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SELECTED PAPERS

V INTERNATIONAL CONFERENCE

EUROPEAN DIMENSIONS OF THE SUSTAINABLE DEVELOPMENT and ACADEMIC – BUSINESS FORUM: LET'S REVIVE UKRAINE TOGETHER

in terms of the EU ERASMUS+ projects
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EU renewable energy strategy as a roadmap for Ukraine (101085755 – JM RE – ERASMUS-JMO-2022-HEI-TCH-RSCH), and European Union policies and best practices in academic project management (101085243 – ProEU-ERASMUS-JMO-2022-HEI-TCH- RSCH

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ECONOMIC COMPONENT OF SUSTAINABLE DEVELOPMENT

"DREAM BIG" - UKRAINE OF DREAMS AFTER VICTORY: SUSTAINABILITY, MODERNIZATION AND LEADERSHIP

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Abstract. *The article updates the macro-forecasts of Ukraine's economic development prospects for 2023-2027. The methodological matrix of the author's research on the scenario planning of the business space of post-war Ukraine in the context of two vectors of development: external (with the EU) and internal (for the EU) is determined. A well-founded structure of modeling the business space of post-war Ukraine with the selection of components: political, legal, economic, technological, ecological and cultural. Methodological and methodical aspects of the author's research matrix are based on the combination of three components of the future design process: assessment of uncertainty factors of the country's business environment, outline of the landscape of forecasted scenarios and determination of a specific toolkit of management decisions to achieve the set goals.*

According to the results of the foresight forecasting, the need is substantiated and the landscape of a unified state strategy for the reconstruction of Ukraine is outlined in the context of scenarios: its European integration and post-European integration adaptation. According to the scenario modeling, the ambitious goals are determined: capable institutions, fair justice, effective entrepreneurship, innovative technologies and an inclusive society. A substantiated and specified toolkit of management decisions to achieve the set goals: synchronization of legislation to EU Directives; legislative and personnel support of the state and corporate sector; independent anti-corruption system; an open and transparent system of monitoring the use of funds for the post-war reconstruction of the country; international transfer of capital and technologies; effective digital state; public advocacy and monitoring of changes, eco-orientation of future generations.

Introduction. The reality of Russia's prolonged military invasion of Ukraine (February 24, 2022 - the date of the invasion) continues to shock the world community. It is extremely difficult to assess the impact and consequences of the war for Ukraine. The victory of the military forces of Ukraine and the events at the front give hope for the continuation of the liberation of the territories occupied by the invaders and for victory with sufficient support from Western partners. But it is necessary to get out from the bottom: from the ruins of mutilated cities and towns, from the infrastructure destroyed by the enemy, with the crippled and impoverished population and its millions of losses, with the widespread de-professionalization of personnel. And it is necessary to start this path now, without waiting for the day of Ukraine's victory over the aggressor and in any available format. Stability, modernization and leadership should become the key triggers for the development and implementation of Ukraine's post-war reconstruction strategy.

The purpose of the research is to update the macro forecasts of Ukraine's economic development prospects for 2023-2027 with an assessment of the basic scenarios of its post-war development; development of a research matrix for modeling post-war Ukraine development scenarios and substantiation of the landscape of a unified state strategy for its reconstruction after the war in the context of European integration.

Materials and Methods. The research used methods of analysis, synthesis, methods of Foresight forecasting and theoretical generalization.

The issue of modeling forecasts of the strategic development of countries has been on the agenda for many years. The main point of this question is whether it is possible to predict the country's development strategy in conditions of uncertainty in both the external and internal environment. The author's research uses the Foresight forecasting methodology. The term Foresight is a systematic attempt to look into the long-term future of science, technology, economy and society in order to identify areas of strategic research and manifestations of innovative technologies that promise to bring the greatest economic and social benefits (Foresight, 2023).

To understand the main characteristics, key varieties, basic principles and methods used in Foresight forecasting, we will give a short section of the literature review. The difference between Foresight forecasting and other tools for the study of future development: in the orientation towards the application of specific measures and the adoption of specific decisions to shape the future; in taking into account various alternatives of the projected development in conditions of uncertainty, in involving various interested groups of actors (participants of the Foresight session); in the interdisciplinary nature of the study of a complex of factors that can determine future development scenarios. In the scientific expert environment, two areas of application of the Foresight-forecasting methodology are key. The first fundamental one is the modern methodology of technological forecasting. A striking example is the study of L. I. Fedulova (Fedulova, 2008), which describes in detail most of the previously obtained conclusions regarding the issue of forecasting scenarios of technological development, positioning and discussion of the hypothesis of their effective application. And the second is the methodology of socio-economic and market-oriented Foresight, which focuses on problems that cannot be solved and that continue in time, when the technological forecast is "attached" to options for solving a specific problem or their combination. In addition, the key emphasis is on assessing the social and cultural consequences of the manifestations and implementation of innovative technologies and the implementation of management decisions. The basic principles and most productive forecasting methods used in socio-economic Foresight scenarios are discussed in Schwarz J.O. (Schwarz, 2008).

The methodology of the research matrix is presented in Fig. 1.

The author's research methodology is based on a combination of three components of the future design process: assessment of factors of uncertainty in the country's business environment, outlining the landscape of forecasted scenarios and determining a specific toolkit of management solutions to achieve the set goals. It should be pointed out that it uses the top-down approach of Foresight - forecasting, which emphasizes the information analysis of a large number of sources and the formation of a discussion and presentation platform for the exchange of opinions, knowledge and strategic approaches between experts and persons who make management decisions.

In the author's research, the following methods of Foresight-forecasting the formation of crane strategic policy were applied: (1) - Development of scenarios (Scenarios); (2)- SWOT analysis (SWOT-Analysis); (3) - Development of the future (Futures Workshops); (4) - Road map (Road mapping); (5)- Analysis of mutual influence of factors (Cross-Impact Analysis). The author's choice was based on a preliminary assessment of their role in terms of maximum immersion in the environment of uncertainty in the context of awareness of the importance of interdisciplinary cooperation of external and internal agents of action for the development of the country, consolidation of specialists from various fields with the aim of forming development priorities and distributing the pool of funding for specific development scenarios.

Scenario planning of the business space of Ukraine: **Vectors: external (for the EU) and internal (with the EU)**		
Political space: Political regime: democracy or autocracy Interstate agreements The country's participation in political and international blocs economic unions Political parties and leaders Public organizations Business policy vector Regional government *Political stability*	**Legal space:** Consistency of the legal system of Ukraine and the EU Regulation of export-import operations Protection of property and personal rights Regulation of capital movement Regulation of creation and transformation of business Regulation of labor relations Price regulation Antimonopoly legislation The taxation system *Stability of the legal system*	**Economic space:** Economic growth: GDP, investments, foreign trade turnover, export, import Population: structure Resource Communications: transport and communication Digitization Technologies *The level of economic problems: inflation, unemployment, poverty, depressive symptoms*
Technological space: Technological policy Branch technological support Technological transfer - prices, forms, process Strategies of scientific and technical cooperation *Sustainable innovative development*	**Ecological space:** Resource Environmental legislation *Environmental preservation and restoration*	**Cultural space:** Values: social orientation – individual or group attitude to the authorities - respect or tolerance attitude to uncertainty – acceptance or non-acceptance behavioral patterns – active or passive time orientation - long-term, short... Risks *Harmony and valuable preservation*

Fig. 1. Methodical aspects of the matrix of the author's research for the Foresight forecast of the post-war reconstruction strategy of Ukraine

The key focuses of the Foresight session of forecasting post-war reconstruction scenarios of Ukraine were directed on the analysis process and the final products of the analysis.

