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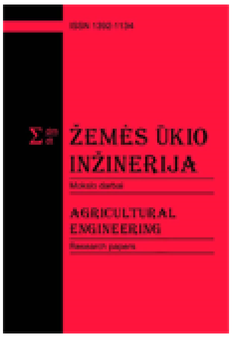

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The journal of ***Agricultural Engineering*** is a research journal published by Vytautas Magnus University Faculty of Engineering. It is an international medium for the publication of multidisciplinary and interface between agriculture engineering and other fields of science works. Language of publication are English.

The ***Aim*** of ***Agricultural Engineering*** publish original unpublished research papers dealing with mechanization of cropping and animal husbandry; green energy engineering; development, maintenance and reliability improvement of agricultural and other machinery; development of agriculture and other problems related to areas covered by agricultural engineering and interface between agriculture engineering and other fields of science.

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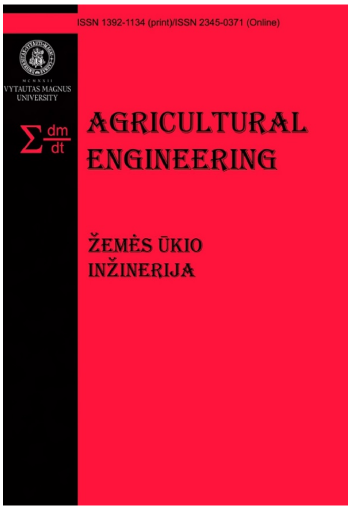

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AGRO-TECHNOLOGICAL ASPECTS OF PRODUCTION OF DIGEST AS FERTILIZER

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Abstract

The deficit and dependence on imported energy resources, mineral fertilizers, their price growth, negative changes in climatic conditions, pollution of water resources, air and soil, withdrawal of a large part of agricultural land due to hostilities aff ect the functioning of the agricultural sector. This creates threats to ensure food, energy and environmental security of Ukraine. As part of the implementation of the Sustainable Development Strategy in Ukraine, which is based on ensuring national interests and fulfilling international obligations, it is envisaged to overcome the imbalances that exist in particular in the environmental sphere, to harmonize global climate change trends with international standards. The priority is land resources, agriculture, forestry, water resources, bioenergy, biodiversity. The scientific article examines the provision of rational use of natural resources thanks to effective waste management. The concept of a resource-saving agro-industrial complex was formed due to the development and implementation of bio-organic technologies for growing agricultural crops for the production of biofuels from agro-biomass and animal husbandry waste. The agro-technological aspects of ensuring the energy independence of the industry and the formation of the country's food security have been proven. The main areas of effective use of agrobiomass and utilization of agricultural waste for the production of biofuels have been determined. On the basis of the researched state of supply of energy resources of the agricultural industry and assessment of the available potential of the industry in agrobiomass, the theoretical volumes of biofuel production to ensure the energy independence of the industry are calculated. A comprehensive analysis of the European experience in the production of biogas from crop and livestock waste and the use of digestate obtained on the basis of anaerobic fermentation in a biogas plant has been developed.

The purpose of the study is the analysis of agro-technological aspects of digestate production, taking into account the international experience of adaptation to climate change in order to guarantee the reduction of the degradation processes of the soil cover of Ukraine.

The subject of analysis was bio-organic technologies of digestate production with the intention of using it as fertiliser.

The study research methodology is based on experimental studies of scientific topics: «Development of bio-organic technologies for growing agricultural crops for the production of biofuels and ensuring the energy independence of the agricultural sector».

Keywords: global climate change, land resources, agriculture, digestate, biogas, bioenergy, biodiversity.

