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Comparative study on biogas production using cow and swine manure mixed with *Miscanthus x giganteus* as substrate

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GEORGIANA MOICEANU*, GHEORGHE VOICU, MARIANA FERDEȘ, GIGEL PARASCHIV, MIRELA NICOLETA DINCĂ, VALENTIN VLĂDUȚ, IULIA GAGEANU, MIHAI CHIȚOIU
Faculty of Biotechnical Systems Engineering, University "Politehnica" of Bucharest
***Address correspondence to:** Faculty of Biotechnical Systems Engineering, University "Politehnica" of Bucharest, Splaiul Independentei, 313, Sector 6, 060042, Romania.*
Tel.: +4021402 9648; Fax: +4021318 1018; Email: moiceanugeorgiana@gmail.com

Abstract

Biogas production through anaerobic fermentation represents a key technology for agricultural biomass sustainable usage as a renewable source of energy. In biogas production equipment, each type of substrate has its own potential in order to produce biogas. Substrate particle dimensions used can significantly influence the decomposition speed and the stabilization of anaerobic fermentation process. The aim of this paper consisted in determining the influence of substrate on the performance of anaerobic fermentation process in order to obtain biogas. The experiments were realized on a small biogas plant, in mesophilic temperature regime (35±1°C), retention time in the fermentor being 14 days, using cow and swine manure mixed with Miscanthus x giganteus plant. The obtained results demonstrated that using both cow and swine manure as fermentation substrate determined similar production of methane and total biogas volume. In the case of using cow manure as substrate, was recorded a production of 0.225 m^3total volume of biogas/batch with a concentration of methane of 58% (v/v), and in the case of using swine manure, the total volume was 0.220 m^3/ batch, with a percentage of methane of about 57% (v/v). Results presented in this paper can be of real use for specialists in the field of biogas production from animal and agricultural manure.

Keywords: cow and swine manure, biogas production, renewable energy, *Miscanthus x giganteus*

1. Introduction

Biogas production through anaerobic digestion process, has gained considerable attention due to sustainable energy generation, environment protection, social and economical benefits [12]. In biogas plants, various input substrates can be used in order to produce biogas. Essential as substrates and used as the starting point of biogas production are organic materials. Anaerobic digestion represents a method to decompose organic fraction with the help of a variety of anaerobic microorganisms under anaerobic conditions. The end product of anaerobic digestion process includes biogas and digestate which is used as fertilizer in agriculture [11]. The main constituents of biogas are methane and carbon dioxide, but it canal so contain traces or significant quantities of undesirable contaminants, such as: hydrogen sulfide, ammonia, water vapors etc. [2]. Biogas production through anaerobic fermentation represents a key technology for agricultural biomass sustainable usage as a renewable source of energy. The anaerobic digestion is a complex process that can be divided in four stages of biomass conversion and degradation, namely: hydrolysis, acidogenesis, acetogenesis and methanogenesis [1]. Biomass is considered to be the best option for energy supply in a sustainable manner. It is known that energetic plants (lignin biomass) are made mostly out of cellulose, hemicellulose and lignin. Out of these components, lignin doesn't decomposes that easily being insoluble in water and resistant to microorganism decomposing process. Hendriks et. al shown in their studies that a useful way to decompose lignin is mechanical pre-treatment, meaning particle size reduction [5]. According to Khullar et al [7], mechanical pre-treatment is a necessary step in lignocellulosic bioconversion in order to decrease particle size and increase total accessible specific surface area and to increase pore size of particles and the number of contact points for interparticle bonding in the compaction process. Thus, changing the particle size dimensions used in anaerobic fermenters can influence the performance of the biogas process which is directly correlated with methane concentration in its composition. The rate of degradation is enhanced through organic fractions particle size reduction process [3].The main pretreatments applied on raw materials used as substrate in anaerobic fermenters can be grouped as follows: particle size reduction, solubilization, improving the biodegradation process, and decrease organic material (loss of organic material) [3]. Particle size reduction represents the most used factor in order to describe the surface area increase resulted after pre-treatment [6]. The main objective of this research was to determine the influence of substrate on the performance of anaerobic fermentation process in order to obtain biogas. The *Miscanthus x giganteus* biomass had particles size of 2-5 cm. To assess the performance of anaerobic digestion process, there were monitored the production of biogas and the percentage values of gases in biogas composition (methane, carbon dioxide and hydrogen sulfide).

