

Effect of Mephosphonee on methane generation in organic waste processing

*I Kh Gayfullin**, *B G Ziganshin*, *I N Safiullin*, *B L Ivanov*, and *R K Khusainov*

Kazan State Agrarian University, 65, Karl Marx St., Kazan, Republic of Tatarstan, 420015, Russian Federation

Abstract. The purpose of the study is to determine an effective technological method for the complete anaerobic processing of agricultural waste. It also aims to create and implement an effective technological method of sufficiently complete anaerobic processing of agricultural waste, including taking into account biologically active additives. A new technology for the disposal of organic agricultural waste and the influence of Mephosphone on the process of methane formation using a biogas unit at a processing facility developed at Kazan State Agrarian University is considered. The results of theoretical and experimental studies are presented, which made it possible to significantly reduce the utilization time, and reduce the cost of electricity and fuel. The experiments were carried out in a low-capacity biogas unit (LCBU) without air access in a heat-insulated reactor filled by 2/3. The results of numerical studies of the products of conversion of cattle manure are presented. Manure was kept in the reactor for 7 days. The use of Mephosphone in ultra-low concentrations (10⁻⁴) made it possible to obtain a useful product in the form of high-quality organic biofertilizer and biogas. The results of microbiological analysis of experiments in the test center of the Tatar Interregional Veterinary Laboratory are shown.

1 Introduction

Modern agriculture causes major damage to the environment similar to industrial enterprises. Animals consume up to 45% of the world grain harvest, emit 16% of methane generated in nature into the atmosphere, which affects the global warming more than carbon dioxide. The introduction of organic waste processing facilities will reduce methane emissions into the atmosphere. Non-controlled methane affects the greenhouse effect up to 20 times more strongly than carbon dioxide and is present in the atmosphere during 12 years. The use of new technologies for the collection of methane emitted into the atmosphere will make it possible to prevent the global warming [1].

The human impact on the ecosystem increases daily. People cultivate lands and create agricultural land. Annually, there are new species and varieties of plants in crop production and animal breeds in animal husbandry. This is a conscious human activity. Human activity makes rivers shallow, affects the development of soil erosion, extinction of plant and animal species, pollution of air, groundwater, destruction of useful insects (bees) etc. [2, 3].

The environment is polluted, especially with the development of technological progress. At the same time, poisonous substances cause great damage to nature when they enter water, soil, and air. Along with the above sources, debris, animal manure and the exhaust gases of improperly operating vehicles serve a significant source of natural pollution.

Every day there is a shortage of fossil organic fuels, the cost of their extraction and transportation increases

significantly. The search for alternative, renewable energy sources and the creation of new energy-saving technologies is quite relevant [4]. One of the most important areas for renewable energy sources is the use of organic waste. Special attention is paid to the development of technologies for the production of biogas during the processing of organic waste. During the processing of all generated organic waste from fifty cattle heads it is possible to obtain more than 120 m³ of biogas, respectively 3.2 tons of biofertilizers per day [5].

Biogas is a valuable source of energy, which is especially promising in small peasant farms.

The limited reserves of fossil carbohydrate raw materials forced many European countries to intensify research in the field of alternative technologies. Currently, there are more than 500 energy complexes in Russia, including 5 large ones. One of them (Fig. 1) is located in the Republic of Tatarstan in the Aznakaevsky district, Aktyuba settlement [6].

The biogas unit is located on the basis of a livestock complex and processes cattle manure and other waste (grain waste, substandard corn silage, etc.). The generated electricity serves the own needs of the nearby farm and other facilities of the unit owner. With the current installed capacity of 0.5 MW, the unit has the prospect of expansion to 1.5 MW (provided the electric energy is supplied to the network).

* Corresponding author: ilnur-gai@yandex.ru



Fig. 1. Aktyuba biogas unit.

2 Materials and Methods

In terms of their design all biogas units are quite similar. The main element of the unit is a sealed container – a methane tank. Depending on the geometric parameters, the methane is made of glass, metal, plastic, concrete or a combination of both. The ratio of the height of the methane tank must be equal to its diameter. Methane tanks produced in Europe are usually more elongated than those made in the United States. Their filling capacity is 2/3.

The biogas unit (Fig. 2) developed at Kazan SAU consists of a reactor with a double housing, which acts as a cooling box. Hot steam or air can be supplied to the cooling box, and the necessary temperature regime of the substrate is heated and maintained in the reactor using a heating element. The reactor size ratio is rational ensuring the maximum production of biogas. The advantage of the plant is that it operates in various modes, including mesophilic and thermophilic, moreover, its operation is fully automated, thereby ensuring continuous control of biogas and fertilizer production. The biogas unit has a mechanism for substrate mixing. The mixing mechanism is simple. Mixing contributes to the activation of methane-forming bacteria, which facilitate the production of biogas. The novelty of the technical solution is protected by the patents of the Russian Federation for utility model No. 150764, No. 208815 [7, 8].