Results and Discussion.

1. Macro forecasts of the economic development of Ukraine for 2023-2027

In the economic review "Weak grown, high inflation, and a cost-of-living crisis" of the Europe and Central Asia region from the World Bank /April 6, 2023/, attention is focused on a sharp slowdown in economic growth in 2022 (WORLD BANK, 2023). The key reasons for this situation are defined as: the Russian-Ukrainian war, rising inflation and a sharp tightening of monetary policy. A significant increase in the prices of food and energy sources caused the growth of inflation rates in the region, which were not observed in the last 20 years. According to the results of the World Bank, the poorest countries in the region of Europe and Central Asia faced higher inflation rates than the richer ones (WORLD BANK, Spring 2023).

The International Monetary Fund estimates that the outlook for global economic growth over the next five years is the worst in more than three decades. The global economy is projected to grow by about 3% over the next decade and a half due to rising interest rates (IMF, January 2023). This is the lowest medium-term global growth forecast since 1990 and less than the five-year average of 3.8% over the past two decades (IMF, April 2023).

World gross domestic product in 2023 is likely to grow by less than 3%, which corresponds to the IMF's January 2023 forecast of 2.9% (IMF, April 2023). About 90% of advanced economies will see growth slow this year due to tighter monetary policy, which is weighing on demand and slowing economic activity in the US and the Eurozone.

Regarding the prospects for the economic development of Ukraine in 2023, the Law on the State Budget of Ukraine foresees a growth of real GDP by 3.2%, although in the Project of the State Budget for the specified period the relevant indicator was determined at the level of - 4.6%.

In February-March 2023, international experts significantly lowered Ukraine's economic growth prospects for 2023 (IMF, March 2023; IMF, January 2023). It should be noted that, in general, there is a very large spread in the forecasts of Ukraine's GDP growth in forecasts from various analysts.

Thus, EBRR in its report Regional Economic Prospects UPDATE "Not out of the woods yet" significantly worsened the forecast of Ukraine's GDP growth in 2023 to 1%. Given the continuation of the Russian-Ukrainian war and the limitations of the current territory of the country, which produced less than 20% of GDP before the war, it is quite likely that the real volume of production will stabilize at the level of about 70% by the level of 2021 (EBRR, February 2023).

The World Bank presented even worse forecasts for Ukraine's GNP growth in 2023 - up to 0.5%, although in previous calculations it was 3.3%. GDP growth in 2024 is forecast at the level of 3.5%, in 2025 – 6.5%. Inflation at the end of the current year may reach 18% (WORLD BANK, Spring 2023).

According to forecasts, the highest growth of Ukraine's GDP is expected in 2025 - 6.5%, and already in 2026 - 5% and in 2027 - 4%. Inflation forecasts are as follows: in 2023, it will be 20% (that is, it will decrease compared to last year by almost 10%), in 2024 - 12.5%, in 2025 - 8%, in 2026 - 6%. According to calculations, inflation will return to the pre-war level (5% per year) only by 2027. This means that Ukrainians can expect a significant increase in prices for at least the next few years. At the same time, real wages will grow at a much lower rate. According to expert forecasts, salaries will generally decrease by 2% in 2023, increase by 2.5% in 2024, 5% in 2026, and 4% in 2027. It should be noted that IMF experts expect consumer spending to grow: by 2027, it should be 93% of pre-war levels [that is, it will grow more dynamically than GDP, which by that time will reach only 83% of the 2021 figures] (IMF, March 2023).

By the way, some economists saw a hidden meaning in these forecasts. They believe that the growth of consumer spending (and revenues to the budget, in particular, from VAT) against the background of low salaries is possible only if taxes are increased, in particular, the same tax on added value (Ksionz L., 2023). It should be noted that the IMF forecasts do not say anything about increasing tax rates in Ukraine.

The trend of increasing debt burden in 2023-2027 is alarming for Ukraine. If in 2021 the state and guaranteed debts of Ukraine amounted to 50.4% of GDP, and in 2022 to 81.7%, then in 2023 the figure will increase to 98.3%. And already from 2024 (which in general should be better for the economy than 2023) debts will exceed the size of GDP (make up 105% of GDP). By 2027, a gradual decrease in the debt burden is expected, but it will still be more than 100% of GDP [2025 - 104.1%, 2026 - 102%, 2027 - 100.2%] (IMF, March 2023).

The IMF's forecasts for investment inflows to Ukraine in 2023-2027 are very restrained - only 0.4% of GDP in 2023-2024, 2.4% in 2025, 4.7% in 2026, 4, 8% - in 2027 (IMF, March 2023). This completely diverges from the expectations of Ukrainian experts according to the "Marshall plan" for our country, which should ensure record investments and explosive growth of the domestic economy (Ksionz L., 2023). Macroeconomic forecasts of the IMF and the World Bank are usually a kind of reference point for international investors, and they are not very rosy.

Scenarios for the development of the Ukrainian economy from the IMF for 2023-2024 with detailed indicators are presented in the Table 1.

Table 1.

Development scenarios of the Ukrainian economy from the IMF, 2023-2024

Indexes	Scenarios			
	Base		Negative	
	2023	2024	2023	2024
	Military stage	Peace	Slow recovery	
GDP growth	-3% - 1% - 0,5%	3,2%	-10%	-2%
Ukrainian export	40% pre-war		Gray area /no specification/	
Inflation	20%	12,5%		
Salary	-2%	2,5%		
Unemployment rate	20,9%	11,9%		
Debt burden	98,3% GDP	105% GDP		
Direct foreign investment	0,4% GDP			

Source: Adapted (IMF, March, 2023).

In the basic scenario of economic development for 2023-2027, the dynamics of Ukraine's GDP in 2023 is a very approximate indicator - from -3% to +0.5% [see Table 1.]. And the key reasons for this condition are the damage to the energy infrastructure, the decline in agricultural production, the drop-in world prices for grain, and the significant reduction in metallurgical production. According to the negative economic development scenario for 2023-2027, the Ukrainian economy will decline for another two years. Moreover, in 2023, GDP is expected to fall by 10%, and in 2024 - by 2%.

According to experts' expectations, inflation may also accelerate, imbalances in the foreign exchange market will persist, consumer demand will continue to decline, and the need for debt financing will increase. It should be noted that the description of the negative scenario in the IFV forecasts is less detailed than in the base scenario - with a gray area of specification of Ukraine's development indicators. [see table 1.] That is, apparently, the Fund still focuses on the base scenario, although it does not rule out the worst.

2. Foresight forecasting the economic development of post-war Ukraine

According to the European Commission's report on the assessment of Ukraine's ability to undertake commitments to join the EU (Commission, February 2023), which is based on data as of June 2022, Ukrainian legislation is on some points at the initial level of compliance with EU standards. And although the Ukrainian authorities report that they have done everything to implement the seven recommendations of the European Commission, which Ukraine received along with the status of a candidate country for EU membership, international expert assessments differ.

