BIOGAS INSTALLATIONS WITH ROTATIONAL TYPE OF ANAEROBIC DIGESTERS

Gennadii Golub, Savelii Kukharets, Oleg Marus
National University of Life and Environmental Sciences of Ukraine
Gennadii Golub, gagolub@mail.ru

ABSTRACT: One of the ways of liquid manure utilization in agricultural production is its fermentation in anaerobic conditions to obtain biomethane, which provides partial disinfection of manure and its deodorization. Production and use of biomethane requires significant capital expenditures, but it is important to preserve natural environment, which requires focusing on the development of methods and means to provide cost-effective production and use of biogas installations. Scientific problem is the lack of practical experience, scientific groundwork and examined regularities for determination of structural and technological parameters of machines and equipment, which would allow increasing the level of energy autonomy of agricultural production by use of renewable biological energy resources. The aim of the article is to develop the biogas installations with rotational type of anaerobic digesters for use in agroecosystems. Experience of using biogas reactors showed that there are reactors already half-filled with mineral sediment, which can be removed only with an excavator after total stopping of fermentation process. Floating layers, especially based on fibrous substrates, often form a crust and if it is not mixed, the reactor must also be stopped to remove it. We found the relationships between the intensity of organic matter decomposing and specific biomethane and biogas yields, and fermentation time. The main direction in manure fermentation process intensification is increase of organic matter decomposition at the cost of creation of appropriate conditions for the development of anaerobic microflora. This can be achieved by creating stable fermentation temperature conditions and, what is more important, by providing quality biomass mixing, which, on the one hand, must not disturb the symbiosis of acetogenic and methanogenic bacteria, and, on the other hand, prevent the exfoliation of biomass in the reactor to mineral sediment and floating organic layer.

Keywords: biogas, installation, anaerobic digester, fermentation process.

INTRODUCTION

The experience of using biogas plants was completely analyzed by the Agency for renewable resources in Germany (FNR). The authors of the analysis indicate that in the absence of biomass mixing in the reactor, after a while there is a separation of biomass with layer forming due to the difference in density of certain mineral and organic components, as well as to flotation of particles while gas yielding. Thus, the biggest part of the anaerobic bacteria biomass is situated at the bottom of the reactor, and the organic part of the biomass substrate accumulates at the top of the reactor. As a result, the contact zone of anaerobic bacteria with biomass substrate is limited by a boundary layer of mentioned parts of the reactor. Floating crust of solid organic substances also blocks biogas yield. Facilitation anaerobic bacteria contact with substrate biomass is provided by mixing the substrate, but intensive mixing should be avoided, because it can cause stopping of anaerobic fermentation at the expense of disturbance of symbiosis of acetogenic and methanogenic bacteria. In practice, a compromise is achieved by slow rotation of agitators or by their work within a short period of time. Part of the solid mineral inclusions contained in substrates based on manure is released in the process of biological decomposition inside the reactor. Mineral sediment reduces the useful volume of the reactor.

METHODS

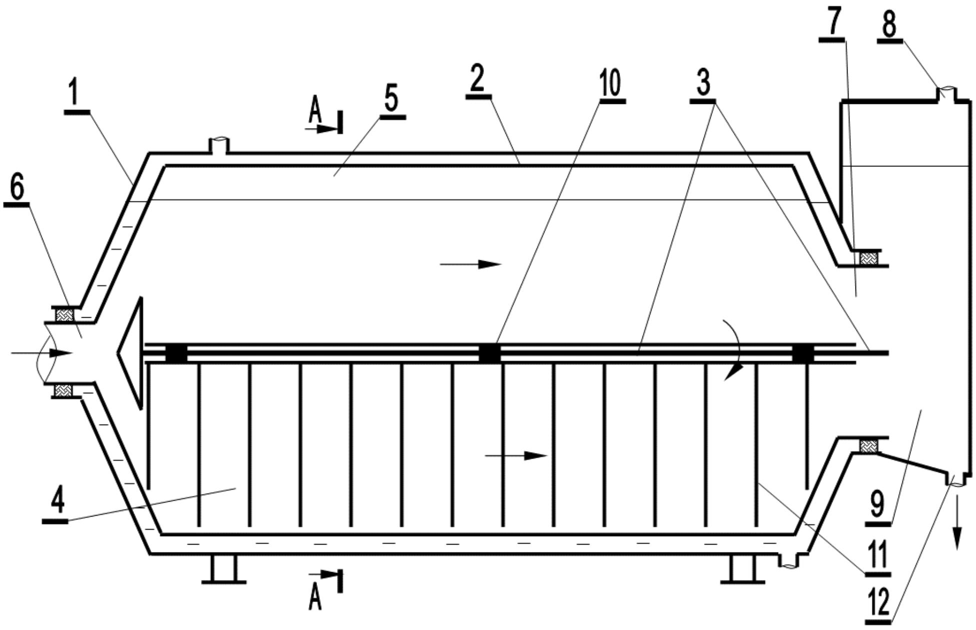
Estimated volume of the produced biogas was determined on the basis of the intensity of organic biomass decomposition during its fermentation.

