Experimental results concerning biogas production through anaerobic fermentation, based on different waste biomass

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Abstract: - The paper presents a comparative experimental analysis between different types of biomass residues, during their behavior along the anaerobic fermentation process for forming biogas. The authors focus the results on the quality and quantity which are produced using different species of agricultural and wood residues: beech dust, linden dust, corn waste and a recipe composed by corn and mix of maize and corn waste. All the research, including measurements and analysis, is carried out on a pilot installation.

Key-Words: - waste, biomass residues, anaerobic fermentation, pilot, biogas

1 Introduction

Global supply of energy is facing several increasing challenges. Energy consumption is on a moderate increase, especially in rapidly developing countries. The overall size of the world energy market nearly doubled between 1971 and 2003, and extended by 2010 to a very high level, driven by rapid expansion in energy use in the developing world, where population and energy activity have grown. The International Energy Agency (IEA) has projected an increase in primary energy demand of 1.6 per cent per year until 2030, when the cumulative increase will be equal to half of current demand. At present, fossil fuels – oil, coal, and natural gas – dominate the world energy economy, providing 80 % of the world's primary energy supply of 449 EJ/year [1].

The use of biomass has for millennia helped human society to fulfill many of its fundamental energy needs, such as for the production of goods, cooking, domestic heating and the transport of people and goods [2]. Agricultural biomass production is generally considered to have the greatest energy potential of the three main biomass sources (agriculture, forests and waste). With current technologies, biomass from agriculture can satisfy a wider range of demands [2].

One of the technologies used for energy recovery from biomass residues (practically considered waste) is the production of biogas through anaerobic fermentation.

Anaerobic digestion and biogas production are promising means of achieving multiple environmental benefits and producing an energy carrier from renewable resources. Replacing fossil fuels with biogas normally reduces the emission not only of greenhouse gases, but also of nitrogen oxides, hydrocarbons, and particles [3].

Biogas could become – according to its physical, chemical, and thermal characteristics - one of the most important alternative fuels, with CO_2 neutral emission, and can potentially replace natural gas and oil as it can contribute to maintain mobility, while other alternative sources of electrical energy and heat generation are available (wind, solar energy, etc.). No negative or limited environmental side effects are observed specially generated because biogas can be produced from all types of "green" biomass [4]. Related to the renewable sources influence inside the European Community, in Table 1 the share of renewable resources at the level is presented. For 2020 the expectation towards growing the renewable share are large.

Table 1 – Share of renewable resources in European Union [5]

Energy source	**Energetic share [%]**
Coal	15
Oil	41
Natural Gas	23
Nuclear	15
Renewable	6

Connected with the allocation of biomass residues at Romanian level, in Fig. 1 is presented the energetic potential related with biomass distribution in the different regions of the country.

Fig. 1 – Energy potential allocation in Romania [6]

Biogas from biomass represents one of the technologies which are evolving in Romania in present times. Because of this, different steps are taken in order to study ways and biomass types useful to produce biogas with good quality and in large quantities.

At the Unconventional Energies Laboratory of the Mechanical Engineering Faculty there was developed a pilot installation dedicated to the study of the behavior for different biomass residues.

2 Pilot plant

In Figure 2 is presented the pilot schematics.

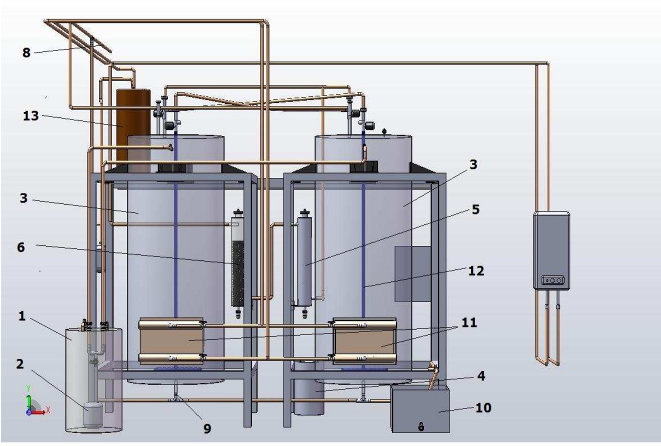

Fig. 2 – Pilot schematics [7], [8]

1 – preparation tank, 2 – pump, 3 – fermentation reactors, 4 – correction agent tank, 5 - filter for retaining the H_2S, 6 - system used for retaining CO_2. 7 - adjacent system for CO_2 desorption and compression, 8 – consumer , 9 - gravimetric system, 10 – system for neutralizing the resulting liquid, 11 – heating system, 12 - bubbling system, 13 - small tank for biogas samples.