Ukraine's progress towards membership in the European Union is slow with the completion of all elements of the bureaucratic and technically complex accession methodology. It should be noted that the Ukrainian authorities (statements by the Prime Minister of Ukraine Denys Shmygal) hope that Ukraine will be able to go through this process very quickly and become a member of the EU in two years. At the same time, the heads of European institutions, on the contrary, speak with restraint on the question of the time frame of Ukraine's accession. And they emphasize that the procedure for accession to the EU does not provide for clear chronological boundaries of various stages, and the speed of accession depends on the merits — the pace and quality of reforms of the candidate country.

According to the monitoring data of the Ukrainian Center for European Policy (UCEP), as of the end of 2022, the overall progress of Ukraine's implementation of the Association Agreement is almost 55%, of which perfect implementation (commitment fulfilled in full) equals 30.6%. The Association Agreement, however, does not cover all sections of EU law, and therefore the progress of Ukraine's implementation of the Association Agreement with the EU is small against the background of more than 14,000 legal acts and nine thousand EU court decisions. The average score of the European Commission is 2.16 (excluding the score for Chapter 23 "Judicial System and Fundamental Rights") out of a possible 5, and the total score for all chapters is 69 out of 160, excluding Chapter 23. Ukraine did not receive a score of "5" in any sector, but this level is actually difficult to achieve at the EU candidate stage, instead "4" may be enough to close negotiations on a separate section, so this score is the optimal level for Ukraine. According to the analysis of the European Commission, Ukraine has a good level of preparation, which in numerical equivalent is equal to "4", only in the sectors of energy, customs union, international relations and foreign, security and defense policy. (Commission, February 2023; Akulenko L., Dyachenko S., 2023).

For comparison, the countries that are in the negotiation process with the EU have a total score from the European Commission of at least 80. The European Commission evaluates the implementation of EU legislation in North Macedonia and Albania, countries with which negotiations on accession began last summer, at the level of a total score 97 and 84.5, respectively (Akulenko L., Dyachenko S., 2023).

On the current path of reconstruction and modernization, Ukraine faces a number of problems: (1) - the most important, unpredictable and turbulent problem is war; (2) – high level of corruption in all sectors; (3) – low level of protection of property and intellectual rights; (4) – low level of development of state institutions; (5) – low level of economic freedom; (6) - raw material economy; (7) – population reduction; (8) - where the professionalization of all sectors of the economy; (9) - low technological level of development.

According to Reuters sources, the board of directors of the International Monetary Fund approved the four-year EFF credit program for Ukraine for $15.6 billion (Shalal Andrea, Lawder David, 2023). This is the first major package of financial lending to the country at war. In addition, the IMF loan is the largest for Ukraine since the beginning of the war. Already at the beginning of April 2023, the IMF issued the first tranche of financial assistance to Ukraine within the framework of the above-mentioned credit program in the amount of 2.7 billion.

The IMF's four-year credit program for Ukraine is designed for two stages. At first, the money will go to meet the urgent needs of the country and maintain stability. The second stage is financial support for structural reforms and European integration. A group of creditors of Ukraine from the G7 countries and members of the Paris Club provided financial guarantees for the IMF program, which include the extension of the moratorium on the payment of Ukraine's debts from August 1, 2022 for the period of validity of the IMF program, i.e. 2023-2027.

According to World Bank estimates, the amount needed to rebuild Ukraine has grown to $411 billion, which is more than twice the size of Ukraine's GDP in 2021 (WORLD BANK, Spring 2023).

In April 2023, representatives of the Council of Europe and the Ukrainian government presented a joint plan for Ukraine for 2023-2026 "Sustainability, recovery and reconstruction". The key goals of the plan are aimed at strengthening the stability of Ukrainian state institutions, strengthening democratic governance and the rule of law, and protecting the fundamental rights of citizens. The named joint action plan will support Ukraine's efforts to comply with its obligations as a member state of the Council of Europe and implement European integration reforms in accordance with the decision of the European Council in June 2022 to grant Ukraine the status of a candidate for the EU.

It should be agreed that the formula for the recovery of Ukraine presented in May 2022 by Vlad Rashkovan (IMF) at the Reconstruction Forum on the platform of the London School of Economics is relevant and positively perceived by the international and Ukrainian expert environment [see Fig. 2].

European "Partnership for Action" initiatives, namely: EUGreenDeal (2019), EU Green Deal Investment Plan (2020), EU Circular Economy Action Plan (2020), NextGenerationEU (2021-2027), EU Green Deal Industrial Plan for a Net-Zero Age (2023), outline the way forward. For future generations, the EU seeks to create a more stable and fairer Europe by: large-scale financial support to Ukraine in its struggle for national independence and civilizational values; formation of a pool of investments and reforms for a sustainable future.

The results of scenario forecasting of the business space of post-war Ukraine (according to the author's methodology) are presented in Fig. 3. According to the results of the Foresight forecasting session, the landscape of the unified state strategy for the reconstruction of Ukraine after the war in the context of its European integration and post-European integration adaptation is outlined. The key emphasis is placed on the justification of its urgent need and the format of goals and the tools of management decisions for their achievement.

The formula for the post-war recovery of Ukraine			
Start now	**Not restoration, but modernization**	**Leadership of Ukraine**	**Inclusivity**
without expectation of victory	*radical changes and breakthroughs*	- own vision - modernization priorities - the architecture of the distribution of financial aid	- *the state* - *business* - *civil society*

Fig. 2. Formula for restoration of Ukraine

Source: Adapted (Dligach A., 2023).

Strategic foresight will play a key role in helping to shape EU policy for the future to ensure that short-term initiatives are grounded in the long-term perspective of Ukraine's post-war recovery.

Conclusions. It is impossible to predict the end of Russia's aggressive war against Ukraine. It is even more difficult to model the scenarios of the strategic post-war reconstruction of Ukraine. According to IMF estimates, two scenarios of economic development of Ukraine for 2023-2027 have been determined: basic and negative. In the base scenario, Ukraine's GDP growth in 2023 is a very approximate indicator - from -3% to +0.5%. According to the negative scenario of the economic development of Ukraine for 2023-2027, the Ukrainian economy will decline for another two years.

Experts believe that the IMF's forecasts for the economic development of Ukraine for 2023-2027 should focus only on 2023 and 2024. Forecasts for 2025-2027 are very approximate. They will most likely depend significantly on the course of both external and internal conditions. However, even the most optimistic scenario of the economic development of Ukraine for these years does not foresee "explosive" growth (which is exactly what some economists are counting on after the war).

All expert forecasts of the economic development of Ukraine for 2023-2027 are, in any case, only expectations - divination on coffee grounds. The turbulence of scenarios and deadlines for the end of the Russian-Ukrainian war, and most importantly, the identification and implementation of guarantees that the war will not start again at any moment - these are the key points on which the variability of Ukraine's economic development in the future depends.

The Foresight-forecasting methodology used in the author's research should be interpreted as a system of methods of expert evaluation of strategic directions of socio-economic and innovative development of society. The key goal of Foresight forecasting scenarios is the identification of technological breakthroughs that can affect the economy and society in the medium and long term.
Each of the Foresight methods used by the author - forecasting the strategic development of post-war Ukraine had specific areas of application and conditions of the most effective use. The selection and complex combination of the use of Foresight forecasting methods was justified by the author in the context of their assessment as dominant sources of information that appeal to the analysis, descriptions and arguments of highly qualified experts.

