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BIOGAS PRODUCTION FROM MIXTURES OF ANIMAL MANURE AND FRESH BIOMASS WITH AND WITHOUT GLUCOSE ADDITION

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Abstract: *Anaerobic digestion is a widely used technology that can process various kinds of organic wastes for biogas production by decomposing organic matter under oxygen-free conditions. Anaerobic digestion of organic matter has been considered as a suitable technology for organic wastes treatment and energy production in the form of biogas. The main aim of the paper is to present the results of different experiments carried out in order to provide data about biogas production from different substrates with and without glucose addition. The experimental data showed that the glucose addition was stimulatory for biochemical reactions and benefic for biogas production. We concluded that the biogas production resulted from anaerobic digestion of animal manure is substantially affected by the composition of feedstocks.*
Keywords: *biogas, anaerobic digestion, animal manure, glucose addition*

1. INTRODUCTION

The modern society generates large amounts of waste that represent a tremendous threat to the environment and human and animal health. To prevent and control this, a range of different waste treatment and disposal methods are used. The choice of method must always be based on maximum safety, minimum environmental impact and, as far as possible, on valorization of the waste and final recycling of the end products [1]. One of the most important processes of biomass conversion is the anaerobic digestion (methane fermentation) of organic matter to produce biogas, consisting mainly of methane and carbon dioxide [2].
Anaerobic digestion of energy crops, residues, and wastes is of increasing interest in order to reduce the greenhouse gas emissions and to facilitate a sustainable development of energy supply. Production of biogas provides a versatile carrier of renewable energy, as methane can be used for replacement of fossil fuels in both heat and power generation and as a vehicle fuel [3]. The main constituents of biogas are methane and carbon dioxide, but it can also contain, depending on the source's composition, traces or significant quantities of undesirable contaminants, such as hydrogen sulphide, ammonia and siloxanes, whose presence can cause corrosion, erosion, and fouling to the thermal or thermocatalytic device, and generate hazardous emissions. Therefore, biogas quality (purity and composition) is very important, and its purification represents a crucial final step of the overall production process in view of its final application [4].
The anaerobic digestion process can be divided into four major steps [5-7], namely: hydrolysis, acidogenesis, acetogenesis and methanogenesis. Firstly, high molecular materials and granular organic substrates (e.g., lipids and carbohydrates, protein) are hydrolyzed by fermentative bacteria into small molecular materials and soluble organic substrates (e.g., fatty acids and glucose, amino acids) [8]. Then, these small molecules are converted by fermentative bacteria (acidogens) to a mixture of volatile fatty acids and other minor products such as alcohol [9]. Thirdly, the acetogenic bacteria convert the volatile fatty acids to acetate, carbon dioxide and hydrogen, which provide the substrates for methanogenesis phase. Among the four microbial groups, methanogens bacteria have the slowest growth rate and are the most sensitive to changes of environmental conditions, such as temperature, pH, and the concentrations of inhibitors [10].
Crop residues and animal manure have recently been used together to produce biogas by anaerobic digestion process. Compared with the single digestion of feedstock, the co-digestion of crop residues and animal manures increases the rate of biogas production because of the greater balance between carbon and nitrogen [11]. Anaerobic co-digestion consists of the anaerobic digestion of a mixture of two or more substrates with complementary characteristics. It is well known that one of the main issues for the co-digestion process lies in

