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AGRICULTURAL FEEDSTOCK CHARACTERIZATION USED IN BIOGAS PLANTS

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Abstract: Anaerobic digestion is a biochemical decomposition process that is used for the treatment and energy recovery from biomass, like organic residues, agricultural and industrial wastes, animal manure and energy crops. The paper presents results of experimental research on the physico-chemical characteristics of the agricultural biomass (corn stalks, wheat straw and alfalfa) that can be used in co-digestion with animal manure in biogas plants. Parameters with a significant role in the process of anaerobic fermentation were assessed: total soluble solids (TSS%), the pH, the moisture content as well as the reducing sugars in the liquid fraction of the tested substrate.
Keywords: agricultural feedstock, corn stalks, wheat straw, alfalfa

INTRODUCTION

In the last period, the anaerobic fermentation of organic fraction has been recognized as a valuable method that can convert the substrate used into useful products such as biogas and digestate (*Khalid et al, 2011*).

The most commonly used substrate for biogas production by anaerobic fermentation process is the manure containing nutrients necessary for the growth of anaerobic microorganisms. However, due to the low concentration of total solids and a high concentration of ammonia present in the manure, it is a common practice to blend in various residues of crops and energy crops (*Regueiro et al, 2012*). The anaerobic digestion of agricultural wastes mixed with animal manure, in a co-digestion mode, can improve significantly the fermentation process and also the biogas production. The most important reason for using co-digestion of animal manure and agricultural biomass is the adjustment of the carbon and nutrient balance and also the quality and stability of the digestate (*Cestonaro et al, 2015; Parawira et al, 2004*). Moreover, agricultural wastes are a desirable material to co-digest with dairy manure because of its high biodegradability.

The final products of anaerobic fermentation process are the biogas that is a mixture of methane (CH_4), carbon dioxide (CO_2), hydrogen sulphide (H_2S), nitrogen (N), oxygen (O_2) and water vapors and the digestate that can be used as soil amendment (*Scano et al, 2014*). The biogas production resulted from the anaerobic fermentation of organic fraction is considerably influenced by the substrate composition (*Ahn H.K., 2010*). Even for the same species of the biomass used, its composition may vary according to geographical area, the season of harvest and the storage mode (*Templeton, D.W., 2009*). Thus, the characterization of substrate components used in anaerobic digestion process for obtaining biogas is very important to estimate the biogas production.

Lately, there were carried out a lot of experiments aiming determination of biogas production resulting from anaerobic fermentation of vegetal biomass, animal manure and other biodegradable wastes (*Cuetos et al, 2011; El-Mashad and Zhang, 2010; Xie et al, 2011*).

Zhang et al (2013) investigated biogas production by co-digestion of goat manure with three crop residues, namely, wheat straw, corn stalks and rice straw, under different mixing ratios. Results showed that the combination of goat manure with corn stalks or rice straw significantly improved biogas production at all carbon to nitrogen (C/N) ratios. Goat manure (GM)/corn stalks (CS) (30:70), GM/CS (70:30),

GM/rice straw (RS) (30:70) and GM/RS (50:50) produced the highest biogas yields after 55 days of fermentation.

In the present paper, there were tested the physico-chemical characteristics of the agricultural biomass consisting of corn stalks, wheat straw and alfalfa, in order to identify the most efficient substrate that can be used in co-digestion with animal manure in biogas plants. It is well known that the anaerobic digestion of organic matter is related to its composition, thus it is necessary to find out what the characteristics of the substrate to be fermented are. Parameters with a significant role in the process of anaerobic fermentation were assessed: total soluble solids (TSS%), the pH, the moisture content as well as the reducing sugar in the liquid fraction for corn stalks, wheat straw and alfalfa.

MATERIAL AND METHOD

Corn stalks, wheat straw and alfalfa plants used during experiment were obtained from a household located in the Teleorman County, Romania.

Regarding the biomass processing, grinding was done with the help of an electrical grinder for vegetable residues Viking GE150 and then with a laboratory mill Grindomix GM-200 for 1 minute at 5000 rpm (fig. 1).