<table>
<tr><th colspan="3">Scenario planning of the business space of Ukraine:
Vectors: external (for the EU) and internal (with the EU)</th></tr>
<tr><td>Political space:
Political stability</td><td>Legal space:
Stability of the legal system</td><td>Economic space:
The level of economic problems: inflation, unemployment, poverty, depressive symptoms</td></tr>
<tr><td>Technological space:
Sustainable innovative development</td><td>Ecological space:
Environmental preservation and restoration</td><td>Cultural space:
Harmony and valuable preservation</td></tr>
<tr><td>What is needed:

Capacity of institutions
Fair justice
Effective entrepreneurship
Innovative technologies
Inclusive society</td><td colspan="2">How to solve:

Synchronization of Ukrainian legislation with EU Directives
Legislative and personnel support
Intersectoral interaction
Independence and effectiveness of the anti-corruption system
An open and transparent system of monitoring the use of funds for the reconstruction of the country (external and civil control)
International transfer of capital and technology
An effective digital state
Public advocacy and change monitoring
Eco orientation of future generations</td></tr>
</table>

Fig. 3. Scenario forecasting of the business space of post-war Ukraine (according to the author's methodology)

The matrix coordinates of the author's research of modeling the scenario space of the development of post-war Ukraine are: two vectors of development: external (with the EU) and internal (for the EU); the structure of the business space with the allocation of political, legal, economic, technological, ecological and cultural components; a detailed map of the multi-criteria development of each of the above-mentioned spaces.

According to the results of modeling the scenario space of the development of post-war Ukraine, two key scenarios are distinguished: the integration of Ukraine into the EU and its post-European integration adaptation. The framework of the format of the unified state strategy for the reconstruction of Ukraine after the war includes: goals - capable institutions, fair justice, effective entrepreneurship, innovative technologies and an inclusive society; and the toolkit of management decisions to achieve the set goals: synchronization of legislation with EU Directives; legislative and personnel support of the state and corporate sector; an independent anti-corruption system; an open and transparent monitoring system for the use of funds for the post-war reconstruction of the country; international transfer of capital and technologies; effective digital state; public advocacy and monitoring of changes, eco-orientation of future generations.

Strategic forecasting of the future post-war recovery of Ukraine can help build collective intelligence in a structured way to strategically plan the EU integration Roadmap through large-scale transitions: green and digital; for joint "partnership of action" during the Russian-Ukrainian war and reconstruction of Ukraine after the war. In addition, the EC defines the mechanisms for integrating strategic foresight into the EU policy-making process and delineating its relevant priorities. This is vital for Ukraine, where action-oriented foresight will drive strategic thinking and shape post-war recovery policy.

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ENERGY SECURITY OF UKRAINE IN TERMS OF RUSSIAN AGGRESSION

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Abstract. *Energy security is a key component of economic growth and sustainable development. Russian invasion of Ukraine in February 2022 and following energy crisis over Europe revealed significant dependence of European states, including Ukraine from Russian energy resources. Current strategy of the EU on total replacement of Russian energy supplies and accelerated implementation of renewables, being challenging now, lead to energy security of Europe in long term. Ukraine currently are meeting all burdens of the war, including thousands killed people and millions of refugees, ruined infrastructure and occupied territories. National energy security is one of many challenges for the country. Strong international support, national integrity and determination are key elements for both Ukrainian victory and postwar rebuilding of the country. Following the EU strategy, Ukraine needs urgent transformation of its energy sector in sustainable way, e.g., Ukraine has a huge potential in bioresources, including biogas / biomethane production being one of the largest producers of agricultural crops in the world.*

Introduction. Energy security is one of key components of economic growth and sustainable development. During last decades, the European Union made significant efforts for transition of its energy sector to sustainable renewables-based and climate-neutral trend. But Russian invasion of Ukraine in February 2022 and following energy crisis over Europe revealed dangerously significant dependence of most European states, including Ukraine, from Russian energy resources. Current strategy of the EU on total replacement of Russian energy supplies and accelerated implementation of renewables being challenging now lead to energy security of Europe in long term. Ukraine currently are meeting all burdens of the war, including thousands killed people and millions of refugees, ruined infrastructure and occupied territories. National energy security is one of many challenges for the country.

Energy security is the protection of national interests in the field of ensuring access to reliable, sustainable, affordable and modern sources of energy in a technically reliable, safe, economically efficient and ecologically acceptable way in normal conditions and in a special or emergency state (CMU, 2021b). This is a definition of energy security from Ukrainian government's Strategy of Energy Security before the Russian war in Ukraine. Obviously, the sustainability and environmental issues are important parts of long-term national enerhy security strategy. But we should agree, that in times of energy, social, and political crises the demands for sustainable development may go beyond the paradigm of the ideology of securitization (Żuk and Żuk, 2022). Thus, the sustainability may be compromised, at least in short term, by urgent demands for the nations in available energy resources.

And today's urgent needs for most European countries to replace Russian gas and oil by more reliable alternatives force the nations search other options, including, e.g., returning to coal, which is obviously not the environmentally friendly choice. On the other hand, current energy crisis over the Europe due to Russian invasion of Ukraine may accelerate the transition of the EU to renewables, and change the situation in long term. For example, significant part of recent REPowerEU strategy of the European Commission to cope the EU dependence on Russian gas involves renewables (EC, 2022). And the first reactions of the German government to the possible energy crisis caused by the Russian war in Ukraine indicate that this war is accelerating the deadline for achieving full renewable energy supplies from 2050 to 2035 (Żuk and Żuk, 2022).

Ukraine is becoming an integral part of European Union community, which means Ukraine may and should be a part of energy sector of the EU, sharing all challenges and approaches of the EU for its energy security. On the other hand, Ukraine has to work hard to solve its energy problems and collaborate with other European countries to solve the energy problems of Europe in general.

In this article, we analyze the energy security for Ukraine in terms of the Russian war against Ukraine, and effective strategies, which may be applied.

Energy security of the European Union

The European Union is a global leader in the sustainable development and in climate change fighting. In terms of this strategy, among other priorities, the EU was determined to reach 20% renewables in total energy mix of the Union in 2020 (EC, 2010). The goal was achieved as in 2020 renewable energy represented 22.1% of energy consumed in the EU (Eurostat, 2022). Further climate / energy goals of the EU were set in the European Green Deal (EC, 2019) and in Fit for 55 Communication (EC, 2021), including, e.g., 40% of renewables in the EU energy mix in 2030. While renewables were a priority for the EU during many years in terms of global warming, restriction of dependence of the Union on Russian energy supplies also implied.

Meanwhile for Europe Russian gas was cheaper than from other sources (it was one of Putin's geopolitical tricks), and European countries, particularly Germany only increased their dependence on Russia's energy supplies during last years. This resulted in more than half share of Russian gas in natural gas imports in many EU member states (Korteweg, 2018).

But open Russian aggression against Ukraine became a real game changer for most European leaders and for the European community. Just in a few days after the beginning of the war, the European Commission issued the communication on energy security of the EU member states REPowerEU, increasing the level of demands (EC, 2022). The communication has a clear purpose to solve the problem of energy dependence of the EU on Russia as soon as possible.

