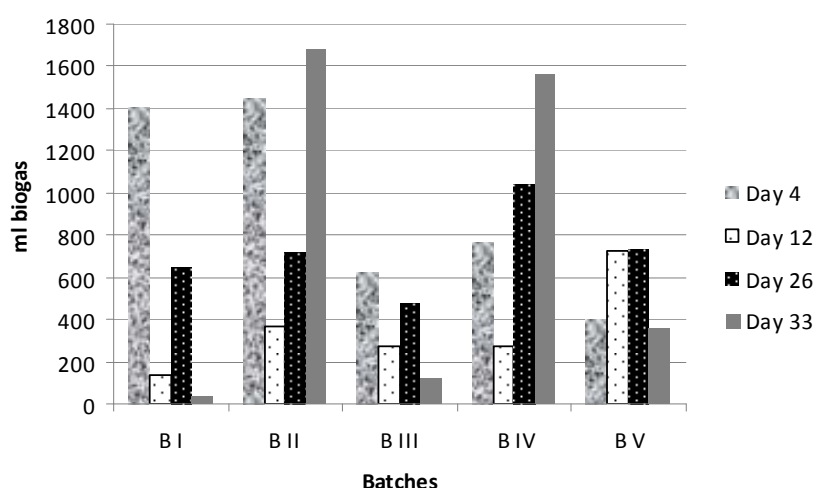


Figure 7. Biogas production rate in the five batches during the 33 days of fermentation

At the first harvest (after 4 days of anaerobic digestion, see Figure 7), the highest amount of

biogas was obtained in batches B II (1450 ml) and B I (1410 ml), followed by batches B IV

(700 ml), B III (620 ml) and B V (400 ml). After 12 days of experiment, the pH value decreased for B I, B II, B III and B IV, which negatively influenced the production of biogas in all these batches. An exception was batch B V, where the

pH value was not changed and the biogas production increased. At the last harvest (33 days of fermentation), the highest amount of biogas was produced in batch B II (Figure 7).

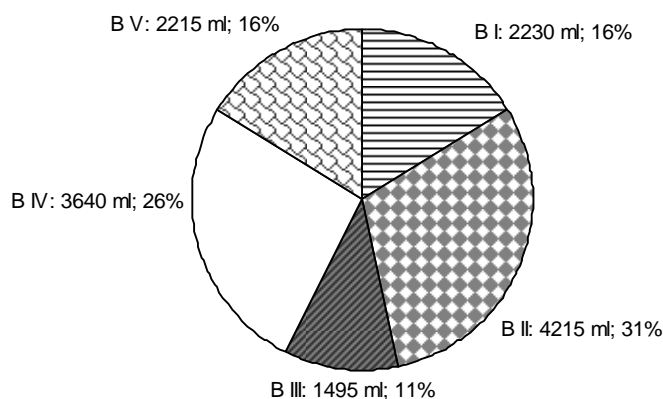


Figure 8. Total amount of biogas obtained during the 33 days of experiment

By summing the amounts of biogas harvested in all four harvests for each batch, we obtain the total biogas yields for each experimental batch during the 33 days of experiment - yields are presented in Figure 8. After 33 days of anaerobic digestion, the biogas production was insignificant in all batches and the experiment has been terminated. Analyzing the total biogas yields in the five experimental batches, we see that batches II (wheat straw and activated sludge) and IV (wheat straw and cattle manure) produced the highest amount of biogas: 4215 ml and 3640 ml respectively. As for corn stalks (batches I and III), inoculated with either activated sludge, or cattle manure, we see that the biogas production potential in the experimental conditions is very low. Moreover, we see that by adding corn stalks to cattle manure (batch III) the biogas production decreases comparatively with cattle manure alone (batch V). This is surely caused because of extra amount of water needed to be added in batch III to adjust the dry weight of the fermentation medium to 8%, as corn stalks have the dry weight very high. The same dilution with water was performed in batch IV as well, where dry wheat straw where used, but in this case, the biogas production was higher compared with batch V (cattle manure only).

4. Conclusions

The aim of this experiment was to analyze the biogas production potential using cattle manure compared with activated sludge used as inoculums for biogas production from agricultural wastes as wheat straw and corn stalks. We found that the largest production of biogas is obtained using wheat straw, using as inoculums either activated sludge or cattle manure. Corn stalks added no extra biogas production potential comparing with cattle manure, and the biogas production was low using this agricultural waste as substrate, even inoculated with activated sludge. Wheat straw increased the biogas production potential of cattle manure with 39.2%. As for the differences between the biogas production potentials of the two agricultural wastes, our results indicates that this potential is higher in wheat straw in the range of 47% (inoculated with activated sludge) and 59% (inoculated with cattle manure). In conclusion, cow manure can be used as inoculum for anaerobic fermentation of agricultural waste (especially wheat straw) and biogas production. It is advisable to run other experiments with more experimental batches to compare results.

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