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[1.]Laura TOMA, [1.]Gheorghe VOICU, [1.]Gigel PARASCHIV, [2.]Valentin VLĂDUŢ, [1.]Mirela DINCĂ, [2.]Iulian VOICEA, [1.]Nicoleta UNGUREANU, [1.]Georgian MOICEANU

THE INFLUENCE OF THE TEMPERATURE ON BIOGAS PRODUCTION IN A SMALL CAPACITY PLANT

[1.]University Politehnica of Bucharest, ROMANIA
[2.]INMA Bucharest, ROMANIA

Abstract: Biological fermentation represents one of the waste recycling technologies that can with stands a higher degree of waste capitalisation. It can be applied on wastes with a high organic content and it is possible to obtain a gaseous fuel (biogas) with different uses: heating, cooking, electricity generation, the leftover residues that represents a non-polluting material can be used with great results in agriculture as fertilizer.A number of factors including the type and composition of the substrate, temperature, pH, moisture content and the structure of the bioreactor influence the yield of biogas. Temperature has a major influence in biogas production obtain by anaerobic digestion. The temperature effect on biogas quantity obtain in a small capacity plant was studied in this paper. Experiments were done at a temperature of 25°C, 35°C, respectively 45°C.
Keywords: temperature, anaerobic digestion, biogas

INTRODUCTION

Biological fermentation represents one of the waste recycling technologies that can withstands a higher degree of waste capitalisation. It can be applied on wastes with a high organic content and it is possible to obtain a gaseous fuel (biogas) with different uses: heating, cooking, electricity generation, the leftover residues that represent a non-polluting material can be used with great results in agriculture as fertilizer.

Biogas represents a gaseous mixture composed of methane (max. 80%), carbon dioxide (min. 20%) along with small quantities of hydrogen (H_2), hydrogen sulfide (H_2S), mercaptans and water vapors [5].

Microorganisms that can live only in environments lacking of oxygen are responsible for anaerobic fermentation. The four stages of organic wastes decomposition are hydrolysis, acidogenesis, acetogenesis and methanogenesis [1, 3].

The organic decomposable matter, in natural systems in which it can be found, is the bearer of a varied and active microflora. This mixed microflora ensures specific metabolic compounds for metanobacteria development.

A number of factors including the type and composition of the substrate, temperature, pH, moisture content and the structure of the bioreactor influence the yield of biogas. Some studies have shown that the substrate concentration at the outlet of the fermenter depends on the substrate concentration entering the bioreactor [10].

In the literature, a series of experiments were conducted on the effect of temperature on anaerobic fermentation process.Although, the process is well known in mesophilic and thermophilic domains, the current state of knowledge on biomethanisation process development in psychrophilic domain is not so developed. In nature, it was observed that methane can be obtained at temperatures between 0 and 97°C. There are sufficient experimental evidences that methane can be produced at temperatures below 20°C due to the existence of psychrophilic methanogenic bacteria in the medium [4].

Anaerobic bacteria, especially metanogenic, are sensitive to medium conditions. Many researchers evaluate the performance of an anaerobic system based on biogas production because mehanogenesys represents a limit in anaerobic treatment. Methanogenic organisms are very vulnerable and have a very low rate of growth therefore requires careful maintenance and monitoring of environmental conditions. A change in temperature or substrate concentration can lead to stopping the production of biogas [7].

Many researchers have observed that temperature has a significant influence on bacterial community, kinetic processes but also on the yield of methane. In the process of anaerobic digestion, low temperatures reduce the microbial culture, slow the rate of decomposition of the substrate and reduce production of biogas.On the other hand, higher temperatures result in reduced yield of biogas due to the volatile gas produced by the volatile acids such as ammonia that suppresses the activity of methanogenic bacteria.

In general, the process of anaerobic digestion, carried out in order to obtain biogas, takes place at mesophilic temperatures. Process development in the mesophilic domain is more stable and require less energy consumption.Experiments have shown that the optimum temperature for anaerobic fermentation process is 35ºC, with a retention time in the fermenter of 18 days.In addition, a temperature in the range 35 - 37°C is considered optimal for the production of methane, and the changeover from the mesophilic to thermophilic temperature may cause a decrease in biogas production.

However, the thermophilic temperature presents a number of advantages, such as faster speed decomposition of the organic fraction, a higher production of biogas and the destruction of pathogens present in the substrate [5].

Anaerobic digestion of the substrate in order to obtain the biogas can be inhibited when changes in temperature exceed 1°C/day. To maintain a stable process, studies shown that changes in temperature should be less than 0.6°C/day [2].

MATERIAL AND METHOD

Experimental research presented in this paper aimed to analyze the influence of substrate temperature on biogas production and have been conducted on a small capacity pilot plant (Fig. 1) belongs to the Department of Biotechnical Systems, Faculty of Biotechnical Systems Engineering from the University „Politehnica" of Bucharest [8].