The communication proposes a detailed list of actions, which could decrease the EU demands in Russian gas by two third to the end of the 2022 and totally refuse Russian gas imports by 2030. It is the most radical plan in energy security of the EU that needs many efforts and coordinated activities of the EU member states and their partners. According to the document, by the end of 2022 the EU is able to replace over 100 bcm of Russian gas, following the LNG diversification (50 bcm replacement); increasing wind and solar deployment and green hydrogen production (20 bcm); energy saving (14 bcm); and other steps (EC, 2022).

Biogas and especially biomethane production is also important step to energy security of the EU. For example, Germany had 9,706 biogas plants operating as of 2018. That is the highest number of biogas plants in any country in the world, excluding small scale community plants prevalent in China.

The Hydrogen Strategy for a Climate Neutral Europe was adopted in the EU in 2020 (EC, 2020) to ensure the realization of the ambitions of the European Green Deal (EC, 2019). And while technologies, infrastructure and economic issues are still discussed, the important role of (green) hydrogen in energy transition is generally accepted (Kovač et al., 2021; Parra et al., 2019; Yue et al., 2021)

Current energy crisis over the Europe should spur European states to accelerate investment in renewables and energy efficiency and we totally agree with the assessment (Poitiers et al., 2022) that even if these measures do not completely replace Russian gas in nearest future, in long-term perspective it will have strategic effect on energy security of the European Union (Yakymenko et al., 2022).

Energy security of Ukraine

Before the Russian war against Ukraine, energy production of Ukraine was provided mostly by fossil fuels and nuclear power. In 2020, Ukraine had the following structure of primary energy consumption: natural gas – 27.5%, coal – 26.4%, nuclear energy – 23.1%, oil – 16.4%, renewables – 6.6% (UkrStat, 2021). There has being a significant dependence on natural gas, coal and nuclear energy, and extremely low share of renewables in energy sector of Ukraine.

During last years Ukraine produced about 20 billion cubic meters (bcm) of **natural gas** annually[1]. It covered about two thirds of the national demands in natural gas. The rest of gas supplies, about 8-10 bcm, was imported in the country from some EU member states (Slovakia, Hungary, and Poland). But it was mostly Russian gas by origin. Ukraine also has been 85% dependent on the imports of petroleum products. And the share of oil products produced in Russia or from Russian raw materials in the structure of Ukrainian imports exceeded 80%. Ukraine also has been significantly dependent on nuclear fuel from Russia, which covered more than 50% of needs of Ukrainian nuclear power plants in 2021 (CMU, 2021b).

Thus, Ukraine shares the challenges of most European countries in its dependence on Russian energy resources. The Russian aggression aggravated energy security in Ukraine. The matter is that the Dnieper-Donetsk region of Ukraine accounts for approximately 90% of national gas production (IEA, 2020). Now this region is severely affected by the war. According to national experts, about 70% of gas production facilities in the country currently may be destroyed or out of operation.

Moreover, permanent terroristic attacks of Russian aggressors on Ukrainian energy infrastructure during winter season of 2022/2023 had devastating effects of energy sector of Ukraine. Recent assessment of the United Nations Development Programme (UNDP) and the World Bank of the results of Russian missiles attacks on energy infrastructure of Ukraine confirmed countrywide damages exceeding $10 billion, with Ukraine’s capacity to produce electricity reduced by 61% (Cilliers, 2023).

Among the infrastructural advantages of Ukraine in energy sector, there is a potent gas transportation system, which during decades served as the main transport route for Russian gas to Europe. The other important part of energy infrastructure of Ukraine is the largest in Europe underground natural gas storage facilities (more than 30 bcm), which comprise 21% of total European facilities[2]. While the gas transportation system from Russia to Europe will apparently lose its

[1] https://expro.com.ua/novini/vidobutok-gazu-v-ukran-znizivsya-na-2-do-198-mlrd-kub-m

[2] https://utg.ua/img/menu/company/docs/2021/buklet/%D0%91%D1%83%D0%BA%D0%BB%D0%B5%D1%82_%D0%A3%D0%A2%D0%93_ua_30112021.pdf

significance, gas storage facilities may play important role in energy security of both Ukraine and the EU.

On the other hand, before the war, Ukrainian economy was one of the most energy inefficient in Europe. For example, energy consumption per unit of national GDP in Ukraine was about 3 times higher than average over the EU (BusinessViews, 2019). And the country should use postwar economic recovery for radical technological modernization of all branches of the economy to make it much more energy efficient. In turn, it should significantly reduce the national demands in energy resources, including natural gas demands.

Unfortunately, energy infrastructure of Ukraine is worn and outdated in general. Almost all power units of thermal power plants have exhausted their park resource, are technologically outdated. The power units of nuclear power plants formally should be decommissioned due to the end of their service life. The wear and tear of electrical networks is more than 50%, while the wear and tear of some electrical network objects reaches more than 70% (CMU, 2021b). All these facilities need to be rebuilt and/or modernized in nearest years in terms of national energy security.

Paying attention to the low level of **renewables** in energy mix in Ukraine, in 2021 Ukrainian government proposed National Action Plan for the Development of Renewable Energy until 2030 (CMU, 2021a). According to the plan, in 2030, Ukraine should produce 27% of energy consumed from renewables. This level is much lower than updated plans in the EU, and Ukraine does have the potential to reach more. It is worth to indicate, that in Ukraine about three quarters of renewables are bioresources (UkrStat, 2021). Being one of the largest producers of agricultural crops in the world, Ukraine has a huge potential in bioresources, first of all, in form of agricultural residues. Experts of Bioenergy Association of Ukraine (UABIO) calculated that Ukraine has a biomass potential for energy production in a total of 21.7 million tons of oil equivalent (toe) per year. The main components of the energy potential of biomass are by-products and waste of agriculture, agricultural residues - 9.4 million toe/year or 43% of the total potential, and energy plants - 7.5 million toe/year, 34%. The largest shares of the potential of agricultural residues fall on the straw of cereal grain crops (36%) and by-products/waste from the production of grain corn - 33% (Geletuha et al., 2022). According to the reasonable assessment of UABIO, these bioresources may compensate about 10 bcm of natural gas for Ukraine. Thus successful realization of this potential itself may compensate all national imports of natural gas.

Advanced national strategy was proposed by experts of other industrial company, Ukrainian Technological Company[3] (UTC). Being one of the major industrial companies in biogas technology in the country, UTC assesses potential of Ukraine in **biomethane production** in 10-15 bcm annually with new facilities installation in a scale of about one bcm of biomethane per year. The resources for biogas / biomethane production may be the same agricultural residues and other organic waste, including food waste. This approach is promising for Ukraine. First of all, Ukraine does have a significant amount of bioresources and organic waste. Next, this way Ukraine may use natural gas transportation system and natural gas storage facilities. Also, biogas production generate significant amount of useful side product, digestate, which may be used as organic fertilizer.

