

Biogas - energy efficiency in the technological aspects of the agro-industrial complex

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Annotation. The state of development of technologies and equipment for the production of biogas (biomethane) both in Russia and abroad. The main microbiological processes that take place at the same time, technical and technological solutions, the economy of biogas plants. Special attention is paid to the use of biogas plants for the utilization of grain and potato bard from distilleries and beer pellets. It is noted that in the cold climate of Russia, the use of biogas technology is possible only with the support of the state.

1 Introduction

Due to the significant volume of industrial processing of various raw materials of plant origin at the processing enterprises of the agro-industrial complex (AIC), a huge amount of valuable and suitable for further processing of secondary raw materials (waste and by-products of the main production) is formed.

Unfortunately, the concept of "all values, regardless of the type of resources (raw materials, energy, labor resources, intellectual potential), are national property" has not yet been strengthened in Russia [1].

Otherwise, how can we assess the fact that every year more than 2 billion rubles are exported to landfills, fields, ravines, and lowered into ponds and rivers by various processing enterprises? of so-called waste [2]. At the same time, the involvement of huge resources of industrial waste and by-products in the sphere of production is equivalent to expanding the raw material base of processing enterprises of the agro-industrial complex while saving labor costs. Therefore, the current level of development of the food and processing industry of the Russian Federation, as well as the state of its raw material base, require a fundamentally new approach to the problem of resource use. The essence of this approach is to develop, create and implement new progressive, energy - resource-saving technologies that allow rational use of primary raw materials, comprehensively process and safely dispose of secondary raw materials.

Every year, distilleries produce about 10 billion rubles. liters of liquid waste, which in its natural form cannot be fully realized, which leads to their discharge into the environment, as a result of which it is polluted, as well as the loss of valuable feed products [3].

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In Russia, the cost of disposing of bards increases the cost of alcohol and reduces the profitability of production. Despite the environmental threat, investments to equip distilleries with the necessary equipment can only be found if the invested funds are returned.

One of the possible ways of waste disposal is solid-phase fermentation with the production of biogas.

Biogas is a product of bacterial metabolism, formed as a result of methane fermentation of biomass. The decomposition of biomass occurs under the influence of three types of bacteria. In the food chain, subsequent bacteria feed on the waste products of the previous ones (metabiosis). The first type - hydrolytic bacteria, the second - acid - forming, the third - methane-forming. The production of biogas involves not only bacteria of the methanogen class, but all three species [4, 5].

Biogas is the result of the decomposition of waste of various origins by microorganisms – methanogens. It consists of 50-87% methane, 13-50 % CO₂, minor impurities of H₂ and H₂S. After cleaning the biogas from CO₂, biomethane is obtained. Biomethane is a complete analogue of natural gas, the difference is only in its origin [6, 7], it is suitable for burning in the boiler rooms of an enterprise or generating electricity.

In this paper, various aspects of biogas production in the context of post-alcohol waste disposal will be considered.

2 The state of biogas technology in Russia

The potential production of biogas in Russia is up to 72 billion m³ per year. The potential annual production of electricity from biogas is 151,200 GWh, and heat is 169,344 GWh [8]. The total demand of Russia for biogas plants is estimated at 20 thousand enterprises [9].

The first attempts to create biogas plants in the USSR date back to the 50-s of the last century, the second - to the late 80-s - early 90-s. But both for the first and second time, due to the large difference in the cost of natural and synthetic products (biogas was five times more expensive), the work did not go further than the prototypes, although, in fairness, it must be said that even if the price of the resulting biogas is equated with the price of natural gas, the estimated payback period of the installation was five years [10].

Currently, there are a large number of companies operating in the former USSR that supply complete equipment for producing biogas from agricultural waste: Alternative Energy Association (Ukraine, <http://biogas.in.ua>), Zorg Biogas Company (Russia, <http://zorgbiogas.ru>), Huo Long Biogas Ltd. (China, <http://huo-long-biogas.ru>), LLC "KSB" (Russia, <http://www.ksb.com>), etc. There are also projects implemented on farms in the conditions of the continental climate of Russia [11, 12].

According to the IBCentre report, in 2013-2014, investments in the Russian biogas sector may amount to about \$ 5.5 billion. The results of the study are based on the economically justified resource potential of these countries. The total potential of the market for biogas, as well as electricity and heat generation based on biogas complexes using agricultural waste, is more than \$36 billion in the Russian Federation, Ukraine and Belarus [13].

At the same time, despite the relatively low prices for farmstead and farm - type bio - installations - 20 and 120 thousand rubles, respectively, even with a six-month payback, they still do not have mass demand, which is probably constrained by two factors - the unavailability of credit, and most importantly - the lack of private ownership of land and land banks [14]. In winter, the biogas plant requires up to 70% of the secondary heat removed from the heat generator, in summer - about 10%. The cost of heat and electricity for the needs of the plant itself is from 5 to 15% of the total energy provided by the biogas plant [15].