2. Material and methods

The experimental research in this paper was done using cow and swine manure, obtained in June 2015 from a farm in Teleorman County, Romania. These animal manure were mixed with energetic plant *Miscanthus x giganteus*, a perennial plant, sterile hybrid, harvested from The National Institute of Agricultural Machinery, INMA Bucharest, in its vegetation period. The *Miscanthus* green biomass was cut at the same dimensions in order to evaluate the biogas obtained after the process of anaerobic fermentation. Methane (CH_4), hydrogen sulfide (H_2S) and carbon dioxide (CO_2) parameters were also analyzed. The equipment used for experimental research was a steel bioreactor of 60 l, thermal isolated and an electric boiler charged by photovoltaic panels controlling the reaction environment. Using the command panel connected to the biogas installation during tests the pH and the temperature of the fermentor were recorded. The fermentor was equipped with a palette agitator used to homogenize the substrate. This palette agitator automatically started every 30 minutes and mixed the substrate for 3 minutes. During fermentation process experimental data was recorded.

Studying the specialty literature and taking into consideration the data presented the C/N ratio of the mixture must have values of 20-30, so that the process of anaerobic fermentation to take place in optimum conditions. Also, this relation was calculated in accordance with proposed method by T. Vintilă and V. Nicolik [13], having the value of 25.4 for used quantities. The temperature of the experimental research was raised to $37 \pm 1^{o}C$ in order to have a mesophilic condition. Also the pH had values between 6.8-7.2 necessary to maintain an optimum methanogenic bacteria growth range for the duration of the anaerobic fermentation process. In table 1 the quantities for the cow and swine manure mixed with *Miscanthus x giganteus* are represented.

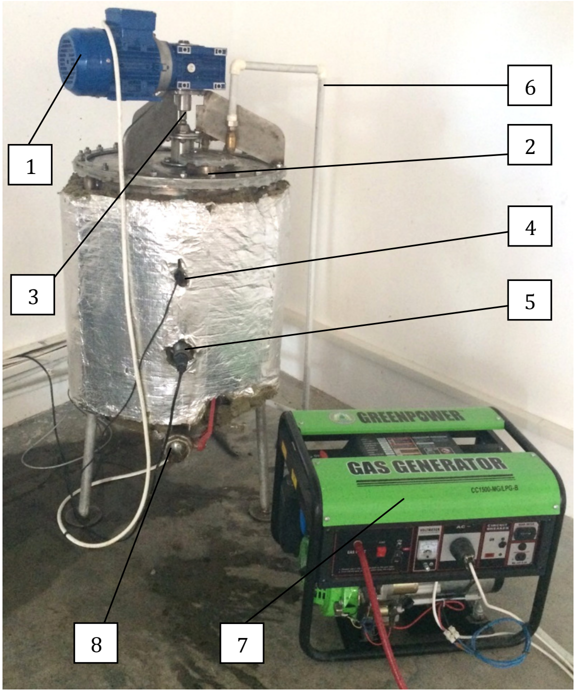

Figure 1. Biogas yield scheme and presentation of the anaerobic fermentation stages
1 – electric motor; 2 – lid with screws for sealing; 3 – paddle stirrer; 4 – temperature sensor; 5 – pH sensor; 6 – hot water circulation pipe; 7 – power generator; 8 – sampling pipe

Table 1. Tested substrate for biogas yield

Substrate	Quantity (kg)	C/N Ratio	Moisture content (%)
			Substrate type 1
Bovine manure	16.5	25 [8]	86 [8]
Miscanthus x giganteus2-5 cm	3	26 [10]	85 [14]
Tap water	14	-	-
Substrate type 2			
Swine manure	16	19.5 [13]	86.5 [13]
Miscanthus x giganteus2-5 cm	2.5	26 [10]	85 [14]
Tap water	14	-	-

In the paper the differences between the two types of substrate are shown by presenting the influence of the two different types of substrate on the process of anaerobic fermentation and was realized through analysis and interpretation of the following values: v/v percentage of methane (CH_4), hydrogen sulfide (H_2S), carbon dioxide (CO_2) as well as the biogas volume obtained for each of the two cases. The volume of biogas was measured daily using a gas meter Sacofgas Milano, fitted with a pulse counter, 1 pulse = 0.01 m^3. Using a portable gas analyzer Mentor/CombIR Series equipped with sensors, methane (CH_4), hydrogen sulfide (H_2S) and carbon dioxide (CO_2) were measured.

3. Results and discussion

The results obtained for experimental research with a small biogas capacity installation are being presented in figures 2-5. Daily evolution of specific methane percentage in biogas for both types of substrates is shown. Due to the small amount of methanogenic bacteria present in bioreactor in initial phase, at the beginning of fermentation process the methane production was insignificant; the biogas accumulations achieved after 48 hours. A fact well known and studied by researches showed that the biogas heating power depends on the methane percentage in biogas production. The methane concentration obtained from anaerobic digestion process of animal manure and *Miscanthus x giganteus* during the 14 days is presented in figure 2. As it can be seen, the methane concentration values are very close for both types of substrate. For substrate type 1 the highest concentration of methane, 58.93% (v/v), was recorded in day 13, and for the substrate type 2 the value was 56.8 % (v/v) in day 14.

