Electric pulse treatment of organic waste before anaerobic fermentation

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Abstract. One of the promising areas of processing organic waste from agriculture is through methane fermentation in biogas plants. They have important advantages over other methods of processing organic waste. Based on these problems, the article describes a method of processing organic waste under anaerobic conditions using electric pulse treatment of organic waste before loading into a biogas plant. The parameters of the production process of the bioenergy plant had the following values: humidity of organic waste 88-94%; the pressure of the gas phase in the bioreactor -2-3 kPa; the dose of daily updating of the mass volume in the bioreactor is 10% / day; the duration of one cycle of mixing 10 min; the frequency of daily mixing 17 days⁻¹. Based on the equation, taking into account the listed optimal values of the factors, the biogas yield per 1 kg of OM was calculated and 0.146 m³ of BG/kg of OM was obtained. Laboratory and production results are given, as well as a comparison of the data obtained.

1. Introduction

The product obtained as a result of methane fermentation of organic agricultural waste does not contain pathogens, even if they were present in the processed organic waste, they die during methane fermentation [1, 2, 3]. In this case, before loading the biomass into the bioreactor, it is processed according to the existing anaerobic technologies [4, 5], and an almost 100% guarantee on the structural improvement of biomass is achieved. Even resistant organisms such as helminth eggs die almost completely during methane fermentation [6, 7, 8]. In this case, the problem of waste disposal is closely related to environmental protection [1, 2, 3]. In practice, there is a method of phytomedical use of water hyacinth, which can remove pollutants in produced water and wastewater from domestic and industrial sources, which are either used as a whole living plant grown in water or use parts of the plant's body as a sorbent [9]. To date, in the Republic of Uzbekistan, a subject is studying the possibilities of using living organisms, systems, or products of their vital functions to solve technological problems provide for any conversion of organic waste into a feed product, and vice versa [1, 8]. The practically useful implementation of such processes is determined mainly by environmental and sanitary-epidemiological and, to a lesser extent, technical factors [8].

This is very important in the processing of agricultural waste (residues of feed, chicken...
droppings, manure, surface grass, urban and industrial wastewater, etc.) containing pathogens by anaerobic fermentation and receiving renewable energy [10, 11].

The intensification of known methods of processing organic waste, including accelerating the process of anaerobic digestion due to the influence of the temperature factor, the use of active impurities and mixing devices of various design features, have exhausted themselves for purely physical, chemical and mechanical reasons [12].

Although recently, a new method has been developed to activate the process of anaerobic digestion, which can improve the quality of organic fertilizers and reduce the time of their production [1], the proposed method makes it possible to obtain biogas in large quantities due to the impossibility of activating the organic substrate in large quantities [13, 14, 15].

2. Methods

According to the laws of thermodynamics, the process of decomposition of substances should be more effective at lowering the fermentation temperature, since the equilibrium of the decomposition reaction is shifted towards the formation of hydrogen compounds and carbon dioxide. However, practically thermodynamics says "yes" in favor of this process, and the kinetics of this process negates it, and kinetics wins since the acceleration of the decomposition process is observed with increasing temperature, which should be explained by the imperfection of the technological process. Despite this, it is preferable to use technologies that allow the reaction to be carried out at a lower temperature since only this will increase the yield of the target energy products (biogas).

3. Results and Discussion

The main factors affecting the operation of the anaerobic process in bioreactors do not allow for a constant temperature effect and a uniform temperature distribution throughout the volume, as well as a sufficient degree of grinding and activation ability of the organic component of the substrate. Since the biogas yield is more dependent on the technology of preparation of the substrate than on the design improvements of biogas plants, the main emphasis is on improving this technology through the use of electrical technologies.

Recently, the current direction is electrical pulsed processing of various materials before the technological processes of anaerobic processing [15, 16]. The development of electric pulse processing is of great interest in terms of high productivity and low energy consumption.

