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DEVELOPMENT OF BIOGAS TECHNOLOGY PRODUCTION FROM POLYCOMPONENT RAW MATERIALS

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Анотація

У роботі проведено аналіз особливостей виробництва відновлюваних джерел енергії, зокрема біогазу. За анаеробної переробки біомаси процес утворення біогазу проходить за такими стадіями: гідроліз, ацидогенез, ацетогенез, метаногенез. Для виробництва біогазу використовують органічні відходи харчових виробництв, побутові відходи, енергетичні культури, відходи виробництва біодизеля, відходи агропромислового виробництва.

У роботі зазначено, що вибір технології переробки органічних відходів ґрунтується на підборі оптимального складу сировини та параметрів (pH, температура, концентрація мікроелементів, співвідношення між C:N, вологість) проходження процесу анаеробного зброджування.

Якість сировини характеризується рядом факторів (вологість, швидкістю розщеплення, ступенем розкладання, наявність живильного середовища для бактерій, вихід біогазу на одиницю сухої речовини, вміст метану в біогазі, співвідношення вуглецю і азоту в сировині). Саме від цих показників залежить час його зброджування, кількість одержуваного біогазу та його склад. Важливим фактором, що впливає на вихід біогазу, є співвідношення вуглецю та азоту в переробляється сировина, доцільно використовувати наступні співвідношення поживних речовин C:N=10:1 або 30:1. Запропоновано використовувати як сировину гній свиней та відходи цукрового та сокового виробництв.

Гній тварин характеризується порівняно високою буферною ємністю, містить ряд важливих макро- та мікроелементів, необхідних для метаболізму популяцій бактерій, що обумовлюють метанове бродіння. Використання бурякового жому – перспективний варіант, оскільки до його складу входять вуглеводи, які легко розщеплюються. Проведені дослідження показали, що використання бурякового жому можливе в обсязі 25% від загального обсягу використаної сировини. Використання бурякового жому та яблучних вичавок для виробництва біогазу не лише покращує здатність до хімічного розкладання сировини, багатої на клітковину, а й забезпечує високий потенціал для використання субстрату для виробництва біогазу на додаток до сонячної та вітрової енергії.

Запропоновано технологічну схему виробництва біогазу з сировини комбінованого складу передбачає підготовку технологічного повітря, підготовку органічної сировини, метанове зброджение, очищення та зберігання біогазу.

Abstract

The analysis of the production peculiarities of renewable energy sources, in particular biogas, is carried out in the work. In anaerobic processing of biomass, the process of biogas formation takes place in the following stages: hydrolysis, acidogenesis, acetogenesis, methanogenesis. For the production of biogas organic waste from food production, household waste, energy crops, waste from biodiesel production, and waste from agro-industrial production are used.

The paper notes that the choice of organic waste processing technology is based on the selection of the optimal composition of raw materials and parameters (pH, temperature, concentration of trace elements, the ratio between C:N, humidity) of the anaerobic fermentation process.

The quality of raw materials is characterized by a number of factors (humidity, rate of decomposition, degree of decomposition, the presence of nutrient medium for bacteria, biogas yield per unit dry matter, methane content in biogas, the ratio of carbon and nitrogen in raw materials). It is from these indicators that the time of its fermentation, the amount of biogas produced and its composition depend. An important factor influencing the yield of biogas is the ratio of carbon and nitrogen in the processed raw materials, it is advisable to use the following ratios of nutrients C: N = 10:1 or 30:1. It is proposed to use pig manure and waste from sugar and juice production as raw materials.

Animal manure is characterized by a relatively high buffer capacity, contains a number of important macro- and microelements necessary for the metabolism of bacterial populations that cause methane fermentation. The use of beet pulp is a promising option, as it contains carbohydrates that are easily broken down. Studies have shown that the use of beet pulp is possible in the amount of 25% of the total amount of raw materials used. The use of beet pulp and apple pomace for biogas production not only improves the chemical decomposition of raw materials rich in fiber, but also provides a high potential for the use of substrate for biogas production in addition to solar and wind energy.

The proposed technological scheme of biogas production from raw materials of combined composition provides for the preparation of process air, preparation of organic raw materials, methane fermentation, purification and storage of biogas.

Ключові слова: біогаз, гній свиней, буряковий жом, яблучні вичавки, технологічна схема, метан, вуглець, азот.

Keywords: biogas, pig manure, beet pulp, apple pomace, technological scheme, methane, carbon, nitrogen.

Formulation of the problem. As a result of economic activity, enterprises produce unprocessed residues, the mass and volume of which can reach significant volumes. In particular, the by-products of the food industry are: beet pulp, fruit and vegetable pomace, the volume of which is estimated at tens of tons. All these products are organic raw materials that should be used for the biogas complex. Due to anaerobic fermentation, biogas is obtained from the prepared substrate. In this way, companies get rid of the need to dispose of waste, as well as get the opportunity to earn extra income from the use or sale of their own electricity.

Analysis of research and publications. The issue of renewable energy production is extremely relevant. Recently, both in Europe and in Ukraine, biogas plants are being actively built. The product of these complexes is biogas.