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1. Formulation of the problem

The deficit and dependence on imported energy resources, mineral fertilizers, their price growth, negative changes in climatic conditions, pollution of water resources, air and soil, withdrawal of a large part of agricultural land due to hostilities affect the functioning of the agricultural sector. This creates threats to ensure food, energy and environmental security of the state. The implementation of applied scientific research will involve the development of bio-organic technologies for growing agricultural crops for the production of biofuels and ensuring the energy independence of the agricultural sector. Applied scientific research will be implemented in accordance with the directions of the Strategy for Environmental Security and Adaptation to Climate Change until 2030, the Strategy for Energy Security for the Period Until 2035; The Energy Strategy of Ukraine for the period until 2035 Security, Energy Efficiency, Competitiveness, the Law of Ukraine «On Amendments to Certain Legislative Acts of

Ukraine Regarding the Creation of Conditions for Ensuring Food Security in Martial Law», European Green Deal [3, 13, 40], which will contribute to the fulfillment of obligations of Ukraine regarding European integration aspirations.

As part of the implementation of the Sustainable Development Strategy in Ukraine, which is based on ensuring national interests and fulfilling international obligations, it is envisaged to overcome the imbalances that exist in particular in the environmental sphere, to harmonize global climate change trends with international standards. The priority is land resources, agriculture, forestry, water resources, bioenergy, biodiversity in accordance with the directions of the Strategy for Environmental Security and Adaptation to Climate Change until 2030, the Law of Ukraine «On the Basic Principles (Strategy) of the State Environmental Policy of Ukraine for the Period Until 2030» ; Energy security strategies for the period up to 2035; European Green Deal (European Green Deal); the Project of the Sustainable Development Strategy of Ukraine until 2030; Provisions of the «Economic Strategy of Ukraine 2030» (in the context of responses to risks in the field of agro-industrial production); The Law of Ukraine «On Amendments to Certain Legislative Acts of Ukraine Regarding the Creation of Conditions for Ensuring Food Security in the Conditions of Martial Law» [3, 13, 40].

Regular application of fertilizers in them helps to maintain the health of the soil. The use of mineral fertilizers made it possible to intensify agricultural production, make it more predictable and, accordingly, economically feasible.

One of the main factors in restoring the fertility of Ukrainian lands is organic fertilizers: plant residues, by-products, siderates, etc. The introduction of organic matter improves the agrochemical, physical, and water-air properties of soils [1, 2, 19]. From the point of view of the legislation of Ukraine (Law of Ukraine "On Pesticides and Agrochemicals") [13], agrochemicals are organic, mineral and bacterial fertilizers, chemical meliorants, plant growth regulators and other substances used to increase soil fertility, yield of agricultural crops and improve the quality of plant products. Therefore, having fertilizing properties when applied to the soil, digestate formally falls under the concept of agrochemicals. In addition, digestate is a special type of organic fertilizer because it has a variable composition throughout the year and from year to year. This is due to the difficulty of maintaining stable technological regimes during the operation of biogas plants. Due to the variability of digestate composition, its state registration as conventional fertilizers is practical nonsense [3, 16, 35].

The authors of the project on the topic: «Development of bio-organic technologies for growing agricultural crops for the production of biofuels and ensuring the energy independence of the agricultural sector» have considerable experience in research related to rational nature management, the development of land reclamation measures taking into account the concepts of rational nature management, which ensure the optimization of land use, as well as the biologicalization of agriculture. The scientific research of the authors has been commercialized, in particular, contracts have been concluded for the performance of research within the framework of farm contract topics. The executive of the team of authors participates in the implementation of the scientific work «Development of methods for improving the technology of growing legumes using biofertilizers, bacterial preparations, foliar feeding and physiologically active substances» (state registration number 0120U102034).

The research methodology is based on experimental studies of scientific topics: «Development of bio-organic technologies for growing agricultural crops for the production of biofuels and ensuring the energy independence of the agricultural sector».

Conceptual foundations of sustainable development, «green» economy, and circular economy were the methodological basis of the study. The basis of the research is the case-study method – qualitative research in the social sciences, which consists in the study of a single social object (situation, event, incident, person, social group) or several demonstrative objects in order to understand a wider class of similar cases (class of events). The basis is a successful case – the practice of biofuel production from agrobiomass and the use of a by-product – digestate during the cultivation of agricultural crops at individual agricultural enterprises of the Vinnytsia region and Ukraine, which is recommended for implementation by other agricultural enterprises.