Utilization of the distillate produced during the rectification of alcohol is a serious task for Russian distilleries due to the significant volumes: for each liter of absolute alcohol, approximately 12 liters of post-alcohol distillate (PSB) are produced [15]. Currently, the main

method of processing the bard is its drying with its further use for the preparation of mixed feeds. However, due to the significant energy consumption for drying, this actually means the construction of a second plant, which is comparable to the main production in terms of capital investment. This also adds problems with fire and explosive production, which is the drying shop, as well as the subsequent sale of dried PSB in the conditions of a deep crisis in Russian agriculture.

From this point of view, it is much preferable to process PSB into biogas: the product is used by the plant for its own needs as an efficient fuel. At the same time, the consumption of fuel purchased from the outside is sharply reduced, not only by burning biogas, but also by eliminating the costs of evaporation (in the production of dried bard) and drying (in the production of feed products); electricity consumption is also reduced [16].

3 Microbiology of methane fermentation

The decomposition process can be divided into 4 stages (Fig. 3), each of which involves many different groups of bacteria:

"1. In the first stage, aerobic bacteria rearrange high-molecular organic substances (protein, carbohydrates, fats, cellulose) with the help of enzymes into low-molecular compounds, such as sugar, amino acids, fatty acids and water (the cleavage phase). The enzymes isolated by hydrolysis bacteria attach to the outer wall of the bacteria (so-called exoenzymes) and at the same time break down the organic components of the substrate into small water-soluble molecules. Polymers are converted into monomers, insoluble substances are dissolved and become available for the nutrition of microorganisms. Hydrolysis is slow and depends on the concentration of extracellular enzymes, such as cellulases, amylases, proteases, and lipases. The process is affected by the pH level (4.5-6) and the time spent in the tank " [4, 5].

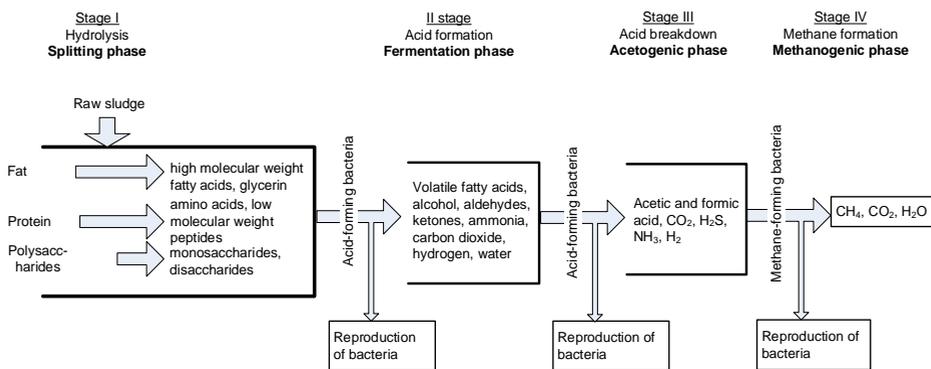


Fig. 1. Schematic diagram of biogas synthesis.

"2. Further fermentation is carried out by acid-forming bacteria (fermentation phase). Anaerobic bacteria take part in this process, consuming the remaining oxygen and thus forming the anaerobic conditions necessary for methane bacteria. At a pH level of 6-7.5, carboxylic acids are produced primarily - acetic, formic, butyric, propionic acids, low-molecular alcohols-methanol, ethanol, and gases-carbon dioxide, carbon, hydrogen sulfide, and ammonia. This stage is called the oxidation phase (the pH level decreases).

Acid-forming bacteria are represented by obligate and facultative anaerobes. From 50 to 92 species have been isolated from the fermenting sediment, half of them are spore-forming forms. They differ in physiological characteristics. The degree of development of individual physiological groups depends on the composition of the treated sediments. Organic substances are decomposed by ammonifying, cellulosic, and fat-splitting bacteria.

Denitrifiers and sulfate-producing bacteria were found in the anaerobic substrate. Species that consume very specific substances as a source of carbon have been found. Macromolecules of proteins, fats and carbohydrates are destroyed mainly by spore-forming bacteria. Important in the fermentation processes are *Clostridium* (genus *Clostridium*). Depending on the substrate used, there are: clostridia, which have saccharolytic activity, which oxidize substances of a carbohydrate nature; clostridia, which have active proteolytic enzymes, which use proteins and their hydrolysis products as a substrate; clostridia, which ferment heterocyclic nitrogen - containing compounds.

3. After that, acid-forming bacteria from organic acids create the starting products for the formation of methane, namely: acetic and formic acids, carbon dioxide (acetogenic phase). Such bacteria are very sensitive to temperature. Oxygen in the medium is gradually consumed for the growth of biomass, fermentation passes into the anaerobic stage.