Biogas is a mixture of gases (methane and carbon dioxide) obtained from biomass due to anaerobic fermentation in special reactors (methane tanks) used as fuel [1, 2]. In anaerobic processing of biomass, the process of biogas formation takes place in the following stages: hydrolysis, acidogenesis, acetogenesis, methanogenesis (Fig. 1) [3].

The formation of biomethane is a staged process that begins with the stage of *hydrolysis*. Hydrolytic microorganisms decompose macromolecules into soluble compounds, which can then be converted into low molecular weight organic compounds. This group of microorganisms includes obligate anaerobic bacteria of the genera: *Enterobacteriaceae, Clostridiaceae, Lactobacillaceae, Streptococaccaceae.* During fermentation by hydrolytic bacteria volatile fatty acids, amino acids, glucose are formed [4].

Acidogenesis (acid-forming phase). Compounds formed in the process of hydrolysis by acidogenic bacteria are converted into compounds with lower molecular weight (acetic, propionic acids, low molecular weight alcohols, aldehydes and ketones), as well as inorganic components H_2, CO_2, N_2, H_2S. This process leads to a change in the pH value of the medium due to the accumulation of acids, which inhibit the process of methanogenesis [5].

Acetogenesis. The group of acetogenic microorganisms includes both obligate and facultative cultures, which are able to ferment organic acids and other components formed in the previous stages to H_2, CO_2 [6]. Other representatives of the stage of acetogenesis are homoacetogenic bacteria, which are able to ferment n-C-containing compounds to acetic acid.

Methanogenesis. Organisms capable of carrying out this process are specialized archaea [7]. Archaea have a number of common features. This applies to the composition of the cell wall, lipids, the apparatus of transcription and translation, prosthetic groups and coenzymes, the mechanism of autotrophic fixation of CO_2, as well as the method of obtaining energy.

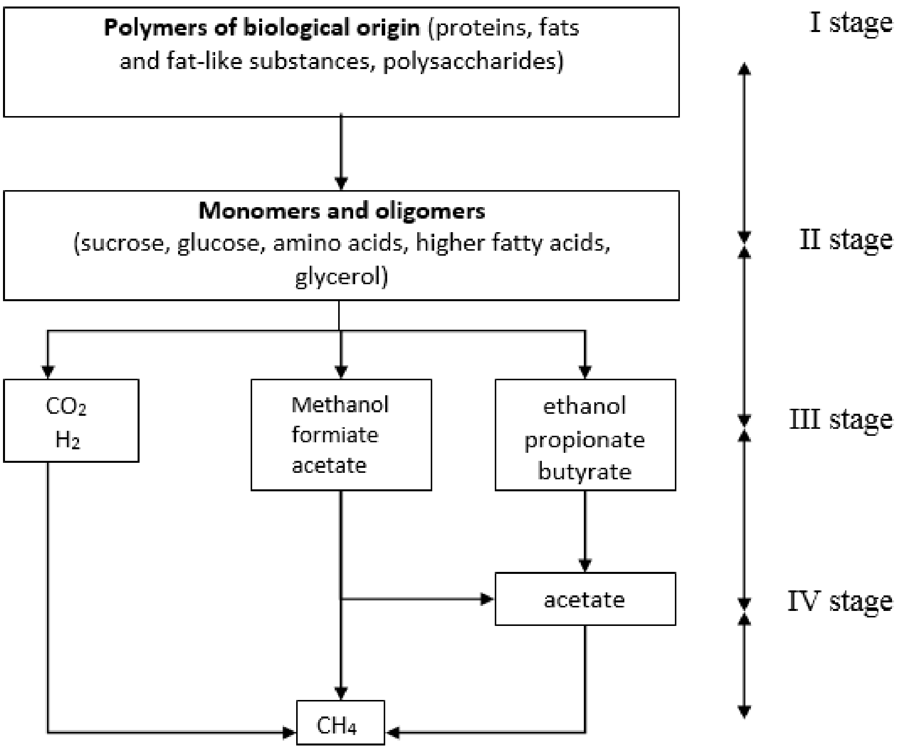

Fig. 1. The process of biogas formation

The development of the direction of biogas production allows to solve a number of important problems of today:

1. Getting biogas and additional energy;
2. Disposal of waste and get rid of the cost of their disposal;
3. To improve the environment due to waste processing;
4. Own electricity gives independence from the central power grids and prevents emergencies caused by its disconnection;
5. Production of organic fertilizers.

The development of biogas technologies in Ukraine is possible in several areas (Fig. 2).