2. Study Subject Analysis

Scientifically oriented aspects of the basics of global climate change, land resources, agriculture, forestry, water resources, bioenergy and biodiversity are highlighted in the works of Ukrainian and foreign scientists. Theoretical, methodological, methodical and instrument provisions of soil conservation and ecological safety of rational nature management of bioecosystems Mazura V.A. aimed at greening agriculture at the expense of limited resource provision due to climate change [1].

Scientifically oriented aspects regarding the foundations of economic and energy autonomy of agricultural enterprises, refusal to purchase mineral fertilizers, additional profit, ecological effect, etc. were substantiated by G.M. Kaletnik. etc. (2019) [2]. On the basis of research carried out by Honcharuk I.V. (2020) established the provision of energy independence of agricultural enterprises and the agricultural sector in general, ecological disposal of agricultural waste, reduction of carbon dioxide emissions, increase in the yield of agricultural crops, increase in soil fertility, reduction in soil acidity, reduction in the cost of applying mineral fertilizers due to the introduction of digestate and increase in profitability agricultural enterprises [3]. Tsytsiura Y.G. proves that biological agriculture can contribute to soil conservation, especially for the cultivation of sideral crops [4]. Amanpreet S. and others. (2020) proposed models of organic crop rotations with elements of biologization when they are saturated with leguminous crops, and also made proposals for the comprehensive development of the field of organic production [5]. Nosheen, S. and others. (2021) summarized the results of using biofertilizers of organic origin to preserve soil fertility [6]. Chabanyuk Y.V. (2018) substantiates the results of the comparison of correlation matrices of natural ecosystems, which demonstrated the formation of specific soil properties under the action of abiotic and biotic factors. With the help of a mathematical approach, it has been proven that chernozems are more stable, compared to gray forest soils, which quite easily lose their fertility due to anthropogenic influence, and also require ecologically stabilizing measures and protection during agricultural use). Issues in the field of organic and biological agriculture are covered in the works of O. Demidenko and others. Experimental studies of Shkatula Yu.M. it has been proven that the use of mineral nitrogen fertilizers, which is not coordinated with the content of fresh organic matter in the soil, leads to the destruction of the organic composition of soils, the consequence of which is a decrease in their fertility. Atudorei D. developed models of crop rotations with elements of biologization when they are saturated with leguminous crops, and proposals were also made for the comprehensive development of the grain production industry. The analysis of international and domestic scientific sources and departmental materials shows the expediency of using biotesting methods, with the use of representatives of systematic groups of different ecosystems due to limited resource provision due to climate change. Obtaining reproducible and comparable data for determining the priority areas of modernization of the environmental safety system in the context of achieving the sustainability of the development of rural areas with the subsequent assessment of their risks is possible only by using the methods recommended by the Organization for Economic Cooperation and Development (OECD), when performed in laboratories accredited in accordance with the requirements ISO/IEC 17025 and GLP. These findings will form the basis of guidelines for environmental testing in Ukraine [1-14, 21, 26].

For intensive agricultural production and complete reproduction of humus reserves in Ukraine, 320-340 million tons of organic fertilizers should be applied annually. Previously, this balance was maintained mainly at the expense of domestic livestock. Currently, on 1 ha of arable land in Ukraine, there are ten times less cattle than in the countries of Western Europe [1, 27, 39]. In recent years, an average of 17 times fewer organic fertilizers than necessary have been applied to crops. Therefore, the soil without organic substances is depleted and yields are reduced. It is known that the loss of 0.1% of humus in the soil reduces grain yield by 0.5 t/ha. If the trend continues, then in the near future Ukraine may be on the verge of a humus famine – a serious ecological disaster. And then no agrotechnical, reclamation, nature protection and organizational and economic measures will be able to restore the agrotechnical potential of the land [2, 3, 7, 28, 40]. In modern conditions of agriculture in Ukraine, the real source of organic matter is straw, stubble, stalks and other post-harvest residues, siderates, therefore it is very important to justify the price of these wastes [4, 8, 29, 38]. Soil organic matter, as an integrated indicator of its fertility, takes an active part in plant nutrition, creation of favorable physico-chemical properties, migration of various chemical elements in it, because the most important soil processes are primarily related to organic compounds [5, 6, 39].

