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ECOLOGISATION OF THE FOOD INDUSTRY THROUGH THE INTRODUCTION OF VERMICULTURE TECHNOLOGY IN AGRICULTURE

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Food plays an important role in the life of every person, but at the same time, it has a negative impact on the environment. The use of traditional technologies for the production of raw materials for food products and outdated production equipment leads to the ingress of hazardous substances and impurities into the final product or the formation of harmful substances during the production process and their release into the environment.

The article emphasizes the main factors that are at the forefront of greening the food industry. The food industry has a harmful impact on the environment, polluting the air, water and land resources with harmful emissions and production waste, and leads to soil degradation. Since the food industry is a link in the food chain, it causes the impact of hazardous and harmful substances that can accumulate in raw materials of plant and animal origin on human health through their ingestion. It has been proposed a comprehensive approach to greening the food industry and solving environmental problems of society through the transition to 'environmentally friendly' technologies on the example of vermiculture technology.

Using this technology, organic waste of plant origin can be effectively disposed of using earthworms, and transformed into complete animal proteins and biologically active substances, accelerating the process of humus formation in the soil, significantly improving the ecological condition of the soil.

The process of cultivating worms in an organic substrate produces a high-quality organic fertilizer (vermicompost or bio humus) containing a full range of macro- and microelements necessary for agricultural plants during their growing season.

The use of vermiculture technology in agriculture allows for continuous use of soils without reducing their fertility. The microorganisms in vermicompost contribute to the conversion of toxic forms of heavy metals into inactive compounds. This factor can be used to improve the environmental condition of land resources near large transport networks and around industrial cities.

The experience of the world's leading countries proves the effectiveness of using vermicomposting technology for bioorganic residues to improve the organic waste management system at the national, regional and community levels.

The vermicomposting technology does not require large areas, can be implemented on vermiculture farms of various sizes and configurations, which will contribute to the development of small and medium-sized businesses producing organic fertilizers. *Key words:* ecologisation, food chain, vermiculture technology, vermicomposting, bio humus, composting.

Екологізація харчової галузі шляхом упровадження технології вермикультури в сільському господарстві. Дюдяєва О.А., Рутта О.В.

Харчування відіграє важливу роль у житті кожної людини, але, в той же час, має негативний вплив на навколишнє середовище. Використання традиційних технологій виробництва сировини для харчової продукції, застарілого виробничого обладнання призводить до потрапляння небезпечних речовин та домішок у кінцевий продукт або утворення шкідливих речовин під час виробничого процесу та потрапляння їх та інших відходів виробництва у навколишнє середовище.

У статті наголошено на основних чинниках, що є передовою екологізації харчової промисловості. Харчова промисловість спричиняє шкідливий вплив на навколишнє середовище, забруднюючи атмосферне повітря, водні і земельні ресурси шкідливими викидами та відходами виробництва, приводить до деградації ґрунтів. Так як харчова промисловість являється ланкою продовольчого ланцюга вона, вона спричиняє вплив небезпечних та шкідливих речовин, які можуть накопичуватись у сировині рослинного та тваринного походження, на здоров'я людини через потрапляння їх в організм.

Запропоновано комплексний підхід екологізації харчової промисловості та вирішення екологічних проблем суспільства через перехід на «дружні до екології» технології на прикладі технології вермикультури.

За допомогою цієї технології органічні відходи рослинного походження, використовуючи дощових черв'яків, можна не тільки ефективно утилізувати, а й трансформувати в повноцінні тваринні білки і біологічно активні речовини, прискорити процес утворення гумусу в ґрунті, значно покращує екологічний стан ґрунту.

Процес культивування черв'яків в органічному субстраті дозволяє отримувати високоякісне органічне добриво (вермікомпост, або біогумус), яке містить повний набір макро- і мікроелементів необхідних для сільськогосподарських рослин під час їх вегетації.

Застосування технології вермикультури в сільському господарстві дозволяє використовувати ґрунти безперервно, не знижуючи їх родючості. Мікроорганізми, що знаходяться в вермикомпостах, сприяють переводу токсичних форм важких металів у малорухомі сполуки. Цей фактор можна використати з метою поліпшення екологічного стану земельних ресурсів біля великих транспортних мереж, навколо промислових міст.