In addition, organic waste treatment has additional benefits for the environment. Organic waste deposited in landfills, produce significant amount of biomethane into the atmosphere. Methane is a powerful greenhouse gas, 80 times stronger for greenhouse effect / global warming than carbon

[3] https://utc.bio

dioxide (UNEP, 2021). On the other side, being treated in the technological process of anaerobic digestion, organic waste will be transformed into valuable energy resource. It still produces carbon dioxide during burning, but the effects for the environment will be much less aggressive compared to uncontrolled decomposing of organic waste in landfills.

It is important, that during methane fermentation of organic waste, e.g., manure, a significant amount of ammonia may be extracted and used as an alternative energy resource (Zhadan et al., 2021). The potential of ammonia as a carbon-free fuel is discussed nowadays. For example, hydrogen as a fuel has an extremely low energy density, which means that its energy density on a volumetric basis remains distinctly substandard to most liquid fuels. Ammonia alternatively is 50% higher in energy density than compressed or liquefied hydrogen. One major advantage there is an existing infrastructure for transportation and distribution of ammonia worldwide (Chehade and Dincer, 2021).

Currently, Ukraine has only about 70 biogas plants with total capacity of 105 MW[4]. For comparison, Germany, the main biogas producer in Europe, had over 9,700 biogas plants with total capacity of 4.8 GW yet in 2018 (WBA, 2022). Meanwhile Ukraine has both significant bioresources for biogas production and sufficient amount of well-educated professionals in the fields of biotechnology and industrial ecology. Under the financial and technological support of European partners, Ukraine may fast reach significant progress in biogas / biomethane production at the national scale.

Important issue for Ukrainian energy sector is the challenge of **nuclear power.** Ukraine is the third European country after France and Slovakia with highest share of nuclear power in energy mix. In 2020, Ukraine generated about 55% of its electricity in 15 nuclear reactors. Moreover, in autumn and winter nuclear generation covers up to 70% of national electricity generation[5]. The challenge here is that most Ukrainian nuclear reactors exhausted its operation life (30 years). Meanwhile, Nuclear Energy Agency (NEA) experts concluded that if nuclear utilities implement enhanced ageing management programmes using readily available technical evidence, while performing the necessary repairs and replacements, long-term operation should not face any major, generic, technical barriers (OECD, 2021).

Nevertheless, Ukraine has a challenging history, having been affected by the biggest nuclear catastrophe in world history—the Chornobyl (Chernobyl) nuclear disaster. See, for example, (Sidorik and Yakymenko, 2013). So, we need both strict international technological control during the operation of nuclear reactors and science-based decisions on its further operation.

The war added new risks and challenges in the field both for Ukraine and for Europe, e.g., currently the largest Ukrainian nuclear power plant, the largest in Europe, with 6 nuclear reactors, Zaporizhzhia NPP, is under the control of Russian invaders.

Ukraine has good climate conditions for **wind and solar power** generation and a big reserves here. Today not only Ukraine has low level of renewables in national energy mix (about 6.6%), but most renewables (75%) are represented by bioresources, mostly solid biofuels (UkrStat, 2021). Meanwhile international experts assess the potential of wind power generation in Ukraine in stunning 320 GW (IRENA, 2017), which technically may cover all national energy demands. Of course, this potential should be restored yet through the deoccupation of southern regions of the country. Because the most promising wind power regions are the southern and southeastern parts of Ukraine, where the

[4] https://ecolog-ua.com/news/za-rik-ukrayina-zapustyla-68-biogazovyh-stanciy
[5] https://www.energoatom.com.ua

average wind speed at the height of the rotor axis of modern wind power plants reaches 7 m/s and higher[6].

Solar generation also has good potential in Ukraine. Even though Ukraine is in the bottom of the list of countries according to its photovoltaic power potential, the country is ahead of many European states, including Germany, Austria, Czech Republic and Poland (WB, 2020).

The National Renewable Energy Action Plan of Ukraine for the period up to 2030 foresees a significant increase in the installed capacity of solar and wind power plants - up to 9,947 MW and 5,033 MW in 2030, respectively (CMU, 2021a). Compared to the indicators of 2020 (6,872 MW of solar generation and 1,314 MW of wind power plants, this is an increase of 1.5 times for solar and 3.8 times for wind power plants. Obviously, it is not enough ambitious plans compared to the best indicators in the EU member states and keeping in mind current challenges for Ukraine.

Due to the plans for the construction of 10 GW of electrolyzers for the production of **green hydrogen** on the territory of Ukraine, the country can become an integral part of the implementation of the ambitious goals of the European Green Deal (Prokopchuk, 2020). In addition to Ukraine's role as a producer of green hydrogen on the European market, the EU may be also interested in adapting the Ukrainian gas transportation system to supply a mixture of hydrogen and natural gas. As experts note, there is no infrastructure for hydrogen in Eastern Europe. Its creation will take ten or more years. The possibility of using existing gas pipelines for the transfer of hydrogen or hydrogen mixtures requires research and practical tests but are promising.

Discussion. Ukraine makes great efforts to follows strategies and policies of the European Union in all the fields of sustainable development. And the precise plan for implementation of the EU regulatory principles and norms in Ukrainian legislation was developed in terms of Association Agreement between the European Union and Ukraine (AA, 2014). The Agreement had a tremendous effect on effective transformation of Ukrainian legislation toward European Union high standards, see, for example (CMU, 2022). And during last years Ukraine achieved a significant progress in many directions related to the sustainable development (Shapovalov et al., 2022; I. Yakymenko et al., 2018). Russian invasion of Ukraine interrupted the normal life of the country and put millions of Ukrainians in front of the challenge to defend their country, their freedom and their lives. And while the democratic world, including the EU, demonstrate undeniable support of Ukraine, the military, economic and social aspects of this war in the center of Europe need more and more international attention and determination.

Meanwhile, Ukrainian government presented an ambitious plan for the postwar recovery of Ukraine at the conference in Lugano, Switzerland, yet in June 2022 (Vinokurov, 2022). The total amount of financing in the next ten years may amount to about $750 billion. In the field of energy security, it is expected to attract about $130 billion. Among the projects are the construction of hydroelectric power plants and hydroelectric storage power plants, power plants based on renewable energy sources with a capacity of 5-10 GW, completion of two power units of the Khmelnytsky NPP, modernization of other NPPs, and construction of infrastructure for the production of green hydrogen. It is supposed to attract another $150-250 billion to increase the energy efficiency of residential buildings, build new ones and repair damaged buildings.

The bottleneck of the plan is the sources of financing as the primary source should be Russian reparations and frozen assets of the aggressor country and its oligarchs. Obviously, such strategy

[6] https://uwea.com.ua/ua

needs strong international support and the development of effective legal mechanisms for its implementation.

In conclusion, unreasonable and unprovoked Russian invasion of Ukraine threatens European values and undermines European sustainable development in many ways, including European energy security. Significant dependence of most European countries, including Ukraine, on Russian energy resources is a tremendous risk, which European community should overcome as fast as possible. Ukraine being an integral part of European community and defending European democratic values and freedoms, meets huge challenges in all the fields of country's life, including energy security issues. While strong international support is critically important both for Ukrainian victory and for the postwar recovery of the country, Ukraine has its own significant potential in energy sector, e.g., developed infrastructure for gas transportation and storage, a huge potential in bioresources / biogas / biomethane production, and significant electricity production due to nuclear power generation. All these aspects may be used for long-term effective collaboration of Ukraine and the European Union member states in the field of energy security.