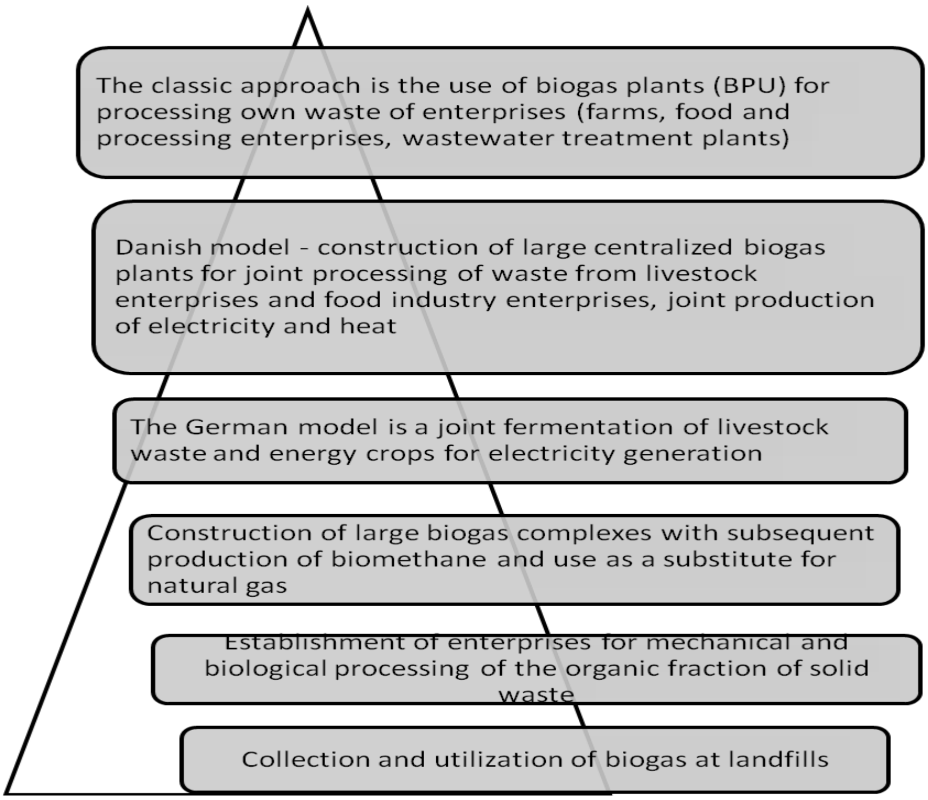

Fig. 2. Directions of development of biogas technologies in Ukraine [8]

The following types of organic waste are suitable for biogas production: manure, bird droppings, grain and molasses, post-alcohol production liquid, beer pellets, beet pulp, fish and slaughterhouse waste (blood, fat, intestines, kaniga), grass, household waste, dairy waste - salt and sweet whey, biodiesel production waste - technical glycerin from rapeseed biodiesel production, waste from juice production - fruit, berry, vegetable, grape aging, algae, starch and molasses production waste - pulp and syrup, potato processing waste, chip production - cleaning, skins, rotten tubers, coffee pulp. In addition to waste, biogas can be produced from specially grown energy crops, such as silage corn or sylph, as well as algae. The type of raw material determines the yield of biogas (Fig. 3).

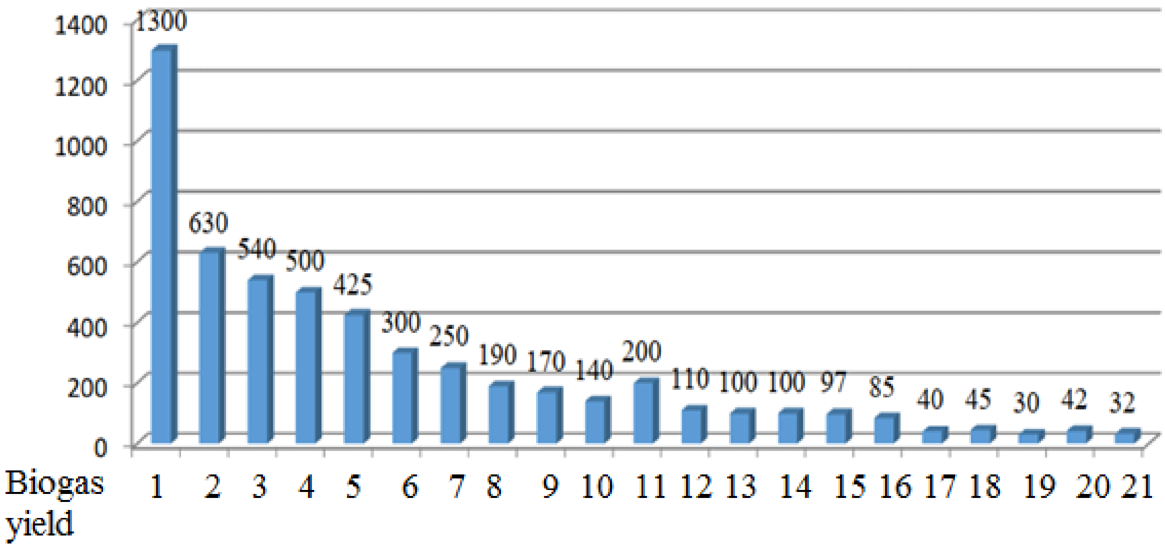

Fig. 3. Yield of biogas from 1 ton of raw material [9]:
1 – fat, 2 – molasses, 3 – grain, flour, bread, 4 –technical glycerin, 5 – straw, 6 – fish waste. 7 – fat pulp, 8 – corn silage, 9 – beet pulp, 10 – beer pellets, 11 – slaughterhouse waste, 12 – fruit and vegetable pulp, 13 – root vegetables, 14 – solid household waste, 15 – cellular bird droppings, 16 – corn mash, 17 – whey, 18 – post-alcohol production liquid. 19 – mashed potato, 20 – pork manure, 21 – cattle manure

