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TECHNOLOGY OF BIOMASS CHEMICAL DISINTEGRATION IN ANAEROBIC DIGESTION OF ORGANIC WASTE

The main methods for increasing the efficiency of anaerobic processing of organic waste are: improvement of methanetanks and additional equipment; changes in the composition of the substrate and its additives; additional stages of substrate treatment. The comparative analysis of the use of methane fermentation technologies for the mechanical, physical and chemical degradation of biomass is given. The application of chemical disintegration of biomass during anaerobic treatment of organic waste is substantiated. It is shown that biomass processing with hydrogen peroxide can be successfully used to increase the degree of organic waste recycling in biogas.

Key words: *anaerobic treatment, organic waste, chemical disintegration, biomass, biogas.*

Introduction. Nowadays, annually more than 50 billion tons of energy, industrial, agricultural and domestic waste fall into the atmosphere, water and soil, and more than 150 millions tons of which are from industrial enterprises [3, 4]. Total volume of solid waste in Ukraine is 10–11 millions tons per a year. 2600 hectares of land in the country are occupied by landfills. The average volume of solid waste is 1 ton per person per one year in cities. The annual amount of formed waste in 2014 in Ukraine is about 354 millions tons. Only 112 millions of them are recycled or disposed. And the rest is preserved in landfills [5].

There are very large reserves of using secondary resources in the country. This is the way to economical regime, that promotes the transition from extensive to intensive factors of economic growth and recovery of Ukraine.

The total amount of organic waste produced in Ukraine is given in Table 1.

Thus the potential of biogas receiving in the country is extremely high. It's known that one person produces 0.5–3 kg of household and industrial waste per a day that may be transformed into 0,00125–0,5 m^3 of biogas. Amount of received gas depends on waste type and recycling technologies [1].

The potential of bioenergy is 60% of all renewable energy sources in Ukraine. The most significant reserves of biomass in Ukraine are: straw, manure, secondary waste, wood [2, 6]. Organic waste recycling in biogas reactors would largely solve the energy problem in villages and farms in Ukraine [6].

Using anaerobic organic waste processing technology allows to dispose various kinds of manure (including bird droppings), to process plant remains (overwintered silage, foliage food crops, etc.) and to utilize organic waste of slaughterhouses and poultries, and products of wastewater treatment. Waste processing – is primarily a cost-effective system that increases the level of environmental security.

Modern technologies of bioenergy waste disposal under anaerobic conditions in digesters have some disadvantages: ineffective process of biotransformation of waste into biogas, low level of methane in biogas, long duration of fermentation, reducing the amount of received biogas while limiting the biogenic elements in substrate.

Table 1

Organic waste in Ukraine by types [6]

Branches of waste production	Mass of waste, million tons
Animal husbandry and poultry farming	46
Plant growing	32
Solid wastes	12
Sewage waste water	1,4
Wastes from woodworking, food processing etc.	8,6

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So, there is a necessity in researching the methods of increasing of productivity of organic waste recycling, reducing fermentation time and increasing the received amount of biogas with increasing proportion of methane in it.

The aim of the work is to develop the method of intensification of organic waste anaerobic fermentation.

Materials and methods. Research methods:

– physical-chemical, chemical-analytical, hydrobiological, mathematical analysis, computer modeling and technical-ecological analysis of obtained results;

– use of methods of system analysis of innovative technologies of methane fermentation and also in order to improve the information support of waste digestion systems.

Statistical methods of research were used to assess the state of waste anaerobic fermentation process. The information base was provided by publications of Ukrainian and foreign scientists in the field of organic waste utilization.

Ways of intensification of biomass methane fermentation. The following directions of development of technologies of increasing productivity of organic waste recycling are defined on the base of review of modern research and publications:

1. Constructrions of digesters and supplement equipment.

This category includes all methods of increasing the efficiency associated with changes in configurations of digesters or their components to ensure more complete and effective methane fermentation process.

2. Changes in composition of substrate and its additives.

They include such methods as: changing the composition of substrate by mixing of different types of organic matters for achieving synergy effect, bringing additives and supplements into substrate that directly affect on some elements of the methanogenesis cycle and thus increase efficiency of the process.

3. Additional steps of substrate processing.

This category includes methods in which the substrate is subject to pretreatment (physical, biological, etc.) before bringing in digester.

The main ways of intensification of technologies of bioenergy waste disposal are: increasing temperature of fermentation and rate of mixing of waste in digester, continuous loading and unloading, two- and many stepped fermentation, in which the second and next stages are used to separate excess water and reduce amount of biomass, and also technologies of mechanical, physical and chemical disintegration of biomass [2].

Quantitative biogas yield in anaerobic digestion in two different temperatures is established as approximately equal [7]. Period of biodegradation of organic substances is reduced in 2 times in thermophilic regime, however, it requires more energy expenditure (mixing, heating).