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FORMATION OF METHODIC FOR SOLVING PROBLEMS OF INNOVATIVE FACTORS MANAGEMENT OF SUSTAINABLE SOCIALLY ORIENTED DEVELOPMENT OF THE NATIONAL ECONOMY

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Abstract. *On the basis of complex, interdisciplinary, systemic and selective approaches, methods of analysis and synthesis, a methodology for solving the problems of managing innovative factors of sustainable socially oriented economic development (SSODE) has been developed. It is represented by a structural econometric model for assessing the state and forecasting of innovative factors of the SSODE, is based on the formed system of socio-economic indicators for evaluating the subsystems of the management system of innovative factors of the SSODE, meets the criteria of stability, optimality and efficiency of management of economic systems, allows to assess the level of satisfaction of the vital interests of the population and make predictions based on the Modernized Human Development Index (HDI). The developed method of assessment and forecasting of sustainable innovative socially oriented development of the national economy consists in conducting a comprehensive analysis of the economic, social, and environmental subsystems of the system of management of innovative factors of SSODE based on the index method, factor and correlation-regression analysis and on two contours of the economic system corresponding to the conditions of stability (more than 61.8% of the population whose vital interests are satisfied) and instability (less than 61.8% of the population whose vital interests are satisfied). At the same time, in the first case, GDP per capita was chosen as the objective function, and in the second case, the human development index (HDI). The developed methodology will make it possible to formulate conclusions regarding the effectiveness of management decision-making by state regulatory bodies.*

Introduction. The new challenges faced by modern economic policy, including those related to the current scientific and technological revolution, require a comprehensive approach to the elimination of obstacles to simultaneous and balanced provision of all vectors of economic development. Therefore, solving the problems of innovative factors managing of sustainable socially oriented development of the national economy is now becoming urgent.

Materials and Methods. Materials and Methods. The relationship between social and innovative components of economic development is highlighted in the studies of I. Buleev, M. Zgurovsky, S. Kuznets, P. Nikitenko, O. Meh, V. Solovyov, L. Fedulova, and I. Yashchyshina (Yashchyshena, I. V., 2012); the interdependence of innovative and sustainable development of the economy is presented in the works of V. Geits, B. Malytskyi, and L. Hannes (Hannes L., 2011, p. 7–12), the combination of ways to ensure sustainable and socially oriented development is presented in the works of O. Amoshi, V. Antonyuk, and O. Novikova (Novikova O.F. & others., 2012). However, there is a lack of scientific basis for the development of the "economy for man", there is no development of methodic provisions for solving practical problems of innovative factors managing of sustainable socially oriented economic development.

The purpose of the research. Formation of a methodic for solving the problems of innovative factors managing of sustainable socially oriented development of the national economy**.**

The following *methods* were used during the research: analysis and synthesis, comparison, observation, economic-mathematical, logical, generalization.

Results and Discussion. The national economy of any country should be oriented towards increasing the level of satisfaction of the vital interests of the population, which depends, first of all, on the level of socio-economic development of the country. The most simple and widespread indicator that allows this assessment is GDP per capita, which reflects the effectiveness of the management of the national economy as a whole, but shows only its quantitative result. Along with this, the World Bank currently uses more than 100 indicators that comprehensively characterize the standard of living of the population and the satisfaction of its vital interests, shape the further development of the state's social policy and measures for its implementation.

Since 1990, the annual reports on human development (UN Development Program (UNDP)) have been using an integral indicator in order to reflect the capabilities of a person in terms of the realization of three key tasks (to live a long and healthy life, to acquire and expand knowledge, to have a decent standard of living), which was named "Human Development Index" (HDI).

The appearance for the first time of a new Human Development Index adjusted for inequality in the UN report on human development in 2016 (Inequality-adjusted Human Development Index (IHDI), 2016) became the basis for the formation of the author's methodology for evaluating the management of innovative factors of sustainable innovative socially oriented development of the economy. It became obvious that the HDI can be adjusted for any indicator, the influence of which the author considers significant. Therefore, the year 2016 opened up new opportunities for calculating the HDI, which led to the use of this year's report.

It includes three components: longevity (years), level of education (0 and 100%), standard of living (PPS in US dollars per capita), which have different dimensions of absolute values. To calculate the HDI, different methods of formation are used for each of its components. Moreover, for developing countries and industrialized countries, the methods of normalizing even one index also differ. The HDI value ranges from 0 to 1, where 0 is min and 1 is max. HDI classification is based on fixed cut-off points of this index, which corresponds to the criteria for the distribution of component indicators: for a low level of human development, this HDI is less than 0.550, for an average level of human development, it is 0.550-0.699, for a high level of human development, it is 0.700-0.799, and for very high the level of human development is from 0.800 and above. Goes beyond a country's average achievements in health, education and income, and shows how these achievements are distributed among the country's inhabitants The Inequality-adjusted Human Development Index (HDI or IHDI), which contains two interrelated indicators: HDI and "decrease of IHDI" (Inequality-adjusted Human Development Index (IHDI), 2016), and is also sensitive to the distribution of the average HDI level. So, two countries with different distributions of achievements can have the same average HDI value. Under ideal equality, HDI is equal to HDI, but falls below HDI when inequality increases. The difference between HDI and IHDI is the development cost of inequality, i.e. the loss of human development due to inequality.

IHDI makes it possible to directly link inequality in dimensions, to form policies to reduce inequality, to promote a better understanding of inequality among the population and their contribution to the overall cost of human development. Moreover, a multiplicative model and index correction method are used to calculate IHDI. In order to maximally adapt the global ideas of measuring human development to the specific conditions of Ukraine, scientists have developed a methodology for building Regional Human Development Indices (HRID), which allows determining the rating of each region both by the general level of human development and by its individual components (Human development in Ukraine: 2003, 2004, p. 194). At the same time, the basic methods of HRID calculation are the method of normalization and index convolution. Thus, on the basis of the considered list of indicators that allow assessing the level and quality of life of the population, a meaningful chain "GDP – HRID – HDI – IHDI" is built, which requires a logical conclusion.

In addition, the lack of a comprehensive approach to the problem of innovative factors SSODE management and the synthesis of the above created a basis for raising the issue of modifying the HDI (MHDI) in conditions of instability (the level of satisfaction of the vital interests of the population < 61.8% (Bondar-Pidhurska O. V., 2018, Part 2, p. 18–22) with additional indicators based on the methodology of normalization and convolution of indices. which outlined the boundaries of the second level (contour) of the analysis of the innovative factors SSODE management process. In conditions where the level of satisfaction of the vital interests of the population > 61.8% is enough to choose GDP as the objective function, the first level (contour) of management analysis is created by innovative factors of the SSODE. In this way, the main target parameters of the innovative factors SSODE management process are defined: "GDP - HDI - MHDI".

Solving the methodological problems of the innovative factors SSODE management process of Ukraine involves assessing the state and forecasting of the sustainable innovative socially oriented development (SISORE) of the national economy, which was reflected in the sequence of the following stages: 1) planning (formation of the input parameters of the components of SISORE); 2) organization and analysis (development of an assessment system for subsystems of the innovative factors SSODE management system); 3) selection of alternatives according to the criterion of reliability according to the first (GDP as an objective function) and the second contour of the HDI (MHDI) as an objective function); 4) control (determination of the initial parameters of the innovative factors SSODE management system and their compliance with the criteria of optimality, efficiency, stability).