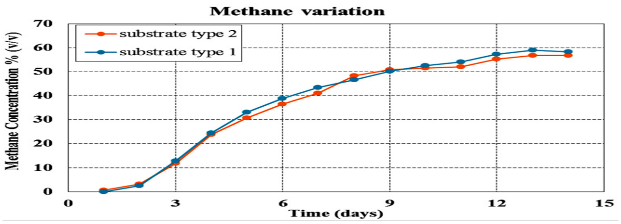

Figure 2. Variation of methane concentration % (v/v) during 14 days of experiment

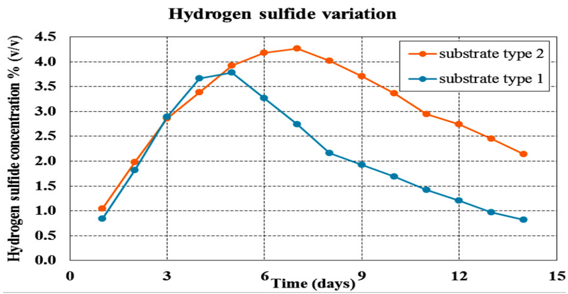

Figure 3. Variation of hydrogen sulfide concentration % (v/v) during 14 days of experiment

In the case of H_2S, it can be observed from figure 3 that for the substrate type 2 this component had a concentration value of 2.14% and in the case of type 1 the concentration was 0.82%.

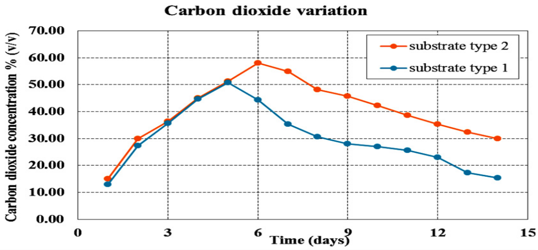

Figure 4. Concentration of carbon dioxide for all types of substrate

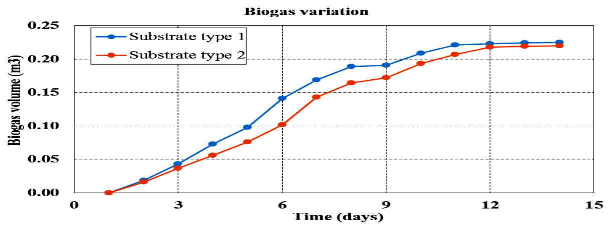

Figure 5. Biogas volume obtained for each day of experiments

The carbon dioxide concentration was higher for substrate type 2 (swine manure mixed with *Miscanthus*), when the recorded value was 30%. For the both types of used substrate it can be seen a delayed start of biogas production, a phenomena that happens due to the lag phase of bacterial growth, required for adaptation of cells to the new culture conditions. In the case of biogas production it can be mentioned that for the substrate type 1 it was recorded a value with 2.3% higher than in the case of substrate type 2. The mixture containing cow manure and *Miscanthus* produced a biogas volume of 0.225 m^3/batch while in the fermentation of swine manure mixed with *Miscanthus* the biogas volume is 0.220 m^3/batch (fig. 5). The obtained results are in accordance with the ones from the literature. *El-MashadH.M. and ZhangR.*[4] tested the efficiency of co-digestion for a substrate consisting of cow manure and food waste, compared to separate digestion of the two substrates. Biogas production obtained from food waste was of 657 L/kgVS after 30 days of digestion, while from fine, coarse and non-sieved fraction of cow manure were obtained 436, 404, respectively 366 L/kgVS. In terms of co-digestion of the two substrates, two mixtures were formed with the following composition: 32% food waste and 68% cow manure, the first mixture, respectively 48% food waste and 52% cow manure for the second mixture. After a period of 30 days of digestion, biogas production was of 455 L/kgVS for a mixture composed of 32% food waste and 68% cow manure and 531 L/kgVS for the second consisting of 48% food waste and 52% cow manure. It was found that cow manure in co-digestion with food waste favors the increase of biogas production. *Zhang T. et al.*[16] investigated the production of biogas from goat manure and several types of crop residues (wheat straws, corn stalks and rice straws) in different proportions of mixture. The results showed that the process of anaerobic co-digestion of goat manure with corn stalks or rice straws were effective, improving significantly the production of biogas. Thus, feedstock used in the following proportions, goat manure/ corn stalks(30:70), (70:30) andgoat manure/rice straw (30:70) and (50:50) produced, after 55 days of digestion, 14840, 16023, 15608, respectively 15698 mL of biogas. Also, Liew N. et al.[9] reported a total methane production of 81.2 L kg-1 VS during anaerobic digestion of maize, followed by wheat straw (66.9 L kg-1 VS), yard waste (40.8 L kg-1 VS) and leaves (55.4 L kg-1 VS).