Increased rate of raw materials decomposition, high biogas yield and almost complete destruction of pathogenic bacteria, containing in raw materials, belong to advantages of thermophilic fermentation process. Disadvantages of thermophilic anaerobic process are: large amount of energy, required for heating material in reactor, fermentation process sensitivity to minimal changes in temperature, low quality of product (biogas) [8].

Methane fermentation under thermophilic conditions affects the rate of reactions occurring at stage of hydrolysis. Thereby, it raises concentration of volatile fatty acids, formed from active sludge, that leads to biogas production increase [7].

Significant reserves of biogas output intensification are use of different kinds of structural and technological methods of anaerobic digestion process intensification. Mixing in process of anaerobic digestion increases area of contact methane-generating bacteria with organic mass, that increases productivity of biogas plant [9].

The main objectives of mixing include: output of produced biogas; mixing fresh substrate and bacteria populations; prevention the formation of crust and sediment; prevention the formation of areas of different temperatures inside reactor; providing steady distribution of population of bacteria; prevention

the formation of cavities and clusters, which reduce effective area of reactor.

In selecting the appropriate method of mixing it should be taken into account that process of digestion is a symbiosis between different strains of bacteria, i.e. bacteria of one type can feed another type. When the community is broken, fermentation process is unproductive by the time of bacteria new community formation, so too frequent or prolonged and intense mixing is adversely. It is recommended to mix raw slowly every 4–6 hours.

Mixing in bioreactor has also some disadvantages: high energy intensity; significant abrasion of equipment; complexity of repair; reducing efficiency due to silting possibility and presence of fibrous materials; insufficient destruction of floating peel under certain conditions; insufficient hermetization of apparatus because of presence of node shaft seal of mixer and, consequently, increased explosiveness [8].

All sorts of damage of intermolecular chemical bonds between the structural elements are the basis of chemical disintegration method for biomass. Neutral salts, organic compounds and other substances are used as reagents in this method [10].

The chemical disintegration of organic waste. The results [11], obtained after chemical pretreatment, show that using H2O2 under alkaline conditions leads to decomposition of the three main structures: lignin, hemicellulose and cellulose. The impact of temperature, reaction time and concentration of H2O2 on the biomass degradation efficiency and the further methanogenesis was also studied.

The best results were achieved when the process was carried out at 25 °C for 24 hours using a 5% solution of H2O2. Although the level of degradation was very high for all three plant sources, biogas production from energy crops that have been previously chemically processed, was heavily hampered by impurity products and residual oxygen formed after decomposition of H2O2.

It points to the fact that the alkaline pretreatment with H2O2 is a very perspective method of plant material degradation for biogas production, but the pretreated biomass should be separated from the supernatant before the fermentation process because of the high concentration of inhibitors and hydrolysates. The best results were obtained for Sida hermaphrodita: production of biogas and methane was 2,29 dm3 and 1,06 dm3 respectively.

Previous chemical processing with using a range of different chemicals, especially acids and alkalis of different strengths, under different conditions was investigated [12].

As it is known, at present chemical preprocessing for biogas production is not carried out on a large scale, despite the fact that it is widely used for ethanol production. Oxidative preprocessing that use hydrogen peroxide or ozone affects the lignocellulose similarly to alkaline processing. Preprocessing like this can also destroy lignin.

Among the examples of using and exploration of this technology – is processing of substrate by wastes from olive production [13]. Olive pulp contains large amount of phytotoxic compounds and is poorly biodegradable, so it is advisable to carry out preliminary processing with an all substrate mass oxidation. Processing with hydrogen peroxide under alkaline conditions reduces the concentration of harmful polyphenols 72%, reduces content of carbon dioxide in biogas at about 77% and increases the yield of methane.