Digestate is a product of bioconversion of organic materials in the process of methane fermentation, as a result of which complex organic matter breaks down into simpler organic compounds, mineralized substances, microbial biomass and biogas, consisting mainly of methane (55-70%) and carbon dioxide (30-45%).

A typical technology for the production of biogas from agricultural raw materials (manure, manure, corn silage, pulp, harvest residues, etc.) is methane fermentation in semi-flow type bioreactors (Fig. 1).

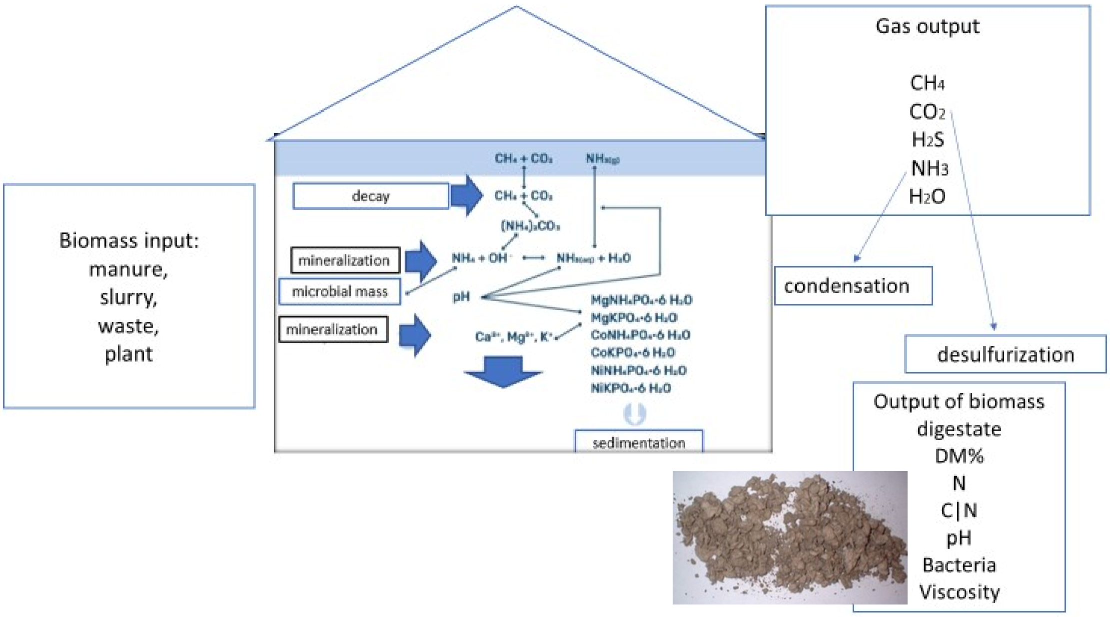

Fig. 1. Production of digestate in the process of methane fermentation

As a result of the decomposition of organic matter, mineralization processes and the release of biogas, in comparison with the input raw materials, in the formed digestate:

• The content of dry matter decreases, and accordingly the humidity increases and the viscosity decreases. The moisture content of the digestate is usually 94-96%, although it can vary in the range of 92-99%.

• The content of ammonia nitrogen (directly available for plant nutrition) increases by 10-70%. The increase in the share of ammonia nitrogen depends on its initial content in the raw material - a smaller increase during the fermentation process is characteristic of pig and cattle manure, a larger one - for food waste and vegetable raw materials.

• The C/N ratio decreases due to the release of part of the carbon with biogas. The C/N ratio at the level of 20-30, which is optimal for the process of methane fermentation, is also considered optimal for soil biocenosis.

• The content of pathogenic microflora and viable weed seeds decreases as a result of simultaneous exposure to temperature (usually 38-40ºC) and acidity in the bioreactor for a long time (at least 25-30 days).