RESULTS AND FINDINGS

Experience of using biogas reactors showed that there are reactors already half-filled with mineral sediment, which can be removed only with an excavator after total stopping of fermentation process. Floating layers, especially based on fibrous substrates, often form a crust and if it is not mixed, the reactor must also be stopped to remove it.

Thus, the improvement of biogas reactor work to ensure the mixing of biomass substrate layers requires new technical solutions, one of which is mixing by rotation of the suspended reactor submerged into water.

We have developed and patented several designs of modular anaerobic digesters of rotational type (Golub G.A., Kukharets S.M., 2015), the design of one of which is shown in fig. 1.



1 – horizontal outer casing, 2 – cylindrical reactor 3 – longitudinal bulkhead, 4, 5 – fermentation chambers, 6, 7 – tubes for cart and removal of organic matter, 8 – pipe for biogas runoff, 9 – unloading camera, 10 – joints 11 – mixing fingers, 12 – pipe for organic matter removing

Figure 1. Construction of anaerobic digester immersed into thermostatic liquid

Our calculations showed that the microbiological decomposition while anaerobic fermentation of 1 kg of organic matter is accompanied by about 0.4 kg of methane yield and by 0.7 kg of carbon dioxide yield.

Adopting the assumption that the volume of produced biogas is determined by the intensity of organic matter decomposing during organic biomass fermentation, biogas yield while fermentation in terms of normal conditions can be defined as follows:

$$V_{БГ} = \rho_{БМ}\left(1-\frac{W_{БМ}}{100}\right)k_{ОМ}k_{ОМ}^{P}\frac{m_{БГ}}{\rho_{БГ}^{H}}, \qquad (1)$$

where: $V_{БГ}$ is a specific biogas yield from the reactor under normal conditions, $м^3_{БГ}/м^3_{БМ}$ per day; $\rho_{БМ}$ – biomass density, $кг_{БМ}/м^3_{БМ}$; $W_{БМ}$ – biomass dampness, %; $\left(1-\frac{W_{БМ}}{100}\right)$ – dry matter content in relation to the total biomass, $кг_{СМ} / кг_{БМ}$; k_{OM} – organic matter content in relation to the volume of the total dry weight in fermenting biomass, $кг_{OM} / кг_{CM}$; k^{P}_{OM} – the number of decomposed organic matter per day in relation to the total organic mass, $кг_{POM} / кг_{OM}$ per day; $m_{БГ}$ – biogas yield per unit of decomposed organic matter, $кг_{БГ} / кг_{POM}$; $\rho^{H}_{БГ}$ – biogas density under normal conditions, $кг_{БГ} / м^3_{БГ}$.

At the same time, specific biomethane yield will be:

$$V_{CH_4} = V_{БГ} k_{CH_4}, \quad (2)$$

where: V_{CH_4} – is specific biomethane yield from the reactor under normal conditions, $м^3_{CH_4} / м^3_{БМ}$ per day; k_{CH_4} – volume biomethane content in biogas, $м^3_{CH_4} / м^3_{БГ}$.

With the parameters introduced in table 1, the relationships between the intensity of organic matter decomposing and specific biomethane and biogas yields, and fermentation time, will take the form shown in fig. 2.