The system has four main parts, namely:
≡ Food compartment consists of biomass preparation system and a pump that transfers the material in the reactor;
≡ anaerobic digester;
≡ gas pipelinewith relative treatment systems;
≡ a tank where the gas is stored prior to use.

In the stirring tank, the fermented material with water and a number of feed substances is inserted (Table 1).

Each batch introduced into the tank is mixed with the water and feeding substances for 1 hour.

Table 1. Quantities of substances necessary for fermentation [8]

No.	Substance	Symbol	Quantity, g/100 L
1.	Glucose	$C_6H_{12}O_6$	6000
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	$MgCl_2{\cdot}6H_2O$	20
7.	Aluminum chloride	$AlCl_3{\cdot}6H_2O$	2.2
8.	Calcium chloride	$CaCl_2{\cdot}2H_2O$	2
9.	Magnesium sulphate	$MgSO_4{\cdot}H_2O$	0.5
10.	Zinc chloride	$ZnCl_2$	0.04
11.	Ammonium molybdate	$(NH_4)_6MoO_{24}{\cdot}4H_2O$	0.2

The material is separated into a liquid phase and a solid phase. Partially fermented liquid fraction is pumped from the stirring tank to the fermentation reactor with a piston pump which is operated from the console.

Fermentation reactor is hermetically sealed to preserve substrate anaerobic conditions throughout the fermentation process. Inside the fermenter takes place temperature and pH control of the liquid sample. The liquid must have a pH around 7 (neutral), and if necessary is adjusted using acid or base solution contained in the two containers. It should be noted that during the process, the pH tends to became acidic and, hence, needs to be monitored.

Fig. 1 - Small capacity plant for biogas production [8]

The sample subjected to fermentation is heated by a heating element. Fermented mass is taken by means of a pump from the bottom or the top of the reactor, where it is further heated by resistance.

Biogas production process begins after about a day. Before arriving in the storage tank, the gas passes through a series of treatment systems, namely activated carbon filter, drier filter and carbon dioxide separator. The amount of biogas can be read directly from the gas meter or from the console.

Finally, the biogas is stored in the storage reservoir that consists of four stacked rubber rooms with 120 liter capacity, suitable for biogas storage at atmospheric pressure.

Before connecting the storage tank to the corresponding valve, it is recommended to remove the air contained in the tank. When the ball was emptied, biogas flow sand fills it completely maintaining atmospheric pressure.

For the study was used the same substrate composed of the manure and feeding substances with a C/N ratio of 20.4 (Table 2), the pH waskept constant, and there tention time was one week (from the moment the imposed working parameters are reached) for the three experiments [8].

Table 2. Composition and parameters of substrate[9]

Substrate	Quantity, kg	C/N Ratio	Drymatter, %	Umidity, %
Pigmanure	2	13	13.5	86.5
Cattlemanure	3	25	14	86
Water	150	-	-	-

Organic materials used as a substrate was weighed and placed in the mixing and homogenization tank. Then, the tank was filled with an amount of 150 L of water for fluidization of the substrate because the homogenisation of the substrate in the fermenter is done by recirculation. The substrate was kept under these conditions for two days during which the substrate partially disintegrates in water and begin the bacteria development needed in process of fermentation.

After two days, feeding substances were added in the resulting liquid, in the specified amounts by the plant manufacturer. All of these were mixed using the mixer inside the tank for one hour.

The feeding pump was powered from the control panel in order to transfer the liquid substrate in the fermenter. After filling the digester, the temperature and pH were kept constant automatically throughout the fermentation process. The liquid substrate was re-circulated to reach the required temperature and pH.

The data acquisition system was started to record the biogas flow, temperature and pH changes that occur during fermentation after the liquid meets the required conditions.

RESULTS

The values recorded during the experiments are shown in Table 3 and in Figures 2, 3 and 4 is represented the change in the production of biogas for the temperatures of 25°C, 35°C and 45°C.

Table 3. The biogasquantities for the studied temperatures [8]

Time, h	Biogas production, m^3/h for 25°C	for 35°C	for 45°C
4	0	0	0
8	0	0	0.0017
12	0	0.001	0.0025
16	0	0.0013	0.0036
20	0.001	0.002	0.0051
24	0.001	0.0026	0.0072
28	0.0013	0.0034	0.0089
32	0.0016	0.005	0.012
36	0.0016	0.0071	0.017
40	0.0025	0.0084	0.016
44	0.0031	0.014	0.019
48	0.0042	0.012	0.021
52	0.005	0.015	0.018
56	0.0046	0.018	0.019
60	0.0051	0.02	0.022
64	0.006	0.022	0.024
68	0.007	0.021	0.022
72	0.009	0.024	0.024
76	0.011	0.027	0.023
80	0.013	0.027	0.021
84	0.012	0.029	0.022
Time, h	Biogas production, m^3/h for 25°C	for 35°C	for 45°C
88	0.015	0.03	0.024
92	0.014	0.031	0.02
96	0.015	0.03	0.019
100	0.015	0.029	0.021
104	0.014	0.032	0.018
108	0.014	0.031	0.017
112	0.013	0.029	0.018
116	0.0125	0.027	0.0185
120	0.013	0.028	0.017
124	0.0125	0.026	0.015
128	0.011	0.027	0.0155
132	0.011	0.025	0.014
136	0.01	0.022	0.0145
140	0.011	0.024	0.0132
144	0.01	0.021	0.0139
148	0.009	0.02	0.0128
152	0.0084	0.022	0.012
156	0.0076	0.019	0.0125
160	0.007	0.016	0.012
164	0.0069	0.016	0.0115
168	0.006	0.015	0.011