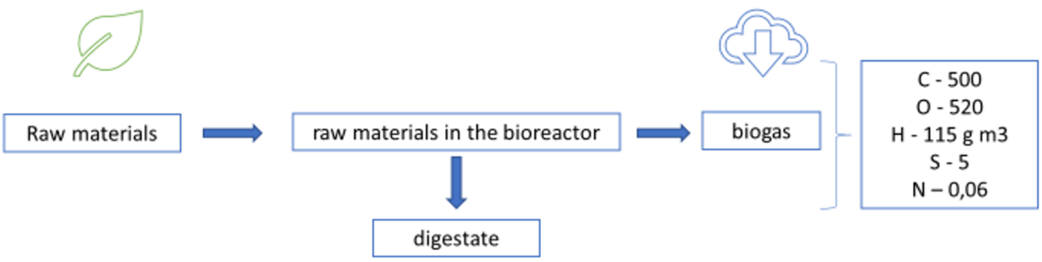

Fig.2. Average yield of C, O, H, S, N with selected biogas

In the process of methane fermentation, part of the organic matter is transformed into biogas, along with which the content of carbon (C), hydrogen (H), oxygen (O), sulfur (S) and nitrogen (N) in the composition of the raw material decreases. With each allocated 1 m3 of biogas, the input raw material loses an average of 500 g of carbon, 115 g of hydrogen, 520 g of oxygen, 5 g of sulfur and only 0.06 g of nitrogen (Fig. 2).

A significant part of the sulfur can be returned to the digestate, if purification from hydrogen sulfide is provided in the under-dome space of the bioreactor. If the desulfurization of biogas takes place in a separate facility, the efficiency of hydrogen sulfide removal is much higher, and the formed sulfur-containing product (in a solid or liquid state) can be a commercial product, for example, for the production of complex mineral or organo-mineral fertilizers. All other input macro- and microelements in the composition of native or transformed compounds are contained in the formed digestate. Therefore, the chemical composition of the digestate is determined mainly by the mixture of components entering the bioreactor, including raw materials for biogas production and various additives (enzymes, micro-nutrients, reagents, water, etc.) [9, 37].

Thus, the digestate has the following important characteristics for soils and agricultural production:

1. Contains a complex of macro- and micronutrients necessary for plant growth (N, P, K, S, Co, Mo, Zn, Fe, Mn and others).
2. It has a high content of readily available nitrogen for plants (60-80% of the total nitrogen content). It has a balanced C/N composition (20-30).
3. It has a pH level close to neutral (6.5-8.0).
4. Does not contain (minimum content) viable weed seeds and pathogenic microflora (provided the required duration and temperature of the process are observed).

The simplest way to use «raw» digestate as an organic fertilizer or soil conditioner is to apply it directly to the fields without any pretreatment. However, this practice has a number of disadvantages and limitations, and therefore is not widespread [18, 20].

Biogas plants, as a rule, work continuously throughout the year, which determines the need to accumulate digestate for the periods between autumn and spring applications to the fields. Long-term storage in leaky tanks (lagoons) leads to sedimentation of solid particles and their accumulation [21, 35] With the increase in the mass of «undigested» organic substances during long-term storage of digestate, emissions of greenhouse gas, methane, into the atmosphere increase proportionally (up to 5-10% of potential in raw materials). In addition, given the often rather high content of coarse particles in «raw» digestate, there are technical limitations in its distribution in soils, effectively leaving room only for surface spraying or spilling. At the same time, a significant part of easily available nitrogen for plants is lost, and unpleasant odors spread over large areas. Considering this, pre-treatment of «raw» digestate is necessary in most cases [19, 23, 25, 33, 36].

As a rule, the first stage of processing «raw» digestate at most biogas plants is to separate it into solid and liquid fractions, mainly in screw-type separators. At the same time, the volume of the liquid fraction can be reduced by 10-20%, depending on the type of input raw material and the type of separator. Separation leads to the formation of two products with different functionality: 1) a solid fraction with a dry matter content of 20-40%, enriched with carbon and phosphorus, and 2) a liquid fraction with a dry matter content of 1-8%, enriched with nitrogen and potassium [1, 2 , 8, 12, 13, 17].

3. Setting out the Basic Material

Digestate is a highly effective organic fertilizer that passes through stages of fermentation, destruction of harmful substances, has useful elements for plants and soil.

Currently using modern technologies to obtain biofertilizers can be used to process various types of organic waste.