4. At the last stage, methane, carbon dioxide and water are formed as a product of the fermentation of methane bacteria of acetic and formic acids, carbon dioxide and hydrogen (the methanogenic phase). 90% of all methane is produced at this stage, 70% comes from acetic acid. Thus, the formation of acetic acid is a factor determining the rate of methane formation. Methane bacteria are exclusively anaerobic. The most typical species are *Methanobacterium soehngenii* and *Methanobacillus omelianskii*. The optimal pH level is 7, and the amplitude of temperature fluctuations can be within the range of 6,6-8" [4, 5].

Biogas is similar in its characteristics to natural gas. If the company uses adjustable burners, the biogas is only drained and the impurities of hydrogen sulfide and ammonia are removed. If the burners are not adjustable, then install a carbon dioxide cleaning system.

Currently, obtaining a license for the production of alcohol without disposing of bard in Russia is impossible, as it was already noted above, which, in most cases, is very expensive and increases the cost of production.

A special feature of the BSU for distilleries is that the alcohol bard enters the bioreactor already warmed up. This means that the cost of maintaining the temperature regime will be minimal. At the same time, the BSU performs the function of a heat recuperator, which, together with the production of biogas, significantly increases the energy efficiency of production as a whole. And obtaining biofertilizers, saving on environmental payments will help to reduce the cost of production by 15-20%.

A plant for the production of alcohol with waste in the amount of 110 thousand tons of bard / year can receive 6.4 million m³ / year of biogas, 30 thousand tons/year of solid biofertilizers, 100 thousand m³/year of clean industrial water and simultaneously solve the issue of bard utilization [17].

The company DGE GmbH (Germany) offers a turnkey set of equipment for block heat and power plants (Fig. 2) [18]. The unit costs 1.475 million euros and can process 48 tons of bard per day. Higher revenue from the sale of electricity offsets lower revenue from the sale of raw alcohol, thus making distilleries viable. In general, even a single installation combined with a factory line will bring the company a significant share of cost coverage. The payback period is 4-5 years, thanks to cheaper electricity supply tariffs.

The biogas combustion and power generation (cogeneration) plants are delivered in standard sea containers and are fully operational after installation on the foundations (Fig. 2).



Fig. 2. Block thermal power plant with a capacity of 50 to 2000 kW, delivered in a sea container (from 20 to 40 feet depending on the capacity) and ready for connection [19].

Project of Reko Bioenergi GMBH (Switzerland). The project was implemented in 2010 in Latvia. As a waste product of the alcohol production process, the plant annually produces 160,000 m³ (about 530 m³ daily) of bards. The annual amount of raw materials laid down was calculated based on 300 days of operation of the plant for the production of ethanol and bioethanol. Plant capacity: 2000 kW + 1.6 tons of steam per hour [20].

Utilization of the bard is carried out by anaerobic digestion. In this case, the organic substance is converted into biogas. The dry matter content of the bard produced in Latvia is about 6-8%. Due to the small volume, the usual fermentation using a single line was chosen. Thus, microbiological cleavage is carried out on one fermentation line, but in two reactors located in a row. The fermentation of the barda begins in a large fermenter with mixing of the product and continues in the central fermentation tank. The remains of the fermentation process are separated by separation into liquid and solid fertilizers. The resulting biogas is converted to electricity, heat and steam at a block thermal power plant (block thermal power plant).

4 Conclusion

Russia annually accumulates up to 300 million tons in the dry equivalent of organic waste: 250 million tons in agricultural production, 50 million tons in the form of household garbage. These wastes can be used as raw materials for the production of biogas. The potential volume of biogas produced annually may amount to 90 billion m³ [21].

From the above, it follows that for an objective assessment of the efficiency of biogas production, it is necessary to take into account all the advantages that anaerobic treatment of manure gives.

The existing experience in the implementation of the process of methanogenesis in agricultural practice shows that the first place is still occupied by its environmental aspect, followed by the effect of obtaining high-quality fertilizers, and only the third place is occupied by the underestimated or isolated energy component of the process. However, in the absence or lack of other sources of energy, especially for domestic purposes, biogas will become increasingly important as a renewable energy source.

By processing post-alcohol bard into biogas, the plants receive the following advantages:

- significantly reduced fuel purchase and electricity consumption;
- problems associated with the sale of feed products are reduced;
- the discharge of organic pollutants to the filtration fields is reduced several times;

- the technology and equipment of biogas production is much simpler than in the production of feed products by drying.

Another advantage of biogas plants: in most modern microbiological industries, they strive for the use of pure cultures of microorganisms and for complete sterility of equipment, media, and air, but in some cases, a product that satisfies the consumer (for example, biogas) can be obtained without pure cultures growing in conditions of non-sterility.

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