Analysis of the implementation of biogas plants: pluses and minuses of the thermophilic digestion

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Abstract. Analysis of world practices in the implementation of biogas plants is presented for the growth energy efficiency in Russia. The object of study is biogas technologies used for the disposal of animal waste products. The subject of the study is a biogas plant for processing animal waste products, implemented in Russia. The purpose of the study is to develop a technological scheme for producing biogas for farms. The advantages of the thermophilic mode of fermentation include: an increased rate of decomposition of raw materials and, therefore, a higher biogas yield, as well as the almost complete destruction of pathogenic bacteria contained in the substrate. The disadvantages of thermophilic digestion include are the need to supply a significant amount of energy to heat the raw material in the digester and maintain its temperature, the increased sensitivity of the process to minimal temperature fluctuations and a slightly lower quality of the obtained fertilizers compared to the mesophilic regime, which maintains a higher amino acid composition of the fertilizer.

1. Introduction
It is known that the development of modern society is provided, first of all, by the energy base. The threat of an energy crisis on a global scale makes the problem of development and popularization of renewable energy sources relevant. Already today in many countries the active use of renewable energy is one of the main priorities of energy policy. Vivid examples of this are programs in the field of alternative energy production in Sweden, Germany, China, France, Denmark, India, Japan and other countries.

Currently, various schemes of biogas technologies are developed and successfully applied in the world. The main purpose of their application is the production of biogas and the disposal of biological waste.

The anaerobic process of decomposition of biological waste with the formation of biogas can be divided into 4 stages, in each of which many different groups of bacteria participate:

At the first stage (hydrolysis) of decomposition, aerobic bacteria rearrange high-molecular-weight organic substances, cellulose, protein, carbohydrates, fats, and low-molecular-weight compounds, such as sugar, amino acids, fatty acids, and water. Enzymes secreted by hydrolytic bacteria break down the organic components of the substrate into small water-soluble molecules. Polymers turn into one-
dimensional. This process has a slow course and depends on extracellular enzymes such as cellulose, amylase, protease and lipase. The process is significantly affected by the pH level (4.5-6) and the residence time in the tank.

Further, acid-forming bacteria are involved in the cleavage. This stage is called the oxidation phase (the pH level decreases). Individual molecules penetrate the cells of bacteria, where they continue to decompose. As a result of this process, anaerobic conditions necessary for methane bacteria are formed. At a pH level of 6-7.5, unstable fatty acids, low molecular weight alcohols, carbon dioxide, carbon, hydrogen sulfide and ammonia are primarily produced.

This step is very sensitive to temperature changes. Acid-forming bacteria with organic acids create the starting products for the formation of methane: acetic acid, carbon dioxide and carbon.

At the last stage, methane, carbon dioxide and water in small quantities are formed as a metabolic product of methane bacteria. 90% of all methane is produced at this stage, 70% comes from acetic acid. Based on the above, it can be argued that the formation of acetic acid in stage three is a factor determining the rate of methane formation. It should be noted that all methane bacteria are exclusively anaerobic. The optimal pH level for anaerobic bacteria is 7, while the amplitude of the oscillations can be in the range of 6.6-8.

2. Literature review
The first experience in introducing biogas plants in Sweden was their construction in municipal wastewater treatment plants in the early 60s, the main purpose of which was to reduce sludge volumes. The technology was further developed during the oil crisis of the 70s. Then, in order to reduce dependence on fossil fuels and reduce environmental problems, sugar cellulose plants began to use anaerobic digestion to treat their waste water. Also at this time, several farms using biogas stations began to dispose of manure [1].

Today, the construction and use of biogas technologies in Sweden is supported by significant government subsidies.

According to official statistics from Sweden, in 2010, there were 135 biogas plants installed in wastewater treatment plants on its territory. The number of operating biogas plants at the landfills was 57. The number of installations used in farms is not significant, and amounts to 14, but gradually their number increases [2,3].

The bulk of biogas obtained by anaerobic digestion is refined and used as fuel for vehicles. During the first half of 2010, 64% of gas sold to automobiles was biogas methane. This is the highest percentage in the world.

Germany is a leader in biogas production in Europe. This is driven by the desire to reduce carbon dioxide emissions by 40% and the rejection of nuclear energy. According to the emission reduction strategy, the national goal for biomethane production is its production by 2020 of 6 billion cubic meters of gas per year and 10 billion cubic meters by 2030. In this regard, we can assume a further expansion of biogas production in Germany[4,5].

So only about 8,792 biogas plants were put into operation by the end of 2011. The main raw materials of these stations are manure and energy crops.

Today in Germany, approximately 92 plants utilize biological waste, including municipal solid waste. About 1,700 plants operate in sewage treatment plants. The number of biogas plants installed on farms is approximately 7,000 [6].

In Denmark, biogas plants became widespread after the 1973 oil crisis. In 2009, there were about 60 biogas plants in sewage treatment plants, 60 on farms and about 20 biogas co-fermentation plants. Sludge from the anaerobic digestion process is used as fertilizer [7].

According to official statistics, annual biogas production in Denmark is 4 PJ, which is 5% of the country's total energy consumption.