Main types of waste:

1. cattle manure (cattle);
2. chicken droppings;
3. pig manure;
4. sugar beet tops;
5. straw and grass;
6. forestry waste;
7. sediment and wastewater;
8. dairy waste (lactose, whey).

Wastes of animal and bird origin are the most valuable organic fertilizers, which include liquid and solid excretions of animals. They contain important elements for the growth and nutrition of plants (Fig. 3).

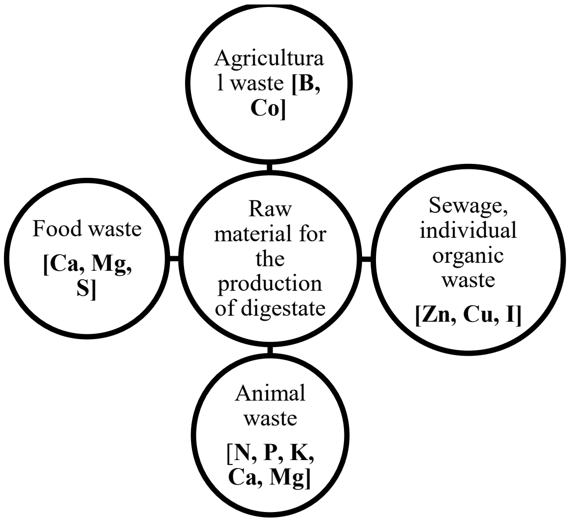

Fig. 3. Raw materials that can be used to produce digestate and important elements for the plant's nutrition
** Source: the figure was created by the author based on the data of the State Statistics Service of Ukraine and the Institute of Soil Science and Agrochemistry*

For example, waste from agricultural enterprises, livestock complexes, poultry farms, food and processing industries, and generally various types of plant and animal waste are used for biogas production. First of all, this applies to waste prone to the process of biodegradation. Today, biogas is mainly produced by from by-products of vegetable and animal origin: silage mass, beet pulp, liquid manure, chicken droppings with litter, etc.

Biogas obtained from biomass is used as a fuel that is not harmful to the environment, as it does not cause additional emissions of the greenhouse gas CO_2 and reduces the amount of organic waste. Unlike wind energy and solar radiation, biogas can be obtained regardless of climatic and weather conditions. Manure is the main organic fertilizer in all regions of Ukraine. It is a mixture of solid and liquid secretions of agricultural animals (chicken droppings, manure of cattle and pigs), with bedding (solid fraction) and without it (liquid manure). Straw, sawdust, etc. serve as litter. Manure has all the useful elements that plants need.

The quality of manure may depend on the species of animals, the composition of feed, the amount and quality of litter, the method of accumulation and storage conditions (table 1).

Table 1. Chemical composition of litter-free manure of different types animals,%

Indexes medium content	Cattle	Pigs	Chickens
Dry matter	10,00	10,00	20,00
Organic substances	6,80	7,70	14,90
N	0,40	0,65	1,52
P	0,06	0,14	0,61
K	0,46	0,27	0,50
Ca	0,21	0,25	1,04
Mg	0,05	0,07	0,11
Na	0,06	0,08	0,12
pH	7,8	6,7	6,8

Organic fertilizers (bedding manure, manure, bird droppings) are collected and stored in special places: manure storage, storage for bird droppings, sites to prevent the infiltration of biogenic elements and toxic substances to the groundwater level. If the dry fraction of manure contains more than 30%, it is stored in the sides, and to prevent the evaporation of nutrients, they are covered with a film or a layer of straw. Litter-free manure is collected in large quantities on farms and livestock complexes.

Organic matter serves as a powerful energy material for soil microorganisms, which is why its application in the soil activates nitrogen-fixing and other microbiological processes. Tables 2 and 3 show the chemical composition of biological fertilizers.