Досвід провідних країн світу доводить щодо ефективності використання технології вермикомпостування біоорганічних решток з метою поліпшення системи поводження з органічними відходами на рівні держави, окремих регіонів та громад.

Технологія вермикомпостування не потребує великих площ, може реалізовуватись на вермифермах різних розмірів та конфігурації, що сприятиме розвитку малого та середнього бізнесу з виробництва органічних добрив. *Ключові слова:* екологізація, харчовий ланцюг, технологія вермикультури, біогумус, компостування.

Statement of the problem. The anthropogenic burden of human activity on the environment and the deterioration of its condition are among the most important problems facing society today. The intensification of industry and agriculture leads to the accumulation of heavy metals and other harmful substances in the soil. They have a toxic effect on living organisms, including humans, as they enter the human body with food.

Relevance of the study. The greening of food production is a process that concerns not so much the production, operation and disposal as the development and implementation of new technologies and new products. It is at the stage of decision-making on the transition to modern technologies and the production of environmentally friendly (safe) products that the impact on individual components of the environment, including living organisms, is analyzed and the effectiveness of environmental and preventive measures is assessed. An integrated approach to greening the industry by considering individual production stages, production in general, use and disposal processes, including environmental factors, ensures an effective solution to the pressing environmental problems of society.

Relation of the author's work to important scientific and practical tasks. The research is relevant in the context of increasing the environmental responsibility of society in relation to human activity and its impact on the environment in terms of the transition to 'environmentally friendly' technologies in food production, as well as improving the environmental awareness of the population regarding healthy and safe nutrition. Finding ways to reduce negative impacts on the environment and human health.

Analysis of recent research and publications. The issues of food safety, production and consumption of environmentally friendly products are in the focus of consideration and search for solutions by scientists and industry experts not only in Ukraine but also far beyond its borders. Food plays an important role in the life of every person, but at the same time, it has a negative impact on the environment. The use of traditional technologies for the production of raw materials for food products and outdated production equipment leads to the ingress of hazardous substances and impurities into the final product or the formation of harmful substances during the production process and their release into the environment [1]. In addition, the greening of the food industry should be associated not only with solving the problems of waste removal and neutralization and the negative effects of production, but also with preventing their occurrence.

The issue of greening the food industry is relevant due to a number of factors. Firstly, the food industry, like any other industry, has a harmful impact on the environment, polluting the air, water and land resources with harmful emissions and production waste. Secondly, as a link in the food chain, the food industry can have a direct or indirect impact on human health through the ingestion of hazardous substances. Such substances can accumulate in raw materials of plant and animal origin. Thirdly, food products may pose a threat to human health due to the use of additives, including dyes, preservatives, emulsifiers and other substances used in technological processes [2, 3].

The use of technologies that reduce the concentration or completely prevent the ingress of harmful substances from contaminated raw materials into finished products or into certain components of the environment will help reduce the negative impact on human health and the anthropogenic burden on the environment.

The development of science and industry, issues of food and nutrition security, the need to find new food resources, the emergence of new food additives, etc. outline the requirements of society to strengthen regulation and environmental assessment of various factors, including environmental factors that are hazardous to health. The development of the chemical industry leads to an increasing number of substances entering the food chain, sometimes with difficult control or uncontrolled, which in turn leads to a danger to human health and the overall environmental well-being of the environment.

Identification of previously unresolved parts of the general problem to which this article is devoted. The article has emphasized the need for an integrated approach to solving the issues of greening the food industry in combination with all components of sustainable development (environmental, social and economic). Greening of food production through the transition to 'environmentally friendly' technologies (for example, using vermiculture technology) will reduce the negative impact on the environment, improve the condition of natural resources (land, water), and the consumption of ecological products. In addition, this will help improve the management of organic waste and the development of small and medium-sized enterprises producing ecological fertilizers.

The results of the research have presented in the article prove that effective greening of food production is possible with the joint cooperation of scientists, farmers, ecologists, producers and authorities.