balancing the C/N ratio. In fact, ideal co-substrates for manures, substrates with high nitrogen contents and high alkalinity, are wastes which have a high C/N ratio[12].
S. Astals *et. al* [13] tested the influence of glycerol on biogas production. Thus, they mixed fresh pig manure and digested pig manure with crude glycerol derived from biodiesel production. The researchers reported that an increase of about 400% in biogas production was obtained under mesophilic conditions when pig manure was co-digested with 4% of glycerol, on a wet-basis, compared to mono-digestion. Moreover, they found out that the digestate stability, evaluated through a respirometric assay, showed that co-substrate addition does not exert a negative impact on digestate quality.
Another study related to co-digestion is reported by K. Bulkowska *et. al* [14]. They tested the digestion process of crop silage (Zea mays L. and Miscanthus sacchariflorus) with 0%, 7.5%, 12.5% and 25% pig manure as co-substrate. The results indicated that the most stable anaerobic digestion was achieved using 7.5% and 12.5% pig manure. The authors concluded that compared to crop silage alone, pig manure favored the production of biogas and methane; the highest production rates were obtained with 12.5% pig manure.
Zhang T. *et al.* [15] 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 from different after 55 days of fermentation.
The main aim of the paper is to present the results of different experiments carried out in order to provide data about biogas production from different substrates (horse and pig manure mixed with fresh biomass) with and without glucose addition. All the experiments were conducted on a small capacity pilot plant for obtaining biogas from biomass and the main parameters, temperature and pH, were kept constant. During the anaerobic fermentation process, the temperature was set in the mesophilic domain (35°C) and the pH value was set at 7. The composition of the obtained biogas was analyzed using a gas chromatography device.

2. MATERIAL AND METHODS

2.1. Feed material

For biogas production, animal manure (horse and pig manure) and fresh residual biomass were used as substrate. The residual biomass consisting of leaves, twigs and grass was chopped using an electric plant for grinding equipped with cutting knives. Pig manure and horse manure were obtained from the agriculture farm in Romania. The substrate subjected to the anaerobic fermentation process was mixed with tap water and the elements listed in Table 1.

Table 1: Substances used in the preparation of the feed substrate

	Substances g/100 L	**Symbol**	**Quantity** *g*
1	Glucose	$C_6H_{12}O_6$	3000
2	Ammonium phosphate	$(NH_4)_2HPO_4$	91.1
3	Ammonium chloride	NH_4Cl	56.6
4	Potassium chloride	KCl	8
5	Ferric chloride	$FeCl_3$	10
6	Magnesium chloride	$MgCl_2.6H_2O$	20
7	Aluminium chloride	$AlCl_3.6H_2O$	2.2
8	Calcium chloride	$CaCl_2.2H_2O$	2
9	Magnesium sulphate	$MgSO_4H_2O$	0.5
10	Zinc chloride	$ZnCl_2$	0.04
11	Ammonium molybdate	$(NH_4)6MoO_{24}4H_2O$	0.2

2.2. Biogas plant design

The experiments were conducted using a small capacity pilot plant for obtaining biogas from biomass. The plant used for the experiments is comprised of four main parts, namely [16]:

- a feed section, consisting of the feed preparation system and a pump to transfer the material into the reactor;

- the anaerobic digester, with all the instruments needed for feeding, measuring and control purposes;
- a gas line with the relative treatment systems;
- a tank where the gas is stored before use.

The anaerobic digester made of plastic, has a working capacity of about 100 L. This is fitted with a sight window for viewing the content of the tank. Also, the digestor is equipped with temperature sensors, arranged lengthwise, that make it possible to asses the temperature variations. Moreover, inside there is a temperature control probe and a pH control probe. Mixing is obtained by circulating the content of the bioreactor through an external circuit by means of a pump.

The stainless steel tank has a working volume of 200 L and it is used to prepare the material to be fed into the digestor. This is equipped with a fixed-speed stirrer (100 rpm) and a level indicator.

2.3. Experimental set-up

The substrate subjected to the anaerobic fermentation mixed with 150 L of tap water and the substances in quantities listed in Table 1, were introduced into the stainless steel tank and for one hour the composition was stirred for one hour with 100 rpm using the stirrer. The concentration of substrate consisting of animal manure and fresh residual biomass is listed in Table 2.

In all the experiments, during the anaerobic fermentation process, the temperature was set in the mesophilic conditions (35°C) and the pH value was set at 7. After stirring the mass and having defined the operating conditions (pH and temperature) from the console, the mass is transfered into the anaerobic digester by means of a pump.

All the experiments, including the biomass preparation and the pilot start-up were carried out for a 7 days period. The experiments were performed with and without glucose addition.