The choice of organic waste processing technology is based on the selection of the optimal composition of raw materials and parameters (pH, temperature, concentration of trace elements, the ratio between C: N, humidity) of the anaerobic fermentation process [10, 11]. Careful analysis, preparation of mixtures and compliance with technological regimes allow to obtain biogas with a high methane content.

The aim of the study. The aim of the study is to analyze the factors influencing the process of obtaining biogas from different types of raw materials; determine the criteria for selection of raw materials for biogas plants; development of biogas production technology from multicomponent raw materials and organization of production control.

Presenting main material. According to the directions of development of biogas technologies in Ukraine, in our opinion, the most optimal is the use of the Danish model, the essence of which is the joint processing of waste from livestock enterprises and food industry enterprises.

The most important factors influencing the productivity of biogas plants are the correct selection of raw material components and its preparation for fermentation.

The quality of raw materials loaded into the fermenter of the biogas plant is characterized by:

1. humidity,
2. the rate of its cleavage,
3. the degree of decomposition,
4. the presence of a nutrient medium for bacteria,
5. the output of biogas per unit of dry matter,
6. methane content in biogas,
7. the ratio of carbon and nitrogen in the raw material [12].

It is from these indicators that the time of its fermentation, the amount of biogas produced and its composition depend.

The breakdown of organic matter into individual components and conversion into methane occurs only in a humid environment, because the various types of bacteria involved in this process can only process substances in dissolved form [13]. According to research, the humidity of the feedstock loaded into the reactor of the biogas plant is at least 85% in winter and 92% in summer, and the yield of biogas directly depends on the type of feedstock used, as well as the temperature of the fermentation process.

The rate of splitting of raw materials determines its residence time in the fermenter and the less this time, the more economical installation. Raw materials always consist of different groups of substances, the rate of decomposition of which differs significantly (Fig. 3) [12]. The unit of measurement for the minimum decomposition time in the fermenter is the time of generation of the corresponding type of bacteria, so if the fermentation time is short, the bacteria will not have time to double their bacterial mass, which will lead to a drop in gas formation.

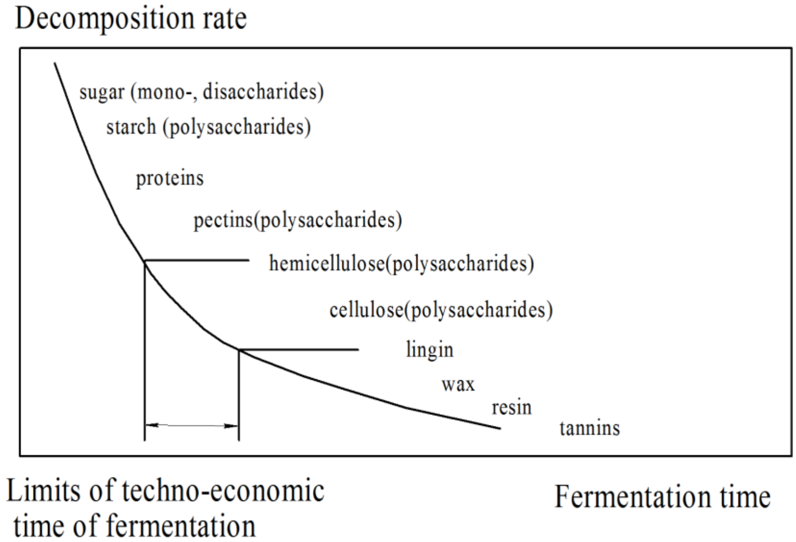

Fig. 3. The rate of decomposition of different groups of substances

The degree of decomposition of raw materials directly depends on its composition and affects the amount of gas produced. Usually its value varies from 30-70%, and for the average fermentation period will be up to 60%. However, plants operating exclusively on renewable raw materials reach a degree of decomposition of 80% of organic dry matter. In addition, the use of enzymes, boosters for artificial degradation of raw materials (eg, ultrasonic or liquid cavitators) and other devices can increase the yield of biogas in the most common installation from 60 to 95% of the theoretically possible yield [14 – 16].

For the growth and activity of methane-forming bacteria necessarily require the presence in the raw materials of organic and mineral nutrients such as carbon, nitrogen, hydrogen, sulfur, phosphorus, potassium, calcium, magnesium and some trace elements iron, manganese, molybdenum, zinc, cobalt, selenium, tungsten, nickel, etc. [17].