The loading of processed substrate and unloading of obtained biofertilizers from a methane tank is carried out by a pump through a branch pipe.

A certain temperature must be maintained in a methane tank to accelerate the formation and production of high-quality organic fertilizers. The basis of anaerobic fermentation of organic waste is the energy balance of technological losses and the preservation of heat in the methane tank during anaerobic fermentation [9]. There are three temperature regimes for biogas units, such as psychrophilic, mesophilic and thermophilic. In a psychrophilic temperature regime a temperature in the range of 15 to 20°C is considered rational. It is recommended to use the psychrophilic regime in summer. Since, for example, in the Republic of Tatarstan, the average annual temperature is about 3 °C, the impossibility of using this regime is obvious year-round. The mesophilic regime operates within the

temperature range from 20–35 °C, and the thermophilic regime from 35–55 °C [10, 11].

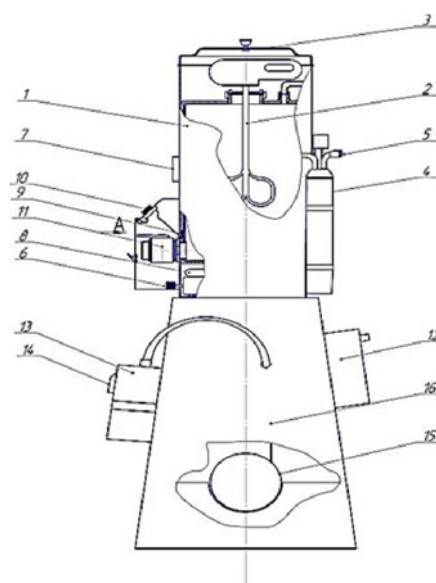


Fig. 2. Biogas unit scheme: 1 – methane tank; 2 – mixing device; 3 – methane tank cover; 4 – small gasholder; 5 – pressure gauge; 6 – filter bowl; 7 – thermometer; 8 – heating element; 9 – thermocouple; 10 – temperature controller; 11 – drainage tap of biofertilizers; 12 – settler; 13 – biogas counter, 14 – panel, 15 – low-speed compressor, 16 – housing support.

Besides, the production of biogas depends on many other factors. The amount of biogas produced from organic waste depends on the quality of the substrate and the bacterial composition. The smaller the particle sizes of the organic components of the initial substrate, the larger their specific surface area and, accordingly, the fermentation processes occur more intensively [12]. Various additives, including chemical preparations, organic additives change the composition of the starting substrate, and may function as a catalyst or moderator. There are more than a thousand strains of bacteria involved in the process of producing biogas alone. Chemical composition and physical conditions of the initial substrate also play an important role [13, 14, 15].

Table 1 shows the chemical composition of organic waste.

Table 1. Chemical composition of organic waste, %.

Composition	Cattle manure	Poultry manure	Horse manure
Carbon (C)	61	83	77
Oxygen (O)	12	9	31
Sulfur (S)	1	0.9	0.07
Hydrogen (H)	8	0.1	9
Nitrogen (N)	81	7	0.75

We studied the effect of Mephosphone on the degradation of cattle manure. The structural formula of the drug used is shown in Figure 3 [16].

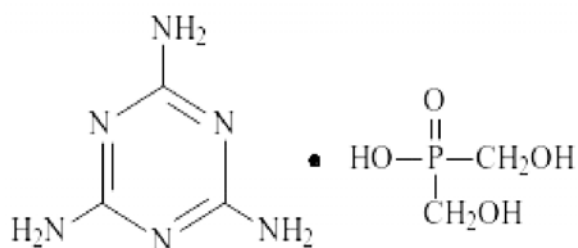
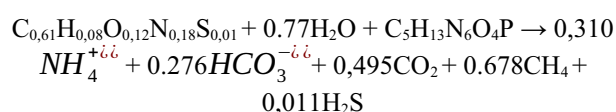


Fig. 3. Mephosphone structural formula.

When Mephosphone is added to the substrate, it decomposes into water and non-toxic nitrogen and phosphorus compounds.

To describe it in the form of a chemical reaction, it is written as follows:



Analyzing the resulting chemical reaction, we can say that 0.495 g of CO₂ and 0.678 g of CH₄ will be released from 1 g of ashless substance.

To determine the reliability of theoretical results, field experiments were carried out at the designed biogas unit. The biogas unit is shown in Figure 4.



Fig. 4. Biogas unit.