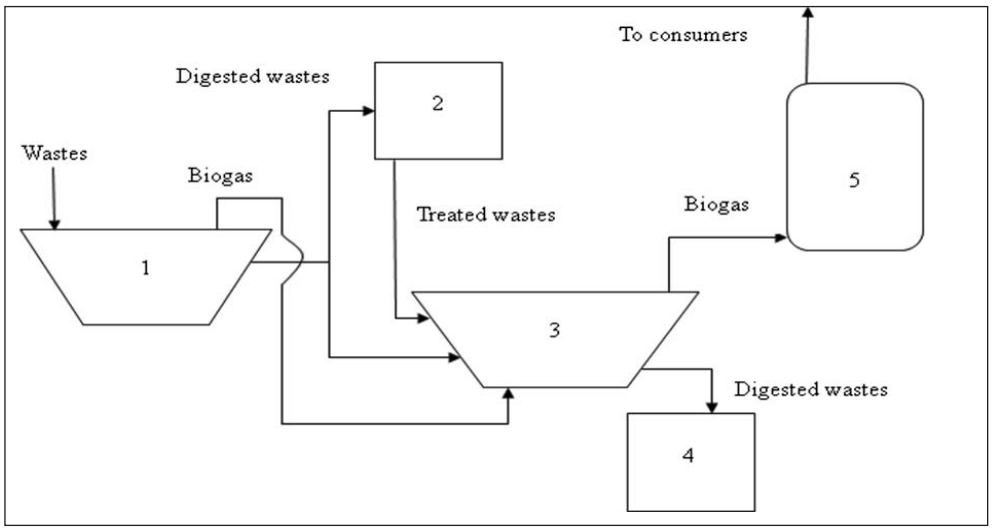

Fig. 1. Scheme of chemical disintegration of organic waste by hydrogen peroxide

Combined pretreatment of waste sludge by free nitric acid and hydrogen peroxide increases methane production by decomposition of organic molecules. It represents a new strategy of preprocessing with combined use of free nitric acid (FNA i.e. HNO2) and hydrogen peroxide (H2O2) to increase methane production from activated sludge with studying of biomolecular mechanisms [14]. The structure of the molecular-weight distribution and the results of chemical analysis revealed the disintegration of soluble macromolecules through the combined preprocessing caused by the oxidation of typical functional groups to proteins, polysaccharides and phosphodiephyrs. These changes improved the biodegradation of sludge.

We have developed a method of intensification of organic waste two-stage anaerobic fermentation process with hydrogen peroxide using (fig. 1).

The method is carried out as follows:

Organic wastes come into the first digester (1) for the first stage of fermentation, and then some of biomass comes into the node of activation (2), where it is disintegrated by hydrogen peroxide, and the rest is put to the second digester (3). After the second stage of fermentation, fermented biomass comes into precipitate receiver (4) for storage and recycling, and biogas comes in gasholder (5) for collecting and then to cogeneration plant.

As a result of experimental research when applying this method in a two-stage periodic process of organic waste anaerobic digestion at a temperature of 45 ±50°C with concentration of organic waste – 19 g per l on dry substances, biogas yield increased in four times compared with the value of control. The heating value of biogas was 20–25 MJ/m3.

The method increases the degree of organic waste processing and biogas yield. This method is an universal because it can be used to intensify the anaerobic digestion of any organic waste digestion in different modes, allows to increase biogas yield due to more complete organic waste conversion into biogas. It significantly increases energy efficiency and environmental safety of the process [15, 16].

Conclusions. The use of biomass disintegration before its methane digestion is a perspective direction of new technologies for organic waste processing and recycling.

According to experiments using chemical methods of process intensification improves the intensity of biogas production. These methods have high efficiency and enough low cost.

The result of using chemical disintegration method is the increasing of organic waste processing degree and biogas yield. Fermented biomass can be used as organic fertilizer.

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ТЕХНОЛОГІЯ ХІМІЧНОЇ ДЕЗІНТЕГРАЦІЇ БІОМАСИ ПІД ЧАС АНАЕРОБНОГО ЗБРОДЖУВАННЯ ОРГАНІЧНИХ ВІДХОДІВ

Основними методами підвищення ефективності анаеробної переробки органічних відходів є удосконалення метантенків та додаткового обладнання; зміна складу субстрату та добавок до нього; додаткові етапи обробки субстрату. Наведено порівняльний аналіз використання під час метанового бродіння технологій механічного, фізичного та хімічного розпаду біомаси. Обґрунтовано застосування хімічної дезінтеграції біомаси під час анаеробної обробки органічних відходів. Показано, що обробка біомаси перекисом водню може бути успішно використана для підвищення ступеня переробки органічних відходів у біогаз.

Ключові слова: *анаеробна обробка, органічні відходи, хімічна дезінтеграція, біомаса, біогаз.*

ТЕХНОЛОГИЯ ХИМИЧЕСКОЙ ДЕЗИНТЕГРАЦИИ БИОМАССЫ ПРИ АНАЭРОБНОМ СБРАЖИВАНИИ ОРГАНИЧЕСКИХ ОТХОДОВ

Основными методами повышения эффективности анаэробной переработки органических отходов являются совершенствование метантенков и дополнительного оборудования; изменение состава субстрата и добавок к нему; дополнительные этапы обработки субстрата. Приведен сравнительный анализ использования при метановом брожении технологий механического, физического и химического распада биомассы. Обосновано применение химической дезинтеграции биомассы при анаэробной обработке органических отходов. Показано, что обработка биомассы перекисью водорода может быть успешно использована для повышения степени переработки органических отходов в биогаз.

Ключевые слова: *анаэробная обработка, органические отходы, химическая дезинтеграция, биомасса, биогаз.*