In Norway, anaerobic digestion involves 23 wastewater treatment plants, 6 household waste utilization plants and 1 large biogas plant for manure processing [8].
The total potential of biogas produced is estimated at approximately 6 billion kWh per year. About 23% of biogas is produced by the utilization of manure, 23% by the utilization of industrial waste and 16% by the utilization of food waste.

The main biogas consumption in the country is for the generation of electric energy[9].

There are 76 biogas stations in Finland with a total biogas capacity of 139 million m³. Landfills and municipal wastewater treatment plants prevail in the country, as in Sweden. At the same time, there is a tendency to develop biogas plants in agriculture, now there are 10 of them.

Today, Russia does not have a wide distribution of biogas technologies. The first biogas station in modern Russian history was launched in 2009 in the village of Doshino, Kaluga Region. Biogas obtained in the process of anaerobic digestion serves as the fuel of a cogeneration plant. The station is located in close proximity to the dairy farm, which is the main source of substrate, a consumer of electric and thermal energy. Surplus electricity is sold to the grid [10].

A biogas station is launched in a similar way, launched in 2010 near the existing pig farm with a capacity of 16,000 heads in the Gruzschansky rural settlement, Borisov district, Belgorod region.

Also in 2012, a biogas plant was put into operation, designed for an electric power generation capacity of 0.5 MW and a thermal energy of 0.4 Gcal / h [11].

It should be noted that all of the above biogas stations are located in the European part of Russia. The indicated regions are characterized by a relatively mild climate in winter.

The potential biogas production in Russia by various experts is estimated to be up to 72 billion m³ per year. The potential generation of electricity from this biogas is 151,200 GWh [12].

In the Russian regions, biogas production capacities are estimated as follows: Volga Federal District - 18.33 billion m³; Southern Federal District - 24.4 billion m³; Far Eastern Federal District - 1.18 billion m³; Ural Federal District - 3.1 billion m³; Northwestern Federal District - 3.5 billion m³; Siberian Federal District - 11.1 billion m³; Central Federal District - 12.1 billion m³[13].

In India, Vietnam, Nepal and other countries, small biogas plants for one family are being built. The resulting biogas is used for household needs. Thus, in India alone, over the past twenty years, 3.8 million small biogas plants have been installed; by the end of 2009, 200,000 small biogas plants were installed [14,15].

At the end of the 1990s, China had the largest number of small biogas plants, numbering more than 10 million. Their productivity was approximately 7 billion m³ of biogas per year, and they provided fuel to about 60 million peasants. At the end of 2010, about 40 million biogas plants were already operating in China. About 60 thousand people are employed in biogas production in China [16].

Based on the analysis of the state of the biogas industry, we can conclude that the developed countries of the world are constantly increasing capacity for the construction of biogas plants [17].

3. Results and discussion

The optimal temperature regime of each type of substrate is different.

Based on empirical data on the operation of Fluid biogas plants operating in Kyrgyzstan, the optimum temperature range for the mesophilic temperature regime of fermentation is 34–37 °C, and for the thermophilic 52–54 °C. The most intensive release of biogas when using plants in the psychophilic mode occurs at a temperature of 23 °C [18].

Today, the majority of industrial industrial digesters operating in the world operate in the mesophilic mode of anaerobic digestion, at a temperature of 37-42 °C and a neutral alkalinity among pH 6.7-7.5 [4]. Due to the low temperature, the psychophilic mode of operation has a long fermentation period and the relatively low gas productivity is not widespread, while thermophilic mode plants are in increasing demand.

The advantages of the thermophilic mode of fermentation include: an increased rate of decomposition of raw materials and, therefore, a higher biogas yield, as well as the almost complete destruction of pathogenic bacteria contained in the substrate.
The disadvantages of thermophilic digestion include: the need to supply a significant amount of energy to heat the raw material in the digester and maintain its temperature, the increased sensitivity of the process to minimal temperature fluctuations and a slightly lower quality of the obtained fertilizers compared to the mesophilic regime, which maintains a higher amino acid composition of the fertilizer.

The effect of the ferments temperature on the activity of bacteria. It can be seen from it that the higher the process temperature, the more sensitive the bacteria to its vibrations, especially if they are short-term.

This can be seen from the relatively narrow maximum of the curve in thermophilic mode.

4. Conclusion
Permissible temperature fluctuations for each mode are as follows:

- at a psychrophilic temperature regime of fermentation - ± 2 C per hour;
- at a mesophilic temperature regime of fermentation - ± 1 C per hour;
- at thermophilic temperature regime of fermentation - ± 0.5 C per hour [1, 3].

Practice has shown that microorganisms are harmed, first of all, by a rapid change in temperature, and on the contrary, methanogenic microorganisms can adapt to its various levels in case of a slow temperature change. Therefore, for the stability of the technological process, the absolute temperature is not so important as the constancy of the temperature level to a much greater extent [19].

When choosing a high temperature regime, it is necessary to provide reliable insulation suitable for the climatic conditions of the station installation region, a system for automating the operation of a biogas plant and a heating system, in order to eliminate sudden temperature fluctuations. In addition, the vast majority of station designs provide for the installation of heat exchangers in order to pre-heat the substrate during its preparation for feeding into the digester.

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