From the biomass deposit, the used material is passed through a mill, and then it's sent to the tank where the preparation of the suspension of biomass is made (1). The biomass suspension is transported with the help of the pump (2) and introduced into the fermentation reactors (3). The correction agent tank for the pH assures, through the control system, the conditions for the process of anaerobic fermentation. The resulted biogas is passed through a filter for retaining the H_2S (5) and after that, through a system used for retaining CO_2 (6), after which takes place the CO_2 desorption and the compression of the CO_2 in the adjacent system (7) and the purified biogas is sent for being used (8). The used material is discharged through the means of a gravimetric system (9), and the solid material is retained for being dried using the natural drying, and after that is sent to a compost deposit for being used as a soil fertilizer. A part of the resulting liquid is neutralized when the case, in the system (10) and sent to the sewerage network, or is transported by the recirculation pump (2) from the suspension preparation tank (1). The fermentation reactors are thermostat heated with the system (11). For the homogenization of the suspension is used a bubbling system (12) made by polypropylene pipes to avoid the possible corrosion. Also, for depositing small quantities of biogas of the purpose of analyzing, the installation is equipped with a small tank (13) positioned at the top of the reservoirs.

Based on this installation one accomplished long term experimental analysis related to biogas quality and quantity using different sorts of wood and agricultural biomass residues.

Fig. 3, 4, 5, and 6 present the biomass residues that were used for the experimental determinations.

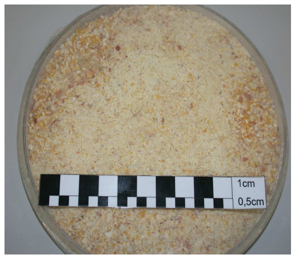

Fig. 3 - Grains of corn Waste [7]

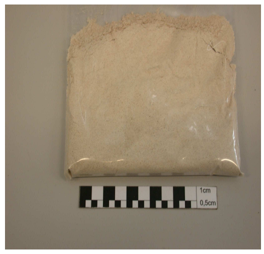

Fig. 4 – Mix of maize and corn waste [7]

Fig. 5 – Beech dust [7]

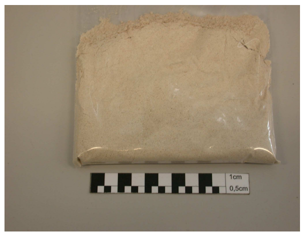

Fig. 6 – Linden dust [7]

One used two different types of agricultural biomass residues used for experimental determinations: agricultural and wood. As result of comparative experiments between each batch involved, the quality of generated gas was determined, according mainly the methane & carbon dioxide present in the resulted biogas.

3 Experimental results and discussion

For each batch there were made measurements in order to determine both quality and quantity of the obtained biogas and its composition.

The following figures will underline the variation of pressure for each batch correlated with the production of biogas.

The temperature regime was between 30 – 38 °C (the mesophilic regime) and the pH was maintained at a value between 7 - 7.5, in order to avoid the negative influence of the process of corrosion on the pilot installation material.

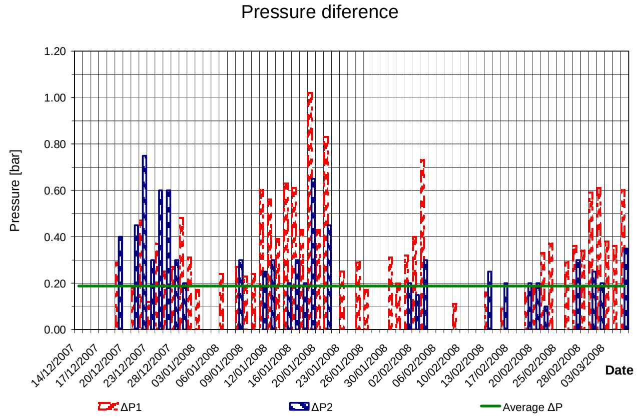

Fig. 7 – Pressure difference for beech dust batch [7]