An important factor influencing the yield of biogas is the ratio of carbon and nitrogen in the processed raw materials. If it is too large, then the lack of nitrogen to inhibit the process of methane fermentation. If this ratio is very small, then such a large amount of ammonia is formed that it becomes toxic to bacteria. Therefore, to maintain it in the optimal range in order to obtain the maximum possible yield of biogas, modern biogas plants run on mixed raw materials, using the following ratios of nutrients [12]: C: N: P = 75: 5: 1 or 125: 5: 1; C: N = 10: 1 or 30:1; N:P=5:1.

The methane content in biogas is determined primarily by the composition of raw materials. Its maximum amount is derived from proteins - 71%, fats give 68%, and carbohydrates - only 50% [17].

Under this approach, it is proposed to use pig manure and cellulose-containing vegetable raw materials, in particular waste from sugar and juice production, as raw material.

Livestock manure, in particular pig manure, is a substrate suitable and often used for biogas production. Their widespread use is due to a number of factors. Manure wastes, especially litterless, due to the high water content, are suitable for dilution of other, more concentrated substrates, which allows them to be pumped. In addition, the composition of the manure is characterized by a relatively high buffer capacity, which makes it useful to prevent sudden changes in pH in the reactor. The manure contains a sufficient number of important macro- and microelements necessary for the metabolism of bacterial populations that cause methane fermentation [18], as well as the actual starting populations of methane-generating bacteria, which makes it almost indispensable when launching methane tanks.

The physico-chemical composition of manure waste can differ significantly. Among the factors influencing the composition of manure are the following: the type of animals, diet, method of keeping animals, the method of accumulation and excretion of their excrement [19, 20].

However, the physicochemical composition of pig manure affects the potential for biogas output from it (Table 1).

In the production of sugar, the yield of by-products is,% of the mass of beets: tops - 50 ... 70, fresh pulp - 70 ... 90, filtration sludge - 8 ... 12 and molasses - 4 ... 6 [21]. By total weight, the largest share of solid waste from sugar production is pulp. Most of the pulp is not currently used and must be taken to dumps or fields before the start of the new production season. This leads to environmental pollution and impairs soil fertility [22]. Given the large volumes of sugar beet processing and beet pulp production, it can be noted that the processing, storage and disposal of beet pulp is a serious problem. Intensively changing economic conditions in the regions of sugar beet processing and the location of processing plants have a special impact on solving this problem.

Table 1

Physico-chemical characteristics of pig manure

Indicator	Units of measurement	Indicator value
The content of the Wed.	% to mass	0,6 – 12,2
Ash content	% to average.	15 – 16
Nitrogen (Ng)	% to average.	2,9 – 6,8
	g / l	0,59 – 5,02
Ammonium nitrogen	% to average.	2,9 – 6,8
	g / l	0,59 – 5,02
LJK *	g equ / l	1,27 – 38,4
Phosphorus (P_l)	% to average.	0,35 – 0,64
	g / kg	0,1 – 2,5
Biogas yield	m^3 / kg COP	0,2 – 0,93
The output of CH_4	m^3 / t COP	0,29 – 0,68

The use of beet pulp is a promising option, as it contains carbohydrates that are easily broken down (Table 2) [23].

Table 2

Characteristics of beet pulp

Indicator	Units of measurement	Value
Crude protein (N. 6.25)	g / 100 g[a]	1.1
Raw fat	g / 100 g[a]	0.1
Starch	g / 100g[a]	2.8
Total sugars	g / 100 g[a]	7.5
Raw fiber	g / 100 g[a]	1.1
Lignin	g / 100 g[a]	< 0.9
pH	-	3.7
N	g / 100 g[a]	1.8
C.	g / 100 g[a]	59.1
The ratio of C to N	-	31.1

Advantages of using sugar beet pulp as a raw material for biogas production:

- methane yield reaches 400 - 468 L_N kg-1 LTR (volatile solids) with increasing biogas yield additionally from the fibrous substrate cofactor;

- contains a large number of easily digestible components that can be rapidly digested by microorganisms.

- stages of anaerobic digestion (hydrolysis, acidogenesis, acetogenesis and methanogenesis) can take effect quickly, especially for raw materials with a high content of lignin or cellulose;- substrate cofactor (raw material with easily fissile substrates shows degassing of CO_2 and higher kinetic indicators of acetic acid production).

Studies have shown that the use of beet pulp is possible in the amount of 25% of the total amount of raw materials used. More pulp, although periodically provides maximum production of biogas and methane, but is not appropriate for long-term implementation in biogas plants.

However, experiments have shown that within the first five minutes after adding beet pulp to the reactor, the methane yield can more than double. At the same time, no signs of process instability were found in the context of lowering the pH value, accumulation of volatile fatty acids (LFA) and decrease in methane content.

Processing of apples is to obtain juices, purees, compotes and other products, as well as to obtain by-products. By-products include pomace, wipes, cleaning, which are rich in nutrients and biologically active substances (Table) [24]. The mass fraction of moisture is 72.4%, the bulk density is 753 kg / m^3, the product density is 1020 kg / m^3 (Table 3).