Figure 1 – a) Laboratory mill Grindomix GM-200 and b) Grinder for vegetable residues Viking GE150

The proportion agricultural substrate – water is presented in Table 1. Each quantity of the tested substrate was placed in the same quantity of water in tightly closed Erlenmeyer flasks. After that, the Erlenmeyer flasks were placed in the bacteriological thermostat for 7 days at a temperature of 35 °C (fig. 2). During the experiment, liquid samples were collected for analysis. Assessment of the agricultural substrate was done by analysing and interpreting the following parameters: total soluble solids (TSS%), the pH and the reducing sugar.

The content of total soluble solids (TSS) was determined with a thermo-balance, after the centrifugation of initial samples at 5000 rpm followed by filtering through a membrane with pores of 0.45 µm. The pH of the liquid samples was determined using a pH meter type Hanna.

Figure 2 - Bacteriological thermostat and Erlenmeyer flasks with tested biomass

Table 1. The proportion of substrate used in experiments (w/w)

	Corn stalks (g)	Wheat straw (g)	Alfalfa (g)	Water (g)
Erlenmeyer flask 1	15	-	-	300
Erlenmeyer flask 2	-	15	-	300
Erlenmeyer flask 3	-	-	15	300
Erlenmeyer flask 4	5	5	5	300
Erlenmeyer flask 5	7,5	-	7,5	300
Erlenmeyer flask 6	7,5	7,5	-	300

In order to estimate the concentration of sugars in the samples taken, was used the method in which is used the 3.5-dinitrosalicylic acid (DNS) (*Miller G.L., 1959).* The absorbance was measured at 540 nm using the T92+ UV VIS spectrophotometer, PG Instruments.

The moisture content for each type of agricultural biomass was measured using a KERN RH 120-3 thermo-balance and the results were the following: corn stalks (14.49%), wheat straw (12.23%) and alfalfa (11.44%).

RESULTS

Based on the data obtained from experimental tests, were plotted the variation diagrams for each index analysed (TSS, pH and reducing sugar) as a function of digestion time (figures 3 - 5).

The total soluble solids contain soluble sugars, soluble proteins, mineral salts, pigments and water-soluble compounds that are used as nutritive substrate for different groups of microorganisms involved in anaerobic digestion and biogas production. TSS value refers to the amount of soluble compounds released into the fermentation medium from the vegetal material, mainly substances with low mass. In addition, soluble substances could be formed by the hydrolysis reactions due to the exoenzymes released by hydrolytic bacteria in order to degrade the macromolecular substrate at assimilable compounds with low mass.

The initial TSS values differ depending on the used substrate type. Analysing the data, it can be observed that in all cases TSS value tends to increase. For the milled corn stalks, the TSS values have increased from 0.5%, value recorded after 24 hours, to 2.5% after 168 hours of incubation.

During the experiment, all the TSS values increase because of substrate degradation, the highest value being 2.6% after 168 hours of incubation, for the mixture of corn stalks and alfalfa biomass. In time, the bacterial populations will consume nutrients from the medium and the TSS values will decrease significantly.

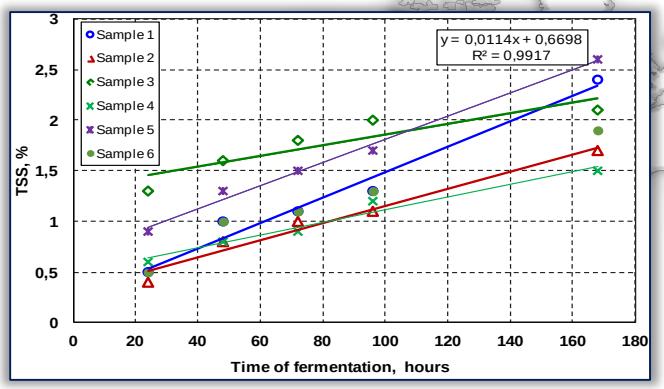

Figure 3 – The TSS variation during fermentation process

The evolution in time of the pH variation for each tested substrate is shown in Figure 4. The pH is a key parameter that provides significant information regarding the stability of anaerobic digestion process. In our case, the pH of analysed liquid samples had an ascending tendency, characteristic for this type of fermentation.

During the 168 hours of experiments, the pH values were maintained in the acid domain due to, probable, the fermentations that produce organic acids, such as acetic, propionic, butyric, fatty acids, alcohols etc.

For each the tested substrate, as well as in the case of thereof mixture, after 24 hours, the pH value start to increase, and at the end of fermentation period have values ranging from 5,8 to 6,5 units.