Table 2: Concentration of substrate used in anaerobic digestion

Experiment	Concentration of animal manure (% w/w)	Concentration of fresh residual biomass (% w/w)	Glucose
1	4	2	0
2	4	2	2%

3. RESULTS AND DISCUSSION

The biogas production obtained from mixture of animal manure and residual biomass with and without glucose addition was measured after 7 days of digestion using a gas chromatography device. Gas chromatography is an optimal analytical instrument for the analysis of components such as CH_4, CO_2, H_2S and siloxanes which are present in the gas.

In the table 3 and 4, are listed the concentrations of different components which are presented in the obtained gas, as a function of the used substrate. The data obtained from the experiments in which the substrate was mixed with glucose showed an improved biodegradability and biogas production compared with the substrate without glucose addition.

The graph in Figure 1 shows the main parameters taken into consideration in the anaerobic fermentation process and biogas production at different time intervals. In this section we present a selection of the graphs which we consider to be most representative for the results obtained in our experiments.

These results indicated that co-digestion with suitable animal manure, fresh residual biomass and glucose mixture is an effective way to improve biogas yield.

The chemical characterization of substrates used in the co-digestion experiment can be observed in Table 3.

Table 3: The chemical characterization of substrates, [15]

	Animal manure	Fresh residual biomass
pH	6,75	5,96
TSS%	25 - 35	75 - 85
VS%	75 -80	90 - 95
C/N	10 -25	80 - 90