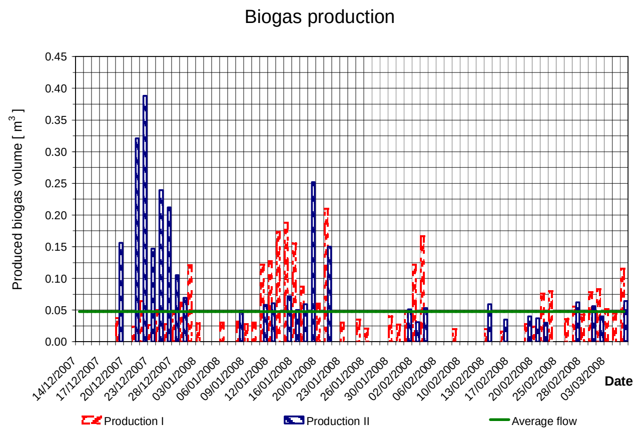

Fig. 8 – Biogas production for beech dust batch [7]

From Figures 7 and 8 it can be observed that the average value for the pressure difference is approx. 0.2 bars, and the biogas quantity is under 0.05 m^3 / day.

In order to verify another type of wood material, there was realized another experimental determination using linden dust. The results are presented in Figures 9 and 10.

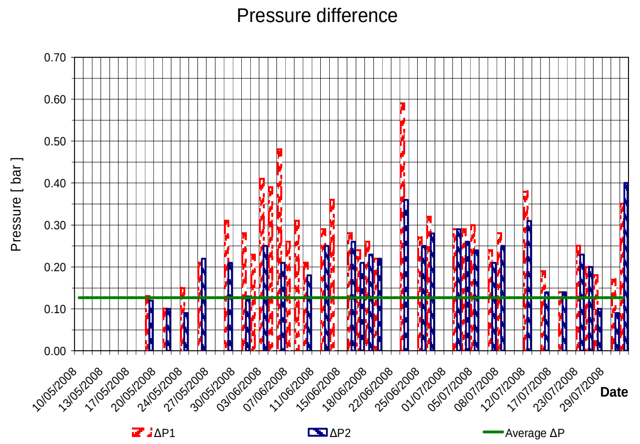

Fig. 9 – Pressure difference for linden dust batch [7]

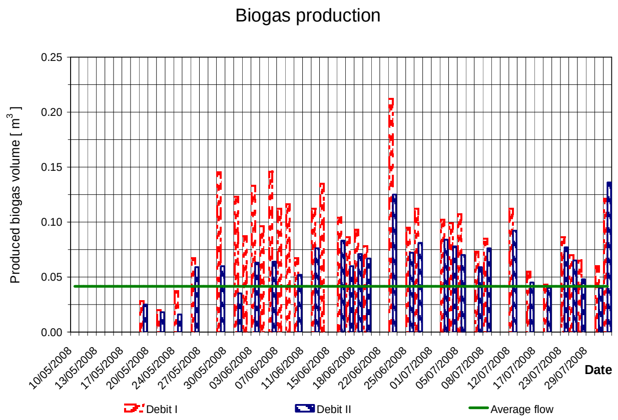

Fig. 10 – Biogas production for linden dust batch [7]

The correlation between the pressure difference and the biogas production is at a low value, of 0.12 bar, meaning an equivalent biogas production of under 0.05 m^3.

The next logical step was to use agricultural waste, so the next experimental determination was made using a mix of maize and corn waste. The results are presented in Figures 11 and 12.

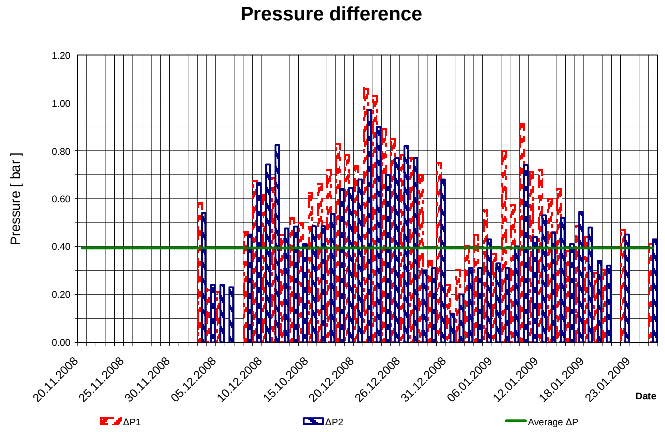

Fig. 11 – Pressure difference for the mix of maize and corn waste batch [7]