The idea of using a high-voltage pulsed electric discharge in water was first proposed by L.A.Yutkin at the beginning of the last century, later it began to be widely used to solve several technological processes based on the electro-hydraulic effect [10, 11]. The electro-hydraulic effect is a method of converting electrical energy into mechanical energy and is accomplished without the help of intermediate mechanical links, which ensures high efficiency. The essence of the method consists in the fact that when a specially formed pulsed electric discharge of various forms is passed inside the volume of liquid in an open or closed vessel, high hydraulic pressure arises around its formation zone, capable of performing mechanical work and initiating a complex of physical and chemical phenomena [12].

The electro-hydraulic effect is based on the phenomenon of a sharp increase in the hydraulic and hydrodynamic effects and the amplitude of the shock effect when performing a pulsed electric discharge in an ion-conducting fluid, provided that the pulse duration is shortened, the front is steepest and the pulse shape is close to aperiodic. Using this method, we conducted a series of experiments from 2014 to 2019 in the TIIAME laboratory. The result was an original method of methane fermentation of waste and a compact unit for its implementation, a general view of which is presented in Figure 1 [17].

The experimental setup included: a volume for pretreatment of organic waste, a heat recuperator of the processed waste, a bioreactor whose design allows for periodic layer-by-layer mixing with simultaneous heating and heat recovery of the processed mass, a compressor with automatic control and a temperature control system, as well as a volume for preliminary processing of biomass with
preliminary electric pulse discharge.

Measurements of controlled and controlled values, as well as the processing of experimental data, were carried out according to the methods regulated in the standards. In calculating the methane fermentation and heat transfer indices, we used kinetic models of methanogens and unsteady heat transfer.

Using the two-dimensional cross-sectional method, it was found that the maximum specific productivity of the bioenergy plant reached 4.5 m$^3$ of biogas per unit volume of the bioreactor per day.

For this case, the parameters of the biogas production process in a bioenergy plant had the following values: humidity of organic waste 88-94%; the pressure of the gas phase in the bioreactor is 2-3 kPa; the dose of daily updating of the mass volume in the bioreactor is 10%/day; the duration of one cycle of mixing 10 min.; the frequency of daily mixing 17 days$^{-1}$. Based on the equation, taking into account the listed optimal values of the factors, the biogas yield per 1 kg of organic matter was calculated and 0.146 m$^3$ BG/kg of organic matter was obtained.

Based on the obtained experimental data on the methane fermentation processes of organic waste under laboratory conditions, a pilot industrial model of a biogas plant was built, designed for excrement from 1700 dairy cows, which successfully works in the Bukhara region (Fig. 2).
In these plants, it was used to increase the biogas yield during anaerobic digestion in the climatic conditions of Central Asia by preliminary electric pulse waste treatment, the improvement of the technology and technical means of which is shown in Fig. 3. This allowed changing the structure of the waste and intensifying the process of its fermentation. Since the physical and mechanical properties of methane-forming bacteria in organic waste do not always perceive a sharp change in the “comfort” of the adapted conditions of the digestion technology. At the same time, the properties of methane-forming bacteria also change, that is, they quickly die and become a source of methane.

The use of organic fertilizer (bio-sludge) obtained by anaerobic digestion with preliminary electric pulse treatment in the cottonseed fields yielded positive results.

Since this fertilizer has everything that is needed for the soil since anaerobic processing removes only carbon in the form of $CO_2$ and $CH_4$ from organic residues. The remaining elements found in plant and animal organisms and taken from the soil are returned to the soil again.

The experiments carried out in 2019 (from April to September) on the application of bio-sludge on cotton showed that its effectiveness is several times higher than that of other mineral fertilizers, which can be seen with the naked eye (Fig. 4 a, b).
4. Conclusions
In general, the relevance of using electric pulse pretreatment of organic waste is closely related to the issue of the use of methane fermentation is increasing. Various technology options are being introduced into practice, depending on the type of recyclable waste in Uzbekistan. However, experiments show that the resulting methane fermentation product must match the economic and epidemiological points of view.

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