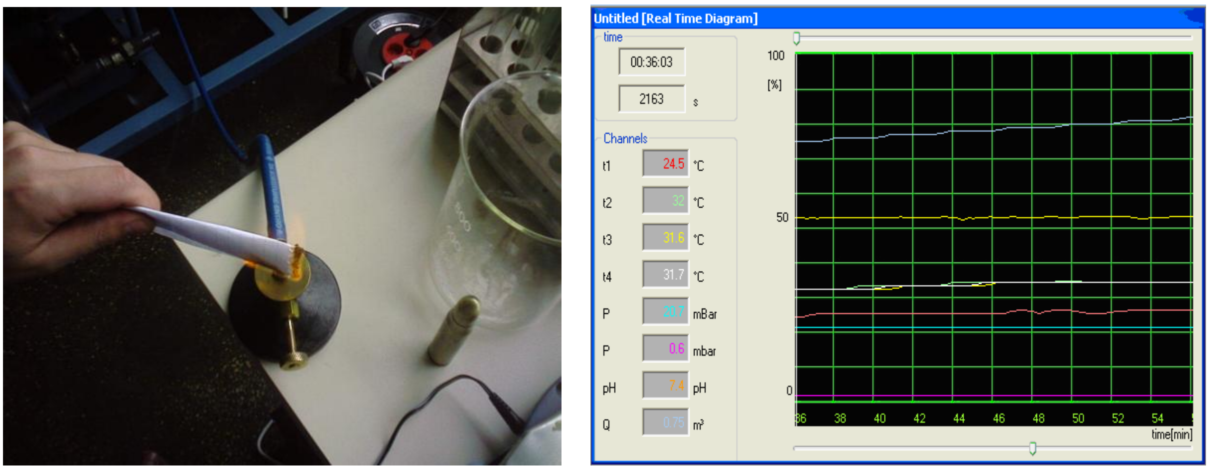

Figure 1: Biogas production at different time intervals

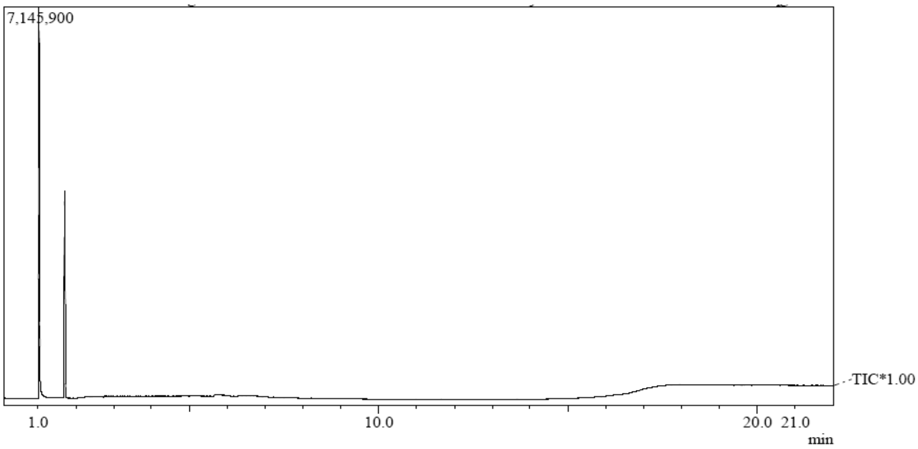

Figure 2: Gas chromatography diagram for the biogas obtained from the mixture without glucose addition

Table 4: The concentration of the biogas components

	Concentration (% v/v)	Proportion of substrate (% w/w)	Glucose addition
CO_2	38.537	animal manure 4 fresh biomass 2	0
CH_4	0.021		
CO	0.913		
N_2	42.723		
O_2	17.806		

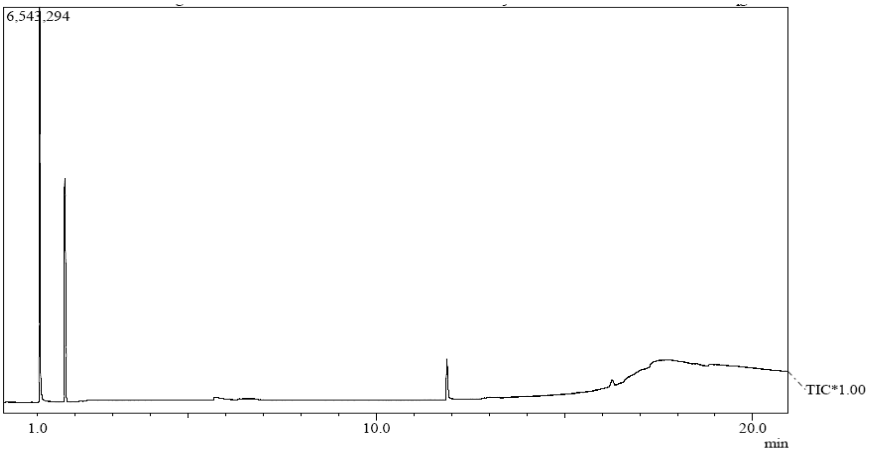

Figure 3: Gas chromatography diagram for the biogas obtained from the mixture with glucose addition

Table 5: The concentration of the biogas components

	Concentration (% v/v)	Proportion of substrate (% w/w)	Glucose addition
CO_2	43.030	animal manure 4 fresh biomass 2	2%
CH_4	0.024		
CO	0.001		
N_2	39.209		
O_2	16.046		

4. CONCLUSION

Biogas production by anaerobic fermentation is considered to be the optimal treatment for agricultural waste, manure and for a wide variety of organic waste, because these substrates are converted into renewable energy and organic fertilizer for agriculture. Moreover, anaerobic digestion is a most cost-effective bioconversion technology that has been implemented worldwide for commercial production of electricity, heat and compressed natural gas from organic material.

This study presented arguments for optimizing the anaerobic digestion process by glucose addition in the used substrate. Anaerobic digestion process efficiency is highly dependent on the type of used substrate.

The anaerobic co-digestion of animal manure, fresh biomass and glucose mixture, is a promising way for improving biogas production. Our results showed that the anaerobic co-digestion of the mixture mentioned above were efficient and produced more cumulative biogas compared with the mixture of substrate without glucose addition.

The future development of biogas from manure co-digestion includes the use of new feedstock types such as by-products from food processing industries, bio-slurries from biofuels processing industries as well as the biological degradation of toxic organic wastes from pharmaceutical industries.

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