The use of beet pulp and apple pomace for biogas production not only improves the chemical decomposition of raw materials rich in fiber, but also provides a high potential for the use of substrate for biogas production in addition to solar and wind energy.

Beet pulp and apple pomace were mixed with water and homogenized with a mixer. To ensure the non-toxic effect of ammonia on methane-producing bacteria, the ratio of carbon to nitrogen in both types of raw materials ranged from 15 to 34. The content of solid materials of plant origin in the mixture is 12% and be pre-crushed to a particle size of not more than 30 mm.

The most rational method of waste disposal may be anaerobic coenzyming of pig manure with cellulose-containing raw materials (food waste) to obtain biogas. This process generates energy that can be used for their own needs, and waste after biogas production is a high-quality fertilizer for agricultural land on which fodder crops are grown.

Substrate from pig manure contains ammonium ions, which are formed during the hydrolysis of urea, amino acids, amines and other nitrogenous substances. High concentrations of ammonium inhibit the activity of the association of microorganisms involved in the enzymatic processing.

The reduction of ammonium content is achieved by reducing the concentration of pig manure, but under such conditions, there is a decrease in biogas yield and increase the cost of processing. To increase the yield of biogas in the fermenter add cellulose-containing raw materials, which are a source of carbon. In the process of fermentation of cellulose-containing raw materials, the content of carboxylic acids formed increases and leads to lower pH and inhibition of the methane formation process, because the rational parameters of fermentation with methane formation are pH values in the range of 6.8 - 7.2. Also during the fermentation of cellulose-containing raw materials, the methane content in biogas is reduced.

Table 3

Chemical composition of apple pomace (%)

Indicators	Units of measurement	Content
Mass fraction of moisture	%	72,4
Crude protein	%	1,80
Crude fat	%	1,20
Crude fiber	%	10,50
Nitrogen-free extractives	%	13,30
Sugars	%	9,91
Tannins	%	0,041
Pectic substances	%	1,98
Raw ash	%	0,80
Valina	mg / 100 g	9,15
Isoleucine	mg / 100 g	5,81
Leucine	mg / 100 g	3,51
Lysine	mg / 100 g	31,12
Methionine + cystine	mg / 100 g	17,16
Threonine	mg / 100 g	4,69
Tryptophan	mg / 100 g	4,58
Pheninanalin + tyrosine	mg / 100 g	9,91
Vitamin B1	mg / 100 g	0,03
Vitamin B2	mg / 100 g	0,01
Vitamin B3	mg / 100 g	0,02
Vitamin E	mg / 100 g	0,05
Vitamin C	mg / 100 g	7,68
Phosphorus	mg / 100 g	20,0
Calcium	mg / 100 g	70,0
Carotene	mg / 100 g	0,28

In the case of using cellulose-containing raw materials with a high content of lignin, the fermentation rate of the raw material is slowed down by reducing the access of microorganisms to the substrate.

To increase the access of microorganisms to food sources, it is necessary to carry out preliminary destruction of raw materials by grinding and / or using pre-enzymatic hydrolysis at pH 5 – 6. In this case the pH of which is in the alkaline range, allows you to set the desired value.

The combined use of pig manure and cellulose-containing raw materials leads to a balanced substrate in the elemental composition, which contributes to the development of the association of microorganisms, the availability of biomass for fermentation and a higher percentage of processed biomass.

To increase the rate of biogas production, the ratio of inoculum / substrate to dry matter should be about 1: 1. From the energy point of view, the fermentation process is proposed to be carried out in the mesophilic mode.

The technological scheme of biogas production from raw materials of combined composition is presented in fig. 4.