Novelty. The main purpose of the study is to green the food industry as a way to improve the environment and consumption of ecological products, to solve urgent environmental problems at different levels of government.

Methodological or general scientific significance. The obtained research results demonstrate the prospects for greening the food industry as a set of solutions to improve the state of the environment and all its components.

Outline of the main material. Today, the food industry is one of the main sectors of Ukraine's economy, including exports. A number of external and internal factors significantly complicate the process of its development. These include the war, the high cost of technical and technological re-equipment of production, and the

lack of a unified state strategy for comprehensive greening, which would provide for the greening of not only the production component but also the entire food chain [3]. Imperfection, and in some cases, the absence of a system of state support and financing of environmental programmes at individual enterprises and the introduction of environmental technologies. This applies to agricultural enterprises that are switching to environmental technologies, including organic ones, in order to grow environmentally friendly raw materials for the food industry. This also includes the introduction of environmental technologies at processing enterprises to produce environmentally friendly and safe food products.

Food processing companies have a negative impact on the environment, which is explained by the low level of implementation of low-waste and zero-waste technologies due to their high cost. In addition, such enterprises often have a low level of wastewater treatment and generate a large amount of production waste. The food industry has the greatest impact on water resources, being one of the leading water consumers among other industries (it ranks first among other industries in terms of water consumption per unit of output). This level of consumption leads to a large amount of wastewater generation, which is highly polluted and hazardous to the environment. Processing plants often consume more water than they process raw materials. At the same time, wastewater entering water bodies depletes oxygen reserves, which leads to the death of living organisms in water bodies. Wastewater pollutes the environment with harmful substances such as nitrogen dioxide, ammonia, hydrochloric acid, soot, difluorochloromethane, phenol, etc., which contribute to the greenhouse effect [4].

The use of environmentally friendly raw materials, the introduction of waste-free and low-waste technologies, optimization of technological processes, modernization of air emission and wastewater treatment systems, and the introduction of modern technologies for the disposal of production waste are steps that will contribute to the greening of the industry, the production of environmentally safe food products of high quality with minimal consumption of natural resources and the maintenance of a sustainable balance in the natural environment [5].

The food industry is one of the priority and strategically important sectors of Ukraine's economy. Firstly, and most importantly, food products are essential commodities, so the state of its development affects the level of food security in the country. Second, the systematic development of the industry ensures social stability in the country and its economic growth [6].

In recent years, the domestic food industry has also confirmed its export potential. Thus, as of September 2022 (six months after the start of the full-scale military invasion), every second company in the industry (53%) did not stop its foreign economic activity, and only 15% of food industry exporters were unable to resume export activities.

But in recent decades, the food industry in Ukraine, as well as in the global world, has faced two major challenges: the need to provide high-quality and environmentally safe food products to the world's population, which could reach 8.5 billion by 2030, and the need to protect the environment. The use of innovative technologies, including those aimed at improving the environmental characteristics of food products, is one of the ways to green the food industry.

This also applies to the development of the agricultural sector, which is the primary link in the food chain. The most harmful are food products made from raw materials grown in areas near transport routes and near large industrial facilities. More than 70% of all harmful substances enter the human body through food. The problem of food contamination with toxins that have an immunosuppressive effect on humans and can cause malignant tumours is very acute. The use of medicines and antibiotics used in veterinary practice leads to the presence of these substances in 15-25% of animal products. The use of pesticides and agrochemicals (fertilizers and plant protection products) in agriculture leads to excessive accumulation of nitrates and heavy metals in plant material. However, with the orderly use of agrochemicals and pesticides, reduction of chemicalization of technological processes in agriculture, it is possible to reduce the content of residual pesticides in food.

A high level of safety and quality of agricultural products provides conditions for their unimpeded entry into international consumer markets and increased competitiveness of domestic products [7].

The competitiveness of environmentally friendly products in the market depends on the use of modern 'environmentally friendly' technologies, such as organic technologies; on the system of control of agricultural products at all stages of the food chain (production, marketing); on the introduction of safety standards for agricultural and food products in accordance with international standards; on proper information support for producers and consumers; and on the use of modern methods of packaging and labeling of products [8-10].