Table 2. Chemical composition of biofertilizers from the biogas plant. Solid fraction 75% moisture*, kg/t

Biofertilizer (fermented mass)	**Chemical composition**				
	N	**NH_4-N**	**P_2O_5**	**K_2O**	**MgO**
Pig manure	6,3	1,8	5,5	6,2	1,7
Bird droppings	17,1	3,4	10,5	8,6	4,3
Grass silage	3,2	1,1	1,5	4,4	0,7
Corn silage	3,1	1,2	1,2	4,1	0,9
Sugar beet tops	2,1	1,2	1,1	3,6	0,8
Grain waste	8,7	2,1	5,7	5,6	1,2
Rapeseed meal	5,3	-	3,5	5,4	3,2

The value of biological fertilizer also lies in the fact that when the manure ripens, it gets rid of some of the nitrites and nitrates that are excessively contained in the manure of birds and domestic animals. In the fermentation process, they are fermented to ammonia and methane. Useful phosphorus, potassium and nitrogen contained in the fermented mass remain completely in biological fertilizers.

Table 3. Chemical composition of biofertilizers from a biogas plant. Liquid fraction 95% humidity

Biofertilizer (fermented mass)	**Chemical composition**				
	N	**NH_4-N**	**P_2O_5**	**K_2O**	**MgO**
Pig manure	3,3	2,3	2,4	2,3	0,9
Bird droppings	8,7	3,4	5,6	7,6	2,1
Grass silage	2,2	0,6	0,8	2,1	1,0

With traditional methods of preparation of organic fertilizers (composting) nitrogen losses reach 30-40%. Fourfold processing of anaerobic manure – compared to unfermented manure – increases the content of ammonium nitrogen (20-40% of nitrogen is converted into ammonium). As a result, compared to ordinary manure, in equivalent doses, the yield increases by 10-20%. The high profitability of biogas technologies is ensured by the simultaneous production of highly effective organic fertilizers, 1 ton (due to the impact on agricultural crops) corresponds to 70-80 tons of natural waste from livestock and poultry farming. Biosludge can be divided into two fractions: liquid and solid with the help of screw separators. Both are fertilizers.

After processing by a biogas plant, biofertilizers have the following advantages:

1. absence of pathogenic microflora;
2. maximum accumulation and preservation of nitrogen-containing compounds;
3. absence of weed seeds;
4. lack of storage period;
5. ecologically effective impact on the soil;
6. resistance to leaching of useful elements from the soil.

Fermented materials improve the physical properties of the soil.

Mineral components are a source of energy and nutrition for underground microorganisms, improve the assimilation of nutrients by plants. This biological fertilizer contains many organic substances that contribute to increasing the permeability of the soil and its hygroscopicity, improve the general condition of the soil and prevent the occurrence of erosion.

Biofertilizers are also the basis for the development of microorganisms. With their help, nutrients are transformed into a form that is easily absorbed by plants. Digestate accelerates seed germination, rapid plant survival, and reduces stress during transplanting.

Due to increased anthropogenic impact on soils, they acquire the relevance of methods that make it possible to detect signs in time anthropogenically caused soil degradation of natural ecosystems and agroecosystems. Recently, the active use of microbiological and biochemical methods of biodiagnosis of anthropogenic disturbances in soils is associated with the rapid reaction of microorganisms to any deviations from the norm in the environment. Degradation phenomena in soils primarily affect biological objects, in particular microorganisms, which leads to a decrease in biological activity and, as a result, soil fertility. In addition, the physical, physico-chemical and chemical characteristics on which soil diagnostics are based are quite conservative and reflect changes in soil properties under the intense or prolonged action of negative anthropogenic factors, when they become noticeable and even sometimes irreversible.

The most important role in maintaining the ecological balance in the soil is played by the supply of humus, which is a nutrient medium for microorganisms that stimulate plant nutrition and their growth processes.

The basis of natural humus is the remains of organic plant substances: fractions that have decomposed the least, fractions that are still decomposing, complex substances obtained as a result of hydrolysis and oxidation of organic substances, which are the result of the viable activity of microorganisms.

Humus includes humic acids, fulvic acids and salts of these acids, as well as humin. Humic has a significant specific surface (600-1000 m^2 / g) with a high adsorption capacity. After adding a small amount of humus to the soil, compared to other fertilizers, not only the chemical composition and qualitative physical and chemical characteristics of the soil changes, but also the composition and structure of the microflora, which, in turn, leads to a change microbiological regime in the soil, activating the processes of transformation of matter and energy. As a result, metabolic processes accelerate, new cycles of microflora development are included, in particular, the activity of nitrogen-fixing bacteria increases.