The loaded processing substrate was mixed periodically throughout the cycle. At the beginning, biogas accumulates in the methane tank and while passing through the hydraulic lock, it enters the small gasholder. From a small gas, at a certain pressure, gas is pumped through filters to a gas cylinder.

3 Results and Discussion

The influence of Mephosphone on biogas production was determined in accordance with the Technological

Regulations developed by scientists of Kazan SAU [17]. Temperature and mixing frequency were monitored during the experiments [18]. The result of the experiments is shown in Figure 5.

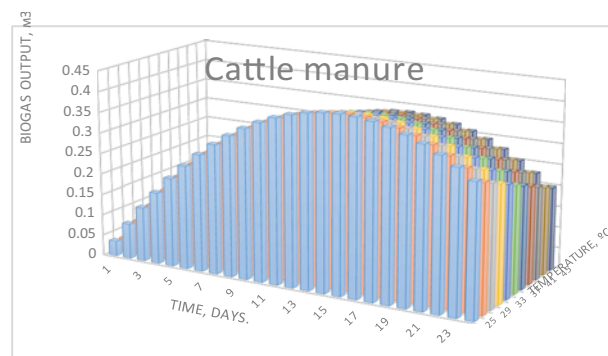


Fig. 5. Results of biogas production from cattle manure.

The diagram shows that while providing rational conditions for methane-forming bacteria, it is possible to obtain a higher output of biogas and organic fertilizers, which is very significant for a country without its own energy resources.

Various indicators were determined [19, 20] such as microbiological, agrochemical, quality, sanitary and parasitological indicators of fertilizers obtained in the test center of the Tatar Interregional Veterinary Laboratory. The results are presented in Table 2.

The composition of the manure substrate with the addition of Mephosphone.

Table 2. Results of the experiments with microbiological indicators.

Microbiological indicators			
Indicator	Measuring unit	Test result	Norm
Coliform bacteria		1	1–9
Enterococci		1	1–9
Clostridium	g	N/D	Not allowed
Pathogenic microorganisms	g	N/D	Not allowed
Agrochemical indicators			
Indicator	Measuring unit	Test result	Norm
Salt extract pH	pH	6	6–8.5
Mass fraction of organic matter	%	79	At least 70
Quality indicators			
Indicator	Measuring unit	Test result	Norm
Mass fraction of total nitrogen	%	0.5	At least 0.1
Mass fraction of potassium	%	0.51	At least 0.05
Mass fraction of total phosphorus	%	2.1	At least 0.05
Sanitary-parasitological indicators			
Indicator	Measuring unit	Test result	Norm
Cysts of enteric pathogenic protozoa microorganisms	Exs/100 g	N/D	Not allowed
Helminth eggs and larvae	pcs/kg	N/D	Not allowed
Sanitary-epidemiological indicators			
Indicator	Measuring unit	Test result	Norm

Larvae L and case K of flies		N/D	Not allowed
---------------------------------	--	-----	-------------

The microbiological analysis of the experiments showed that in the experiment with Mephosphone the content of enterococci and bacteria of the E. coli group was lower than in the experiment without Mephosphone.

In the methane tank, organic waste is processed using bacteria. Mephosphone makes it possible to increase the biomass concentration of these bacteria, as well as their vital products. The biofertilizer obtained in the biogas unit acquires new properties. The final nitrogen content of the Mephosphone treated substrate is higher than that of the untreated substrate. Acidity in untreated substrate is pH 6.7 and in a treated substrate – 7.5.

The studies showed that when Mephosphone is added to the substrate, the release of biogas begins on day 1-2 and lasts up to 7 days. In this case, the output of biogas increases to 25% compared to the use of a control substrate without the use of Mephosphone.

4 Conclusion

The above makes it possible to conclude that our country has a significant supply of renewable energy resources, with the use of which it is possible to fully satisfy the energy needs of the republic. The correct approach and rational use of existing energy resources together with the development and introduction of new technologies will allow our republic to avoid energy, environmental and economic crises. The widespread introduction of renewable energy plants will allow abandoning imported fuel and switching to fuel and energy self-sufficiency.

The disposal of organic agricultural waste using Mephosphone significantly reduced the utilization time and cost of maintaining the methane generation process.