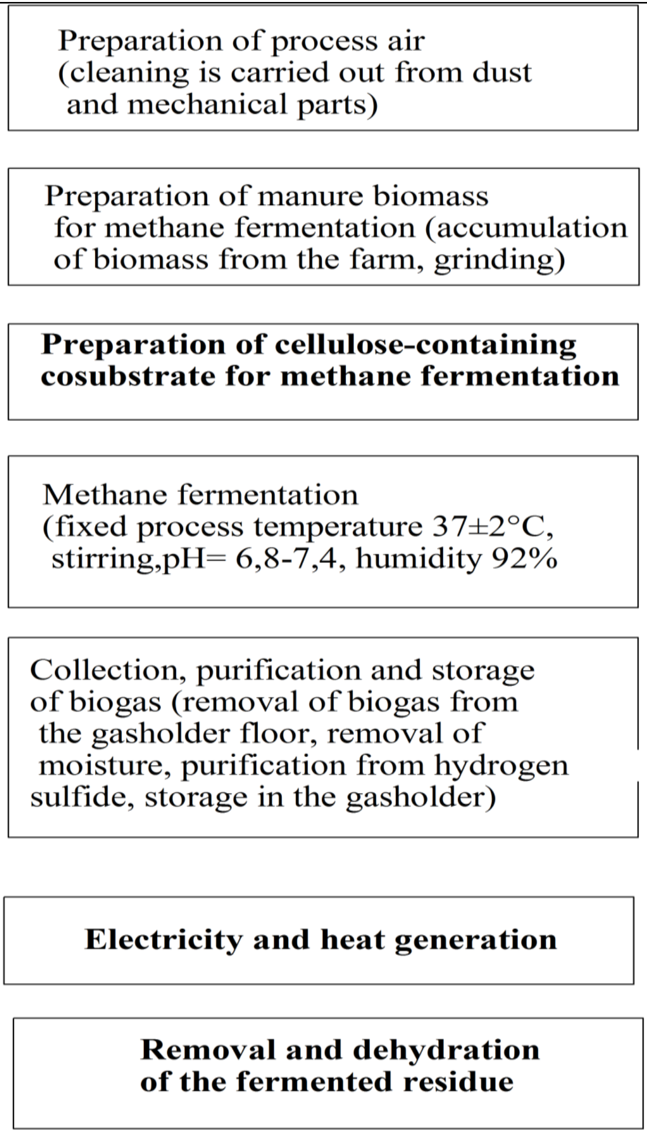

Fig. 4. Technological process of biogas production

The first stage of work is the preparation of process air, during which there is a mechanical cleaning of dust and inclusions of various origins.

Various methods are used in industrial air purification, including mechanical methods (cyclones, dust collectors, filters), the use of antiseptics, elevated or reduced temperatures, ultraviolet radiation and ionizing radiation.

Then carry out the preparation of waste from the farm for disposal by methane fermentation. Manure preparation is an integral part of the technological process, as it affects the parameters of methane fermentation and the yield of biogas as a result.

With the help of pumps, manure is removed from the farm and fed to the drives. Accumulation takes place in warehouses to provide the required volume of substrate for loading into the reactor for a period of several hours to two days. Storage parameters depend on the availability of raw materials and reactor capacity. The area required for storage depends on the volume of the substrate. The presence of odors from storage should be minimal. This can be achieved by placing ventilation systems.

Mechanical treatment of organic waste from agricultural production involves the grinding of solid substrates. Crushers with blades are more often used.

The process of transporting manure and vegetable raw materials to the premixing reactor from the reservoirs is carried out using screw conveyors and screw pumps. Balancing the substrate in terms of nutrient content and C: N ratio is done by mixing pig manure and vegetable raw materials using a paddle mixer.

Methane bacteria can live and multiply when the substrates are sufficiently dissolved in water (at least 50% water). Therefore, technical water is added to the substrate so that the dry matter content in it was 5-15% for the optimal fermentation process. The temperature inside the reactor is maintained at 25 ° C, the pH is 4.5-6. At this stage, the breakdown of high molecular weight organic substances (proteins, fats, carbohydrates) into low molecular weight (sugars, amino acids, fatty acids and water) using exoenzymes of aerobic bacteria.

Then the substrate actually enters the methane tank, where the process of methane fermentation takes place. Anaerobic fermentation is a multi-stage process carried out by several functional groups of bacteria that interact closely with each other. According to food needs, bacteria that carry out methanogenesis are dividedinto 3 types: hydrolytic (acetogenic), homoacetate and actually methanogenic. Hydrolytic bacteria undergo enzymatic cleavage of complex water-insoluble organic polymers - proteins, lipids and polysaccharides. Homoacetate bacteria carry out symbiotic acetogenic dehydrogenation of fatty acids with a longer chain (than acetic acid), a chain (propionic, butyric, benzoic), which is the limiting stage in the formation of methane. Syntrophic microorganisms are represented by both obligate and facultative anaerobes *(Synthrophobacter, Syntrophomonas, Desulfovibro*), their microbiology is not fully understood. The process of decomposition by these bacteria of organic acids and alcohols into hydrogen and acetic acid can be carried out thermodynamically only at very low concentrations of hydrogen.

Methanogens are a group of microorganisms that differ greatly from all others in their properties, physiology and biochemistry. They are characterized by a very low growth rate, are extremely sensitive to environmental conditions and require, above all, the absence of dissolved oxygen and other oxidants in the environment.

To intensify the fermentation process, so that bacteria can work well in a single-stage anaerobic process, it is necessary to create certain technological parameters and living conditions that will provide the most favorable conditions for the formation of biogas. Methane bacteria can live and multiply when the substrates are sufficiently dissolved in water (at least 50% water). Unlike aerobic bacteria, yeast and fungi, they cannot exist in the solid phase.

In General, the anaerobic process of cleavage of organic substrates provides a significant number of microorganisms. About 50% of bacteria are aerobic or optionally aerobic, well tolerate oxygen. Therefore, the small amount of oxygen that penetrates when opening the inspection holes is not harmful. The presence of light slows down the fermentation process. It is possible to eliminate the influence of light on the process in practice by using an opaque cover.

The following ratio of nutrients C: N = 30: 1 can be taken as a guide for mixing substrates. The reactor is loaded according to the selected ratio of components and duration of fermentation in automatic mode (transition to manual control mode is allowed). The process proceeds at pH = 6.8–7.4, which is controlled by a built-in pH meter and humidity of 92%, which is controlled by a stationary moisture meter. Maintaining the temperature in the reactor is performed by heating with hot coolant. In order to ensure a stable fermentation process, the sludge and the remains of the fermented mass are periodically shipped from the reactor.