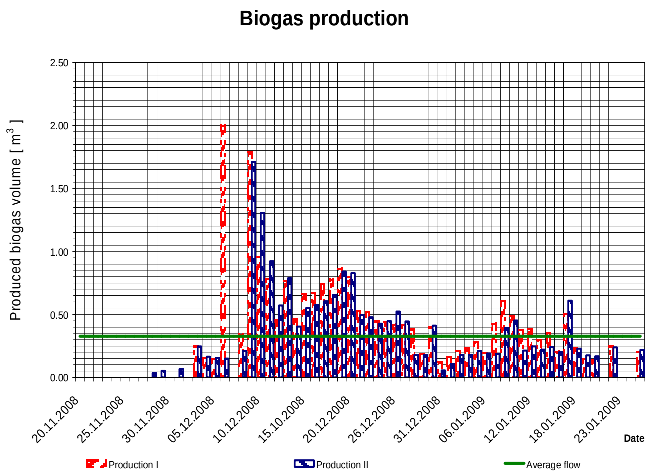

Fig. 12 – Biogas production for the mix of maize and corn waste batch [7]

From the correlation between the difference of pressure and the biogas production it can be observed that the average value is about 0.4 bars and the biogas production has peaks at 2 m^3, with an average value for production of 0.25 m^3 / day.

The last batch was composed only from grains of corn waste, and the results are presented in Figures 13 and 14.

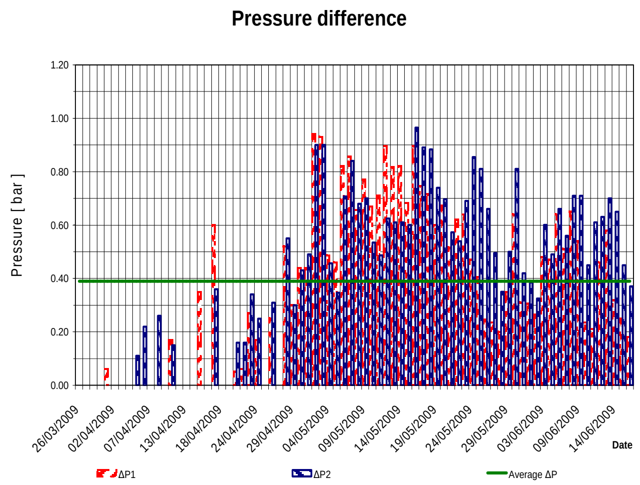

Fig. 13 – Pressure difference for grains of corn waste batch

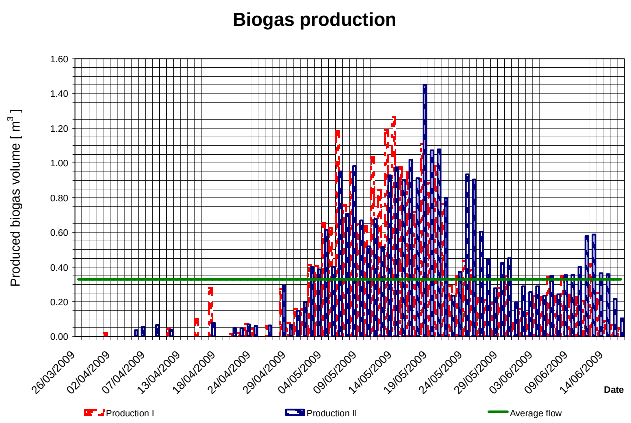

Fig. 14 – Biogas production for grains of corn waste batch [7]

The correlation between the difference in pressure and biogas production shows that this batch had produced the largest quantity of biogas from all the analyzed batches. All data in reference to normal conditions

The comparison between the quantities of produced biogas is showed in Figure 15. Best results are from corn waste, the explanation is based on the best C / N ratio.