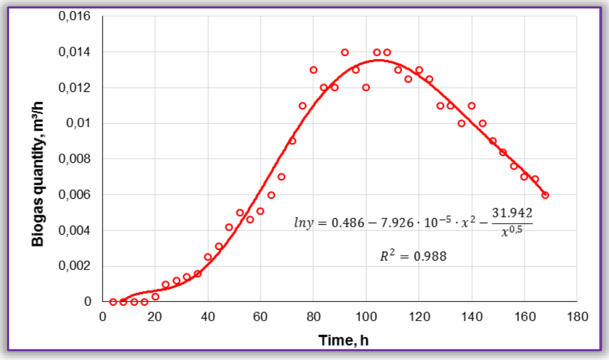

Fig. 2 –Variation of biogas production at 25°C

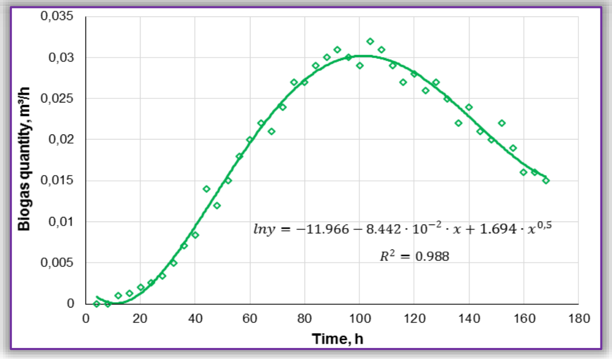

Fig. 3 - Variation of biogas production at 35°C

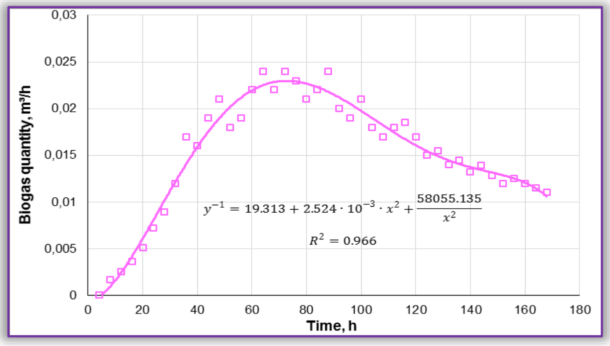

Fig. 4 - Variation of biogas production at 45°C

Experimental data, obtained from the fermentation of a mixture of pig and cattle manure at different temperatures, in the pilot plant RE-biomass with continuous hydraulic stirred cylindrical digester, respectively 25°C, 35°C and 45°C, shows an increasing variation up to a certain moment in the process of fermentation, respectively a decreasing variation in the second part of the test that lasted for approximately 170 hours.

The maximum curve of the biogas production process are recorded after about 110 hours with a value of approximately 0.013 m^3/h for the temperature of 25°C; at the end of the test period, the production of biogas records a value of 0.0065 m^3/h.

For a temperature of 45°C, the maximum of the biogas production curve is recorded after about 75 hours of fermentation, with a value of about 0.023 m^3/h, at theend of the test range, the value is about 0.011 m^3/h, which shows that the fermentation process is not over, as in the first case.

The highest biogas production was recorded for the temperature of 35°C after about 100 hours of operation with a maximum value of 0.03 m^3/h, but at theend of the test range, the amount of biogas production is at 0.015 m^3/h and again the fermentation process is incomplete, being possible the continue.

The variation laws of the biogas production have been identified after the mathematical regression analysis of the data using TableCurve 2D software.

The variation laws of biogas production, for the tests done to determine the effect of temperature on the biogas production that shows the best correlation with the experimental data, are exponential or hyperbolic having a correlation coefficient R^2 of over 0.966.

CONCLUSIONS

Anaerobic digestion is affected by many factors and the results obtained in this work have shown that the temperature is among the most important. In experiments was used the same substrate, the pH waskept constant and the analyzed temperatures were of 25, 35 and 45°C.

The maximum amount of biogas was obtained at 35°C with a total value of 0.7798 m^3. Total biogas production values, for the other two temperatures, were 0.3249 m^3, for the temperature of 25°C, respectively, 0.6394 m^3, for the temperature of 45°C.

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