Dehydrated sludge (humidity about 75-80%) is subjected to drying. Drying of biofertilizers allows to use more fully the potential of the biogas plant and increase its profitability.

Biogas generated during fermentation enters the gasholder, which performs the function of gas accumulation before its purification. Biogas composition: 55-75% methane, 25-45% CO_2, minor impurities of hydrogen (H_2) and hydrogen sulfide (H_2S), nitrogen, aromatic hydrocarbons, halogen-aromatic hydrocarbons. Therefore, before supplying biogas to the gas network, it is necessary to prepare and purify.

Biogas purification is the removal of CO_2 and H_2S. The most common is rinsing with water under pressure, which is based on the different solubility of carbon dioxide in water. Biogas is first compressed to 3 bar, and on the next compressor - to 9 bar, after which the countercurrent flows through a water-filled absorption column. Hydrogen sulfide, carbon dioxide, ammonia and dust dissolve in the column in water. These substances are removed from the system after reducing the water pressure.

The primary purification of biogas from water usually occurs when the gas is cooled to ambient temperature. This occurs in the gasholder and pipelines.

The purified biogas is stored in gasholders, which are made in the form of a bag made of high-strength PVC resistant to temperature changes. The gas pressure inside the gasholder is 0.5 MPa, up to 4000 m^3.

The obtained purified biogas is fed to the gas distribution network.

As biogas has no odor, flavorings must be added to detect leaks. Organic substances containing sulfur are used for this purpose: mercaptans or tetrahydrothiophenes. The addition occurs by injecting the substance into the pipeline.

Also, biogas entering the network must have the same energy value as natural gas. The measure of this is the caloric content, relative density and Wobbe number. Regulation of characteristics occurs by addition of air (at high caloric content) or liquefied propane-butane gas (at low caloric content).

Biogas production is not possible without a clear organization of production control (Table 4), the availability of qualified personnel, laboratory instruments, measuring equipment.

Table 4

Checkpoints on biogas production

Stage of the process	Controlled parameter	Frequency of control	Norms of technological parameters	Control methods
Air intake from the atmosphere	Temperature	Constantly	20˚C <T 40˚C	Thermometer
Air filtration	Pressure	Constantly	p = 6kPa	Manometer
Obtaining a substrate for fermentation	The level of filling the collection; temperature; pH of the medium	Constant pH and temperature, level - at loading	K_l = 0.8, t = 25° C, pH = 4.5-6.0	Level gage, pH meter, Thermocouple
Methane fermentation	The level of filling the collection; temperature; pH	Constant pH and temperature, level - at loading	K_l = 0.8 t = 37°C pH = 6.8-8	Level gage, pH meter, Thermocouple
Dehydration on a filter press	Pressure	Constantly	P = 0.1-0.2 MP[a]	Manometer
Drying of the solid fraction of sludge	Temperature	Constantly	T = 130 ° C	Thermocouple
Accumulation of biogas in a wet gasholder	Pressure in the gasholder	Constantly	10 kPa	Manometer
Purification from carbon dioxide and hydrogen sulfide	Pressure, water temperature, hydrogen sulfide concentration	Constantly	P = 1.2 MPa, T = 10 ° C, C <0.2 g / m^3	Manometer, thermometer, gas analyzer
Condensation in gas pipelines	Water temperature	Constantly at the entrance to the heat exchanger	T = 5 ° C	Thermometer
Accumulation of purified biogas	Pressure	Constantly	P = 1.2 MPa	Manometer
Adaptation of energy value	Concentration	Constantly	Q = 31.8 MJ / m^3	Gas analyzer

Conclusions. Biogas production allows to solve a number of important tasks, in particular the utilization of organic waste. The most optimal is the joint processing of waste from livestock and food companies. The most important factors influencing the productivity of biogas plants are the correct selection of raw material components and its preparation for fermentation. In such an approach, it is proposed to use pig manure and cellulose-containing vegetable raw materials, in particular sugar and juice production wastes, as raw materials.

The combined use of pig manure and cellulose-containing raw materials leads to a balanced substrate in the elemental composition, which contributes to the development of the association of microorganisms, the availability of biomass for fermentation and a higher percentage of processed biomass. Technological scheme of biogas production from raw materials of combined composition provides for preparation of process air, preparation of organic raw materials, methane fermentation, purification and storage of biogas.

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ЗАБЕЗПЕЧЕННЯ ДОСТУПНОСТІ ІНФОРМАЦІЇ У ЦЕНТРІ ОБРОБКИ ДАНИХ НА ОСНОВІ БАЛАНСУ ПРОДУКТИВНОСТІ СИСТЕМИ

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ENSURING AVAILABILITY OF INFORMATION IN THE DATA PROCESSING CENTER ON THE BASIS OF SYSTEM PRODUCTIVITY BALANCE

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