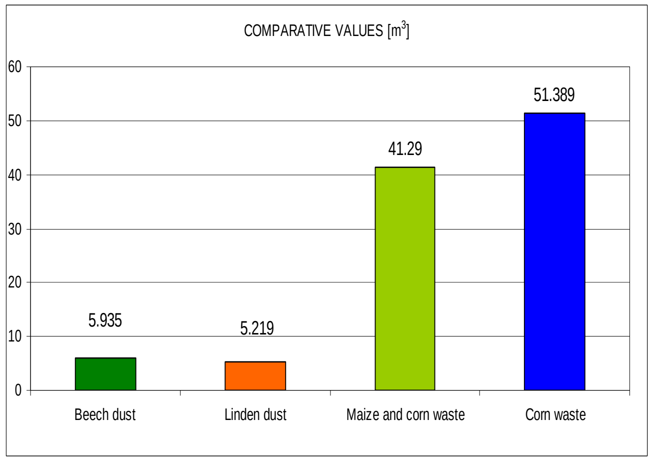

Fig. 15 – Comparative results regarding the biogas amount [7]

In order to determine the percentage of methane and carbon dioxide, there were realized measurements during the anaerobic fermentation process involving three periods of time: the starting period, when, after the Oxygen consumption there are starting to form the anaerobic bacteria, the period with the maximum production of biogas, presented as a peak, and the last period when the process is slowing down. The concentrations of methane and carbon dioxide are presented for each batch / each reservoir in the period with the maximum production of biogas. In Figures 16 and 17 are presented the methane and CO_2 concentrations for the beech dust batch.

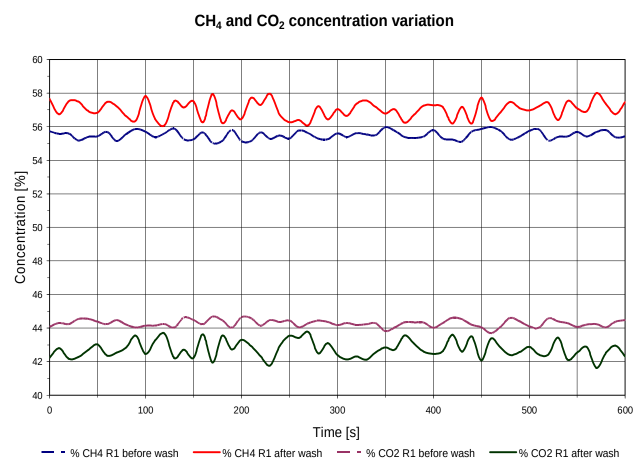

Fig. 16 – Methane and CO_2 concentrations by vol. for beech dust batch – reservoir no. 1 [7]

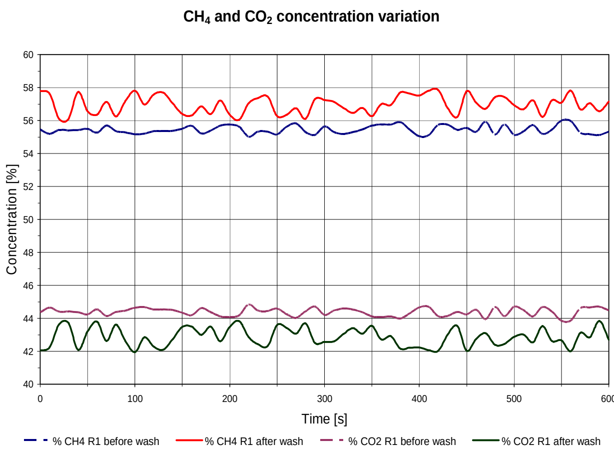

Fig. 17 – Methane and CO_2 concentrations by vol. for beech dust batch – reservoir no. 2 [7]

From the graphics it results that the methane concentration, in % by volume, has about the same values for the same reservoirs, with a maximum value of about 58 %, while CO_2 concentration, in % by volume, is in the range of 41 – 42 %, as maximum value.
In Figures 18 and 19 the methane & CO_2 concentrations by vol. for the linden dust batch are presented.