References

- I. Kh. Gayfullin, Z. M. Khaliullina, B. G. Ziganshin, Effect of Mephosphone on the efficiency of obtaining biogas and recycling carbon-containing waste, *Bulletin of Kazan State Agrarian University* **16-3 (63)**, 19–26 doi: 10.12737/2073-0462-2021-19-26 (2021)
- I. Kh. Gayfullin, B. G. Ziganshin, A. I. Rudakov, Problems of utilization and processing of organic agricultural waste, *Agricultural machinery 2018: VI international scientific congress* (Bulgaria, Burgas, June 25–28) pp 201–202 (Burgas: Scientific-Technical Union of Mechanical Engineering INDUSTRY 4.0, 2018)
- I. Maksimov, N. Adigamov, A. Mustafin, D. Khaliullin, I. Gayaziev, A. Matyashin, R. Lukmanov, Theoretical fundamentals for determining soil erosion potential (energy concept): Part 1, *Quimica Periodical* **16 (31)**, 540–557 (2019)
- L. Xue, P. Zhang, H. Shu, C. Chang, R. Wang, S. Zhang, Agricultural waste *Water Environment Research* **8-8 (10)**, 1334–1373 (2016)
- B. G. Ziganshin, Yu. Kh. Shogenov, I. Kh. Gayfullin, I. I. Kashapov, *Modern Energy-Saving Solutions in Agriculture* (Kazan: Kazan State Agrarian University, 2018)
- S. M. Naiman, Yu. A. Tunakova, Possibility of using biogas technologies for processing organic waste in Tatarstan. Production of biogas and energy, *Bulletin of Kazan Technological University* **16 (19)**, 227–234 (2013)
- F. S. Sibagatullin, Z. M. Khaliullina, R. R. Minnikhanov, Results of practical use of fertilizers from chicken manure in winter wheat cultivation, *BIO Web of Conferences* **37**, 00048 (2021)
- F. F. Sitdikov, B. G. Ziganshin, R. R. Shaidullin, A. B. Moskvicheva, Use of modern technologies in dairy farming, *Bulletin of Kazan State Agrarian University* **15-1 (57)**, 81–87 doi: 10.12737/2073-0462-2020-81-87 (2020)
- V. Petric, Selimbasic, Composting of poultry manure and wheat strew in closed reactor: optimum mixture ratio and evplotion of parameters, *Biodegradation* **11**, 53–63 (2006)
- Q. Zhang, J. Hu, D. J. Lee, Biogas from anaerobic digestion processes: research updates, *Renewable Energy* **98**, 108–119 (2016)
- S. Sakar, K. Yetilmezsoy, E. Kocak, Anaerobic digestion technology in poultry and livestock waste treatment - a literature review, *Waste Management & Research* **27 (1)**, 3–18 (2009)
- D. Y. Suslov, P. S. Sedyh, Experimental studies of the process of obtaining biogas from wastes from agricultural enterprises, in *International Science and Technology Conference "EastConf"*, 8725328 (2019)
- D. E. Belostotskiy, V. A. Miluykov, E. E. Ziganshina, A. M. Ziganshin, M. Siniagina, E. A. Boulygina, Impact of the substrate loading regime and phosphoric acid supplementation on performance of biogas reactors and microbial community dynamics during anaerobic digestion of chicken wastes, *Bioresource Technology* **193**, 42–52 (2015).
- F. S. Sibagatullin, Z. M. Khaliullina, A. M. Petrov, K. O. Sinyashin, The prospects of using various commercial formulations to accelerate the process of "maturation" of chicken manure, *Bulletin of Kazan State Agrarian University* **14-1 (52)**, 53–57 (2019)
- R. Sabirov, A. Valiev, L. Karimova, A. Dmitriev, D. Khaliullin, Influence of physical factors on viability of microorganisms for plant protection, *Engineering for Rural Development* **18** doi: 10.22616/ERDev2019.18.N211 (2019)
- F. S. Sibagatullin, Z. M. Khaliullina, A. R. Safiullina, Fermentation processes studying of chicken manure under the influence of a biologically active supplement "Mephosphone", *Bulletin of Kazan State Agrarian University* **2 (49)**, 42–47 (2018)

17. State Duma Deputy of the Russian Federation, *Process regulations "Reducing the hazard class (neutralization) of animal waste with the use of a biologically-active preparation – Mephosphone"* (Kazan, 2017).
18. A. Sun, W. Cao, C. J. Banks, S. Heaven, R. Liu, Biogas production from undiluted chicken manure and maize silage: a study of ammonia inhibition in high solids anaerobic digestion, *Bioresour. Technol.* **218**, 1215–1223 (2016)
19. C. A. Pierce, R. J. Smernik, T. M. Mc Beath, Phosphorous availability in chicken manure lower with increased stockpiling period, despite a larger orthophosphate content, *Plant and Soil* **373** (1–2), 359–372 (2013)
20. E. E. Ziganshina, E. M. Ibragimov, P. Y. Vankov, A. M. Ziganshin, V. A. Miluykov, Comparison of anaerobic digestion strategies of nitrogen-rich substrates: performance of anaerobic reactors and microbial community diversity, *Waste Management* **59**, 160–171 (2017)