The greening of food production and the modern environmental orientation of the development of the domestic agricultural sector can be effectively implemented through a combination of the social component of society's development for a healthy nation, the economic motivation of the producer, his responsibility and new aspects of the interest of agricultural business.

The introduction of modern principles and methods of management at all stages of agro-industrial production and consumption, including the introduction of environmental technologies, plays an important role in improving the environmental performance of agricultural raw materials and food products [11]. The first important step towards greening food production, as mentioned above, is the cultivation of environmentally friendly agricultural raw materials and their use for the production of environmentally friendly food products.

The production of environmentally friendly agricultural raw materials and food products is possible using various agroecological approaches, one of which is the replacement of agrochemicals with organic fertilizers produced using vermiculture technology [12].

Vermiculture is a modern biotechnology that allows organic waste of plant origin to be not only efficiently utilized but also transformed into high-grade animal proteins and biologically active substances. Earthworms are a key and essential component of vermiculture technology. They play an extremely important role in agriculture (Figure 1).

It is believed that the most productive soils are those where earthworms are present and breed. In a day, an earthworm passes through an amount of soil equal to its body weight. By passing soil through its intestines, the worm can 'eat' its way through dense soil. The extensive network of tunnels in the soil left behind by the worm can be up to 7,000 km/ha. This increases the area of contact between the soil and the air, and ensures the penetration of oxygen and water into the lower soil layers. After the soil passes through the worms' gastrointestinal tract, the content of assimilable nutrients in the soil increases, thereby stimulating the process of humus formation tenfold. Worms actively consume plant residues (up to 200% of their weight) [13]. In addition, earthworms are able to accumulate heavy metals in their bodies, which significantly affect and improve the ecological condition of the soil.

The use of a number of chemicals in agriculture causes the depletion of a number of natural resources. Therefore, renewable natural sources of animal raw materials, such as earthworms, are of particular importance. Earthworms are very promising objects, the use of which improves the environmental performance of agricultural raw materials by using biologically active substances of natural origin and reducing the chemical burden on the environment.

They:

– contain a very wide range of biologically active compounds;

– can be easily cultivated using a variety of organ wastes on an industrial scale, as well as in private settings;

– multiply rapidly;

– have a high coefficient of bioconversion of waste organic matter into their own biomass (up to 10%).

Vermiculture is carried out on vermiculture farms, which can be either industrial or private facilities and do not require large production areas (Figure 2).

The essence of vermicomposting is the ability to use earthworms to produce an environmentally friendly fertilizer from various organic substances – vermicompost, which contains a full range of macro- and microelements necessary for agricultural plants during their growing season. The conversion of manure and other organic waste by earthworms into complete protein and humus fertilizer is a natural process of self-regulation of the environment.

The process of bio humus formation as a result of worms processing organic waste continues throughout the year. In autumn, the working population of worms is removed from the pits and the finished substrate is selected. A new layer of 'food' 25-30 cm thick is placed on the vacant space and the worm population is returned. The place of their placement is watered, protected from the sun and drying out, and a new annual technological cycle begins. An important condition for vermiculture technology is the creation of favorable conditions for the breeding and reproduction of earthworms and microorganisms in the soil, which contribute to the natural restoration of soil fertility, which is necessary for the production of environmentally friendly agricultural raw materials and food products, as well as the protection of the environment from pollution by harmful substances [14].

Thus, the purpose of earthworm cultivation is:

– maximum conversion of organic waste into organic fertilizer (vermicompost, bio humus);

– increasing the biomass of earthworms as the most valuable source of proteins, peptides, enzymes and physiologically active substances;

Fig. 1. The appearance of earthworms in the soil

Fig. 2. Different types of vermiculture farms

– earthworms accelerate the decomposition of organic matter, which allows for the short-term conversion of organic waste into humus-rich fertilizer in an environmentally friendly way [15, 16].