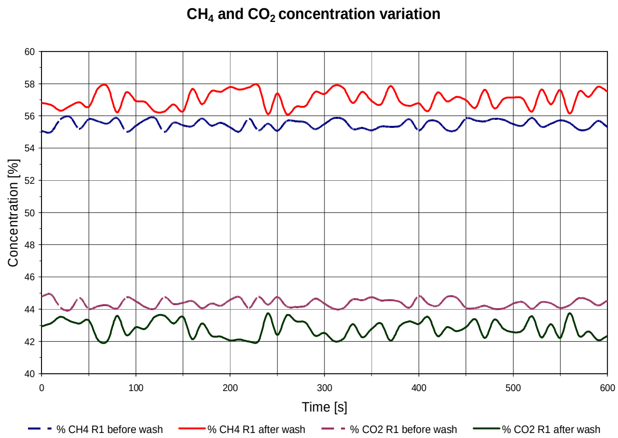

Fig. 18 – Methane and CO_2 concentrations by vol. for linden dust batch – reservoir no. 1 [7]

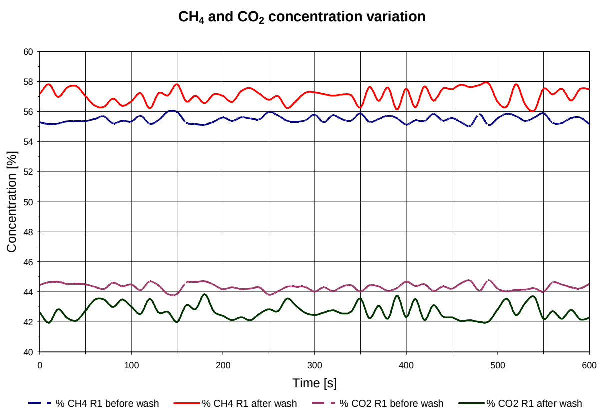

Fig. 19 - Methane and CO_2 concentrations by vol. for linden dust batch – reservoir no. 2 [7]

Through comparison with the values for the first batch, it can be observed that the CH_4 concentration is about the same for the maximum values, like the CO_2 concentration. The explanation resides in the fact that the material is woody and has a large percentage of ligno-cellulose.
In Figures 20 and 21 are presented the methane and CO_2 concentrations, by vol., for the mix of maize and corn waste batch.

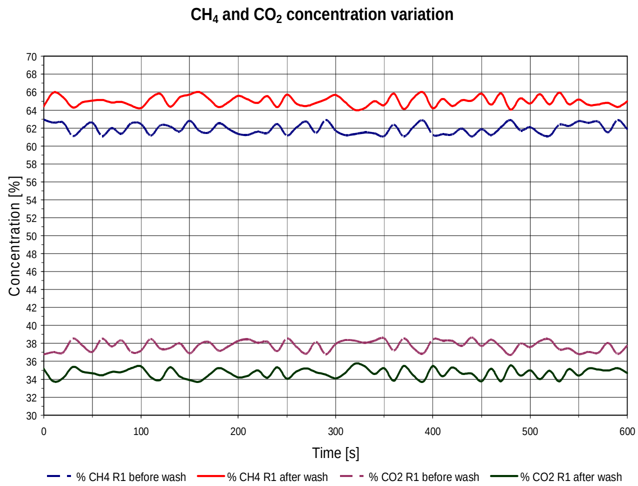

Fig. 20 - Methane and CO_2 concentrations by vol. for mix of maize and corn waste batch – reservoir no. 1 [7]

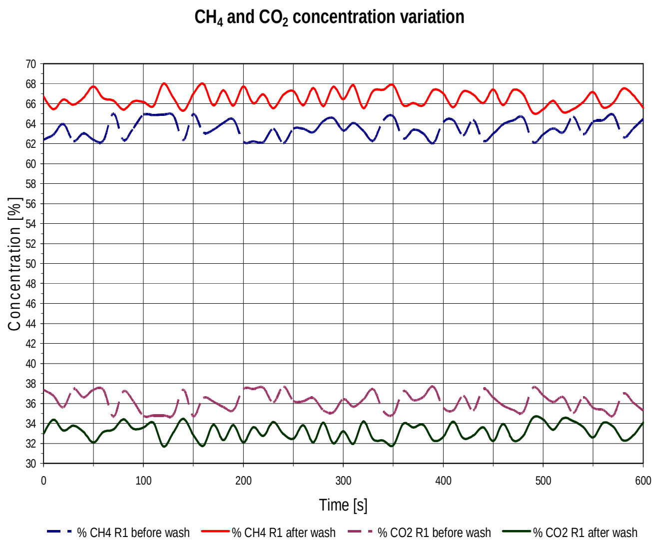

Fig. 21 - Methane and CO_2 concentrations by vol. for mix of maize and corn waste batch – reservoir no. 2 [7]

From the measurements, it can be observed that the CH_4 value is with approximately 1% larger for the second reservoir, this percentage influencing the CO_2 concentration.
In Figures 22 and 23 the concentrations of methane and carbon dioxide for the corn waste batch are presented.