Table 1. Calculation of the specific release of biogas and biomethane

Indicator	Measurement	Values
Manure density	$kg_{БМ}/м^3_{БМ}$	1062
Humidity	%	90
Water content	$kg_{B}/kg_{БМ}$	0,9
Dry weight	%	10
	$kg_{CM}/kg_{БМ}$	0,1
Organic matter content	%	80
	kg_{OM}/kg_{CM}	0,8
The intensity of organic matter decomposing	% per day	3,0
	kg_{POM}/kg_{OM} per day	0,03
	$kg_{POM}/м^3_{БМ}$ per day	2,55
Biogas yield from decomposed organic matter under normal conditions	$kg_{БГ}/kg_{POM}$	1,1
	$м^3_{БГ}/kg_{POM}$	0,92
Biogas yield from the reactor under normal conditions	$м^3_{БГ}/м^3_{БМ}$ per day	2,34
Biomethane yield under normal conditions	$м^3CH_4/м^3_{БМ}$ per day	1,666
The maximum level of organic biomass decomposing	%	38
	$кг_{POM}/м^3_{БМ}$	32,5
Fermentation time	days	12,74

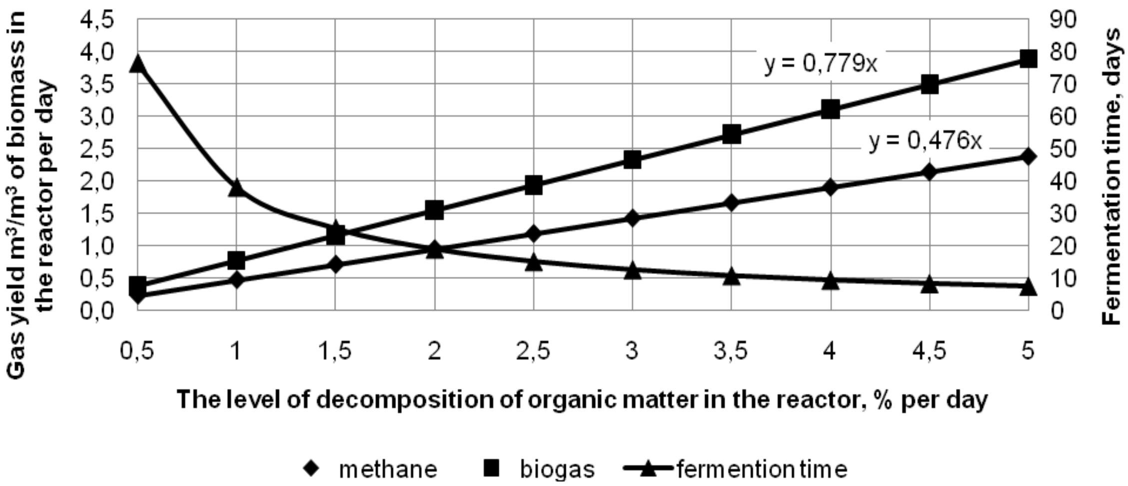


Figure 2. The effect of organic matter decomposing intensity on the specific yield of biomethane, biogas and fermentation time

Biogas and biomethane yields increase proportionally with increasing of level of organic biomass decomposing in the reactor, and the fermentation time decreases exponentially till it achieves 38% fermentation level.

CONCLUSION

The main direction in manure fermentation process intensification is increase of organic matter decomposition at the cost of creation of appropriate conditions for the development of anaerobic microflora. This can be achieved by creating stable fermentation temperature conditions and, what is more important, by providing quality biomass mixing, which, on the one hand, must not to disturb the symbiosis of acetogenic and methanogenic bacteria, and, on the other hand, to prevent the exfoliation of biomass in the reactor to mineral sediment and floating organic layer.

REFERENCES

Guide to biogas. From obtain to using / Renewable resources Agency (FNR). 5th edition, (2012), p. 213, Hyultsov / Germany;

Golub G.A., Kukharets S.M., (2015), Patent № 110077. Ukraine, Methanetanks (Метантенк) Digest №21, p.5.