It can be considered that in this case takes place the first two phases of anaerobic digestion, namely hydrolysis and acidogenesis, where act hydrolytic and acidogenic microorganisms, like: *Streptococcus, Lactobacillus, Bacillus, Escherichia coli, Salmonella.* The highest pH values were recorded for the mixture of corn stalks and alfalfa, from 5.35 units after 24 hours and reaching 6.5 units at the end of the experiment.

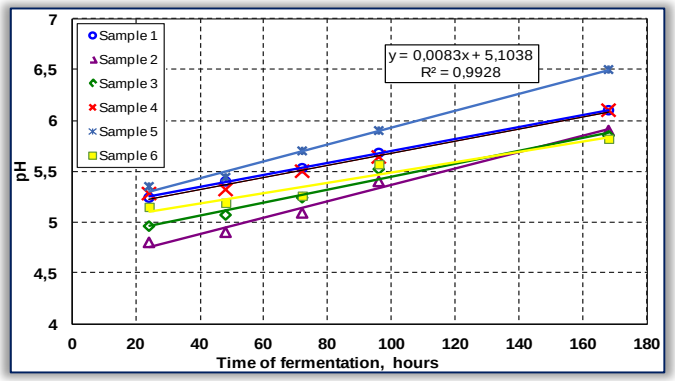

Figure 4 - The pH variation during fermentation process

Due to cellular multiplication and the fermentation produced by these, the reducing sugar concentration had a slightly increasing trend for all the tested substrates during the 168 h of incubation. In time, al the values increase due to saprophytic microorganisms activity with a degradation action of polysaccharides (cellulose and starch) in the plant cell.

During this phase, the sugar concentration is mainly due to extraction process of sugar in water and less to microorganisms' activity, beginning to adapt to the environment and multiply. The growth of microorganisms occurs approximately after the first 24 - 48 hours. They consume the substrate, and also reducing sugars; however, sugars accumulate in the medium at least in the first 168 hours of incubation.

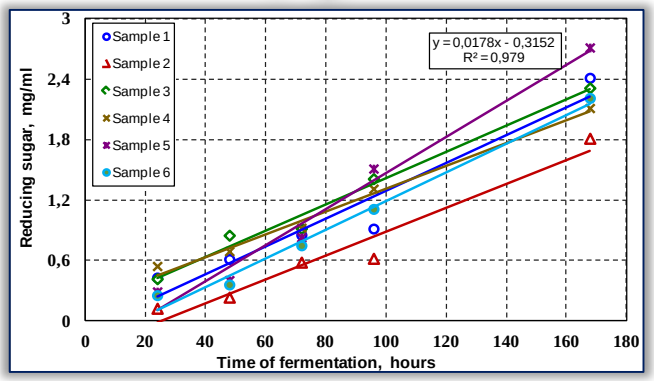

Figure 5 - The reducing sugar variation during fermentation process

After 24 hours the highest concentration of sugars was found in the case of substrate consisting of corn stalks, 0.420 mg/ml, while the lowest concentration was detected in the case of wheat straw, being about 0.115 mg/ml.

Compared to the first day, after 168 hours, for the mixture of corn stalks and alfalfa, sugar concentration increased about 10 times, reaching 2.7 mg /ml.

There is a close correlation between the concentration of sugars and total soluble solids concentration that increase almost simultaneously and are higher in the mixture of corn stalks and alfalfa biomass.

The lowest results were recorded from wheat straw having a siliceous coating, which does not allow microorganisms to access the polysaccharide vegetable wall.

CONCLUSIONS

The anaerobic fermentation is an effective biological process for treating the organic wastes derived from the agricultural and zootechnical sector. The biogas production resulted from the anaerobic fermentation is considerably influenced by the substrate composition.

The achievement of these experiments contributes to the optimization of anaerobic digestion process, in order to obtain biogas from biomass. The characterization of substrate components used in biogas plants is very important to estimate the biogas production.

From the experiments conducted, it was found that the concentration of sugars and total soluble solids increased almost simultaneously in the mixture of corn stalks and alfalfa biomass. After 168 hours, for the mixture of corn stalks and alfalfa, sugar concentration increased to 2.7 mg /ml. For the same substrate, the pH value reached 6.5 units at the end of the experiment.

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