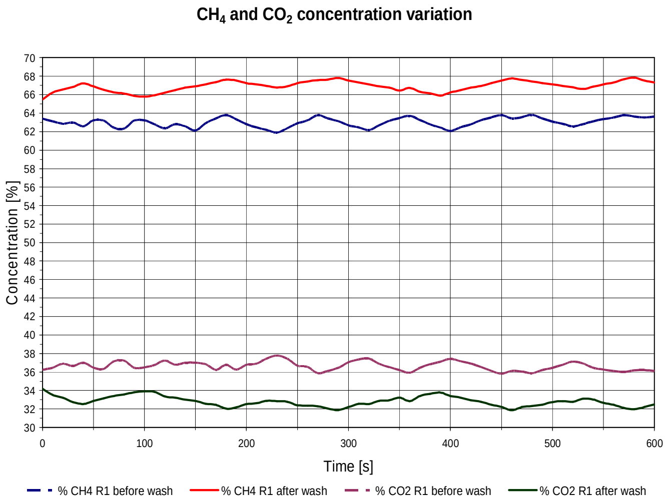

Fig. 22 - Methane and CO_2 concentrations by vol. for corn waste batch – reservoir no.1 [7]

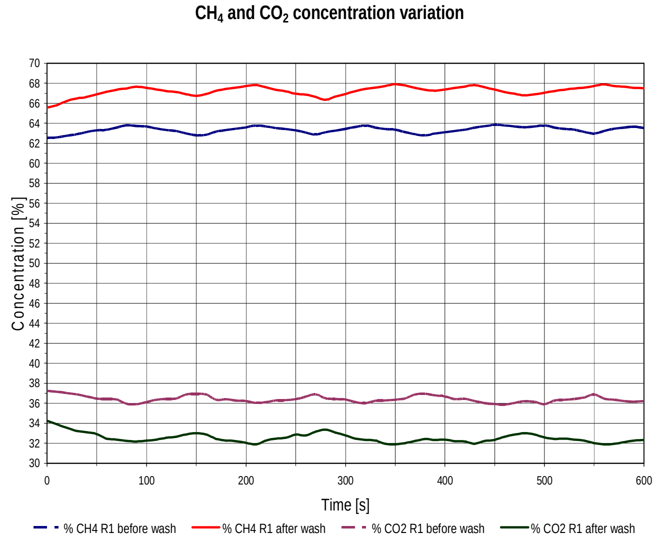

Fig. 23 - Methane and CO_2 concentrations by vol. for corn waste batch – reservoir no.2 [7]

From the measurements, the concrete maximum value for methane (67 – 68 % by vol.), and the influence over the CO_2 concentration, are of importance.

4 Conclusions

Biogas is a type of unconventional energy for the future, one way to produce energy and still tends to assume a growing impact in the present context related to reduce amounts of fossil fuels [8], [9]. Biomass represents an inexhaustible energy resource that can be used partly or wholly for biogas production, both by anaerobic fermentation and other processes (aerobic fermentation, gasification), related technology for anaerobic fermentation process being used in the present. Regionally and globally, stimulated investments are linked to the achievement of plants to produce biogas, a shift in which our country should join the current conditions. The quality of the produced biogas is closely related to the type of biomass which is being used. From the recorded data presented in the figures it is clear that the input material used is very important, meaning the quality of waste (type of biomass residues), the C / N ratio, the duration of the batch, and also the ration between solid matter and liquid volume. Through comparison one concludes that the last two batches produced much more biogas than the first two, strengthening the idea, that it is very important to find further solutions to solve the problem of the difficult degradation of the ligno – cellulose chains. A possible solution would be an acid hydrolysis, but through the process of neutralizing the acid, the result is often a salt, that decreases the speed of the formation of mathanogenic bacteria, and thus, the biogas production is reduced. Because the energetic value of the waste is relatively high, for a full recovery of energetic potential it is recommended to be co-incinerated or treated further for CO_2 retention, thus becoming a high quality gaseous fuel, with CO_2 neutral emissions.

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