4. Conclusions

The composition of fermentation substrate and the solid - liquid mixing homogenization is very important in order to obtain an increased quantity of biogas. In our paper, using a steel bioreactor of 60 l, the determined values are not conclusive concerning the differences between the two types of used substrates during tests and the production of biogas in each case. Although the bovine manure mixed with *Miscanthus* biomass had a higher biogas volume production, the differences are not significant. The anaerobic fermentation of bovine manure and *Miscanthus* substrate (type 1) produced a biogas volume of 0.225 m^3 while the fermentation of type 2 substrate containing swine manure mixed with *Miscanthus* produced a biogas volume of 0.220 m^3. Though, the obtained data are in accordance with the literature and the biogas production can be improved by mixing the animal manure in different proportions. Our experimental results can be used as a starting point for new experimental research regarding the possibility to mix different types of animal manure with *Miscanthus* biomass and the study of the needed power for biomass homogenization in anaerobic fermentor.

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References

1. AHRING B.K. Perspectives for anaerobic digestion. *Advances in Biochemical engineering/ Biotechnology* 81:1-30, (2003).
2. ABATZOGLOU N., BOIVIN S. A review of biogas purification processes. *Biofules, Bioprod. Bioref.* 3:42-47, (2009)..
3. CARLSSON M., LAGERKVIST A., MORGAN-SAGASTUME F. The effects of substrate pre-treatment on anaerobic digestion systems: A review. *Waste Management* 32:1634-1650, (2012).
4. EL - MASHAD H.M., ZHANG R. Biogas production from co-digestion of dairy manure and food waste. *Bioresouce Technology*, 101:4021-4028, (2010).
5. HENDRIKS A.T.W.M., ZEEMAN G. Pretreatments to enhance the digestibility of lignocellulosic biomass. *Bioresour. Technol.* 100 (1):10-18, (2009).
6. IZUMI K., OKISHIO Y.K., NAGAO N., NIWA C., YAMAMOTO S., TODA T. Effects of particle size on anaerobic digestion of food waste. *Int. Biodeterior. Biodegrad*. 64(7): 601-608, (2010).
7. KHULLAR E., DIEN B.S., RAUSCH K.D., TUMBLESON M.E., SINGH V. Effect of particle size on enzymatic hydrolysis of pretreated Miscanthus. *Ind. Crops Prod.* 44: 11-17, (2013).
8. KAZIMIEROWICZJ., DZIENISL. Giant Miscanthus as a substrate for biogas production. *Journal of Ecological Engeneering*, 16(4):139-142, (2015).
9. LIEW L.N., SHI J., LI Y. Methane production from solid-state anaerobic digestion of lignocellulosic biomass. *Biomass and Bioenergy*, 46:125-132, (2012).
10. SORENSENA., TELLER P.J., HILSTROM T., AHRING B. K.. Hydrolysis of Miscanthus for bioethanol production using dilute acid presoaking combined with wet explosion pre-treatment and enzymatic treatment. *Biores. Technol.* 99:6602-6607, (2008).
11. SIDDHARTH J., SHIVANI J., INGO T.W., JONATHAN L., YEN W.T. A comprehensive review on operating parameters and different pretreatment methodologies for anaerobic digestion of municipal solid waste. *Renewable and Sustainable Energy Reviews* 52:142-154, (2015).
12. SURENDRA K., TAKARA D., HASHIMOTO A., KHANAL S. Biogas as a sustainable energy source for developing countries: opportunities and challenges. *Renew. Sustain. Energy Rev.* 31:846-859, (2014).
13. VINTILĂT., NIKOLICV. The integration of anaerobic fermentation and methane capture in the manure management into a dairy farm, *Institutul de Biotehnologii Aplicate*, IBA Timişoara, (2009).
14. ZAWADZKA A., IMBIEROWICZ M.I WSPÓŁAUT. Inwestowanie w energetykę odnawialną. PAN, Oddział w Łodzi, Komisja Ochrony Środowiska, Łódź, 169-184, (2010).
15. ZHANG Y., BANKS C.J. Impact of different particle size distributions on anaerobic digestion of the organic fraction of municipal solid waste. *Waste Manag.* 33(2):297-307, (2013).
16. ZHANGT., LIUL., SONGZ., RENG., FENGY., HANX., YANGG. Biogas production by co-digestion of goat manure with three crop residues. *PLoS ONE* 8(6):66845-66852, (2013).