Humic substances resulting from the decomposition of organic substances actively participate in all important processes of soil formation and form its fertility. The main indicator of soil humus is the content of organic matter, as it significantly improves the physical, chemical and biological properties of the soil, and contributes to fertility. The humic materials produced during fermentation in the methane tank improve the physical properties of the soil: aeration, water retention and soil infiltration, as well as the rate of cation exchange (Table 4).

Table 4. Normative indicators of humus for various organic of waste (kg of humus in 1 ton of substrate)

Substrate	Dry matter content,% (in fresh mass)	Humus content, kg (in 1 t of fresh mass)
Fermented mass (liquid fraction)	4 - 10	6 - 12
Fermented mass (solid fraction)	25 - 35	36 - 54
Filtration sludge	10 - 20	10 - 15

When using humus, a significant increase can be achieved yield and its quality. Wheat yields 15-20% more, corn – 20-30%, potatoes up to 30%, sugar beet up to 20%.

Biohumus has many advantages:

1. increases moisture resistance and moisture capacity;
2. mechanical strength of granules;
3. does not contain weed seeds;
4. contributes to the development of a large number of various useful microorganisms, the formation of antibiotics, enzymes;
5. does not have a harmful effect on the soil.

In Ukraine and in Western countries, biohumus is divided into three fractions. Each of them has its own function: the smallest is used for «treatment» of plants, because it is easily absorbed by plants, promotes the development of small roots; small – for feeding greenhouse and garden crops (flowers, vegetables), large – in horticulture and crop production. In many countries (Denmark, Germany, India, China) since the 1990s, a number of tests have been conducted, the results of which show a significant increase in yield when using digestate as fertilizer.

It was calculated that the use of biogas technology for the processing of organic substances allows not only to completely eliminate the threat to the environment, but also to obtain an additional 95 million tons of standard fuel annually (about 60 billion m^3 of burning methane or biogas, 190 billion kWh). and more than 140 million tons of highly effective fertilizers, which would significantly reduce the extremely energy-intensive production of mineral fertilizers (about 30% of all electricity consumed by agriculture) and help avoid secondary soil acidification, which is often caused by excessive application of nitrogen and phosphorus fertilizers.

4. Conclusions

The research methodology was based on experimental studies of scientific topics «Development of bio-organic technologies for growing agricultural crops for the production of biofuels and ensuring the energy independence of the agricultural sector». It has been established that with traditional methods of preparing organic fertilizers (composting), nitrogen losses reach 30-40%. Therefore, four-fold processing of anaerobic manure – compared to non-digested – increases the content of ammonium nitrogen (20-40% of nitrogen is converted into ammonium). As a result, compared to ordinary manure, in equivalent doses, productivity increases by 10-20%. Therefore, the high profitability of biogas technologies is ensured by the simultaneous production of highly effective organic fertilizers, 1 t (due to the impact on agricultural crops) corresponds to 70-80 t of natural waste from livestock and poultry farming.

Thus, the digestate has the following important characteristics for soils and agricultural production:

Contains a complex of macro- and micronutrients (N, P, K, S, Co, Mo, Zn, Fe, Mn and others) necessary for plant growth. It has a high content of readily available nitrogen for plants (60-80% of the total nitrogen content), balanced C/N composition (20-30), a pH level close to neutral (6.5-8.0).

Does not contain (or minimum content) viable weed seeds and pathogenic microflora (provided the required duration and temperature of the process are observed).

Research has established that when using humus, it is possible to achieve a significant increase in the yield and its quality: wheat yields 15-20%, corn – 20-30%, potatoes – up to 30%, sugar beet – up to 20%.

As a conclusion, it was determined that the use of biogas technology for the processing of organic substances allows to completely eliminate the threat to the environment, namely to obtain an additional 95 million tons of conventional fuel annually (about 60 billion m^3 of burning methane or biogas), 190 billion kWh). and more than 140 million tons of highly effective fertilizers, which would allow to reduce the energy-intensive production of mineral fertilizers by 30%.

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