The introduction of bio humus into the soil not only increases crop yields, but also increases the total number of bacteria, which intensifies microbial processes in the soil and improves the absorption of essential nutrients by plants. The positive impact of bio humus on crop yields is due to the fact that it contains the nutrients necessary for plants in a well-balanced and easily digestible mobile form. It also improves the safety and quality of agricultural raw materials, which is extremely important for the health and life of the population. In addition, the overall ecological state of the environment is improved.

The use of vermiculture in agriculture allows the soil to be used continuously without reducing its fertility. The microorganisms in vermicompost help to convert toxic forms of heavy metals into inactive compounds. This is important when applying vermicompost to soils around large cities, industrial facilities, as well as in conditions of widespread use of mineral fertilizers and pesticides, and will contribute to the improvement of these soils and the environment in general.

Another important aspect of using vermiculture technology in solving the problem of waste management (bioorganic). Today, in most European countries and the world's leading countries, the waste management system through reuse, recycling, composting, etc. allows solving urgent environmental issues of society and the environment. Composting is considered a separate type of recycling in the waste management hierarchy, when bioorganic residues are converted into humus-like substances.

The European Union has set an ambitious target of reducing the amount of waste sent to landfill to 75% of the amount in 1995 in 2010, 50% in 2015 and just over a third by 2020. Achieving this target means reducing all waste by 8 million tones. Moreover, the share of household waste that is organic and recycled or composted has increased from 18% to 45% in the twenty years since 1995.

In the European Union, the United States of America, Turkey and other countries, the requirements and regulation of the use of vermicompost as an organic fertilizer are governed by approved requirements at the level of states, municipalities and communities.

Ukraine is also actively involved in the process of recycling bio waste through composting and the use of its processing product (bio humus) in agriculture. This improves the ecological state of the environment, stimulates the introduction of organic technologies in

the agricultural sector and food production, and contributes to the greening of the industry. Today, a large number of producers are already operating in Ukraine, either composting organic waste, producing organic fertilizers based on vermicompost or growing environmentally friendly agricultural raw materials and producing environmentally safe food products. Information on producers of vermicompost and organic fertilizers is available on the website of the certification body in Ukraine, Organic Standard (https://organicstandard.ua/ru/services/handbooks-and-catalogs).

Conclusions and prospects for using the research results. The greening of food production and agricultural raw materials, as one of the important components of the food chain, is the main challenge of an environmentally conscious society. It is based, along with the rational use of natural resource potential, on the requirements to reduce the negative impact on the environment and to obtain environmentally friendly (organic) food products.

The negative impact of agriculture, which is the first link in the food chain, is observed in soil depletion, soil pollution due to the use of agrochemicals and plant protection products, accumulation of harmful substances in agricultural raw materials and contamination of food products. Therefore, an important task of greening the industry is to reduce the number of harmful substances (nitrates, pesticides, hormones, antibiotics, etc.) in agricultural raw materials of plant and animal origin and their ingress into processed food products.

The transition to and use of 'environmentally friendly' technologies is one of the steps towards greening the food industry.

Vermiculture is an environmentally friendly technology that uses earthworms to not only effectively dispose of organic waste but also transform it into high-grade animal proteins and biologically active substances, accelerating the process of humus formation in the soil tenfold. Earthworms are able to accumulate heavy metals and other toxic substances in their bodies, which significantly improves the ecological condition of the soil.

The process of cultivating worms in an organic substrate produces high-quality organic fertilizer (vermicompost or bio humus), which contains a full range of macro- and microelements necessary for agricultural plants during their growing season.

The use of vermiculture technology in agriculture allows for continuous use of soils without reducing their fertility. The microorganisms in vermicomposts contribute to the conversion of toxic forms of heavy metals into inactive compounds. Using this fact, we can significantly improve the ecological condition of land resources, especially near large transport networks, around large industrial cities, and in the context of an increase in the number of mineral fertilizers and pesticides introduced to the fertilizer market.

Using the experience of leading European and global countries, the vermicomposting technology of bio-organic residues can improve the organic waste management system, which will also help to address pressing environmental issues of society and the environment.

The vermicomposting technology does not require large areas and can be implemented on vermicomposting farms of various sizes and configurations, which will help develop small and medium-sized organic fertilizer businesses.

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