Processing of the list of literary sources ((Bondar-Pidhurska & Solovyov, 2017, p. 122–132), (Hannes, 2011, p. 7–12), (Novikova & othre, 2012)) made it possible to develop a system of socio-economic indicators that create appropriate conditions for satisfying the vital interests of the population, which became the basis for the formation of a structural econometric model of state assessment (complex monitoring) and SISORE forecasting, which is based on a system , complex and interdisciplinary approaches, meets the criteria of stability, optimality and efficiency of management of economic systems, and allows to more accurately assess the level of satisfaction of the vital interests of the majority of the population, as well as to make forecasts based on the MHDI.

The MHDI includes indicators of the social, economic, and environmental subsystems of the innovative factors SSODE management system. So, if groups of parameters X1, X2, X3 represent a combination of indicators characterizing task parameters for each of the management subsystems for the implementation of these tasks, then MHDI) (Y) define Y= f (X1 U X2 U X3).

The methodology for solving innovative factors SSODE management problems of Ukraine is presented in the form of a structural econometric model of state assessment and SISORE forecasting, the main stages of which are detailed as follows:

I) *Justification of input parameters for each innovative factors SSODE management subsystem* (tasks, forecasts, internal and external threats):

1) the economic subsystem (X1ij...Xn) provides for setting the task of innovative development (X1) - compliance with the new technological system, etc. Resources: fixed assets, % of GDP for R&D. Justification of the content of the original information database (indicators) for diagnosis and monitoring of measures of the effectiveness of the economic subsystem of the innovative factors SSODE management system according to the types of economy (information economy, knowledge economy, innovation): 1.1) level of Internet use, % of the population; 1.2) unemployment rate, %; 1.3) labor productivity, million dollars USA per thousand Employed persons; 1.4) rate of depreciation of fixed assets, %; 1.5) % of GDP on R&D; 1.6) inflation, %; 1.7) indicator of import coverage, %; 1.8) consideration of state external debt (% of GDP); 1.9) the level of the shadow economy in % of the volume of official GDP.

2) the ecological subsystem (X2ij...X2nm) involves setting the task of sustainable development (X2), i.e. ecologically clean production, etc. Resources: availability of fuel and energy and other resources in the country. The substantiation of the content of the initial indicators (information database) for the diagnosis and monitoring of measures of the effectiveness of the ecological subsystem of the innovative factors SSODE management system was carried out in the context of the analysis of the rationality of management of the economy and the energy efficiency of production processes: 2.1) energy intensity of GDP according to PPP 2011. (a ton of oil/$1,000); 2.2) indicators of the state of the surrounding environment taking into account global climate warming (CO_2, kg/person); 2. 3) generation of waste per 1 person, thousand tons; 2.4) consumption of fresh water per person m^2, million m^3;

3) the social subsystem (X3ij...X3nm) involves setting the task of socially oriented development (X3) - the optimal structure of population stratification, etc. At the same time, the resources are intellectual and social capital, human potential, and the presence of a national idea.

Justification of the content of the initial indicators for diagnosis and monitoring of measures of effectiveness of the social subsystem of the innovative factors SSORE management system: 3.1. Life expectancy (at birth), years; 3.2. Average duration of education, years; 3.3. Gross national income per capita, USD USA by PKS, current prices; 3.4. Fertility coefficient (total fertility rate), ‰, i.e. ppm; 3.5. The number of suicides per 100,000 people (mortality from intentional self-harm); 3.6. Population of the country, thousands of people; 3.7. Level of satisfaction of the population, points; 3.8. Presence (1) or absence (0) of a national idea that unites all strata of the population; 3.9. Living conditions on average per inhabitant, m^3; 3.10. Social security indicators (the ratio of the average amount of the monthly pension assigned to pensioners who are registered with the Pension Fund bodies (UAH) to the subsistence minimum at the end of the year (UAH)); 3.11. Indicator of inequality in the distribution of available resources (Gini index).

II) Visualization of the evaluation system of subsystems of management of *the innovative factors* SSORE:

1) *Solving the methodological problems of the social management subsystem* innovative factors *SSODE (X3ij...X3nm)* involves the study of the characteristics of the stratification of the country's population, as a result of the different level of satisfaction of the vital interests of the population, which is connected with the definition of "inequality" and the concept of "social stratification", which used to describe it. Thus, in the modern scientific tradition, there are two main approaches to the study of social stratification: class (European) and status (American). Currently,

post-Soviet countries are characterized by European rather than American models of social stratification, focused on the measurement of "objective" indicators, i.e. income level, property size, amount of power, and others. Moreover, economic indicators are the main ones for social stratification.

It is obvious that the state is socially stable if the society is managed by the owners, i.e. the middle class, the phenomenon of which is that it is simultaneously the basis of economic growth, an indicator of the effectiveness of reforms, a criterion of the dynamic stability of the economic system, and material, educational and qualification, psychological criteria. Along with the existing three population groups that have historically formed in every civilized society: the poor, the middle class and the very rich (oligarchs), the ruling elite (the national establishment) has been identified as the one that determines the future fate of the country in the direction of the development of the national idea.

Therefore, the assessment of the social subsystem of the innovative factors SSODE management system (X3ij...X3nm) involves the study of the stratification of the country's population for a certain period and the following measurements: 1.1) assessment by the country's respondents of their own socio-economic status in society; 1.2) dynamics of the general distribution of households based on self-assessment of the level of sufficiency of their incomes to meet the vital interests of the population, %; 1.3) assessments and results of the level of satisfaction of vital interests of the population using various methods (UN indicators on the perception of well-being); 1.4) dynamics of the index of satisfaction with vital interests of the country's population; 1.5) analysis of forecast dynamics of the middle class by world region until 2030; 1.6) the results of the calculation of the index of the social management subsystem of the innovative factors SSODE of the country; 1.7) conducting a factor analysis of the social subsystem of the country's innovative factors SSODE management; 1.8) the results of the generalization of the regression and factor analysis of the development of the social subsystem of the country's innovative factors SSODE management; 1.9) construction of an econometric model of the social management subsystem of the country's innovative factors SSODE. Methods of evaluating the social subsystem of the innovative factors SSODE management system: expert, statistical methods, trend analysis method, system analysis, index method, factor and correlation-regression analysis, and others.

2) *Solving the methodological problems of the country's innovative factors SSODE environmental management subsystem (X2ij... X2nm)* will be facilitated by the analysis of prospective directions for the development of the country's PEC and the energy efficiency policy, which, aiming at the formation of a qualitative state of the national economy, goes far beyond the limits of energy saving (energy saving policy) and provides not only the realization of the potential of energy saving at all levels, but also the fulfillment of a number of tasks in economic, environmental, and energy policy, which allows to evolve in the context of the paradigm of sustainable development. Thus, the methodological basis for its implementation in the country is an assessment of the country's potential, taking into account the presence of primary PES in the direction of methodical provision of energy efficiency assessment of the country's GDP on the basis of the cost approach, as well as a practical consideration of energy efficiency as an indicator of product competitiveness, a guarantee of energy security and a qualitative criterion for the innovative development of the economy .

Therefore, the assessment of the environmental component (subsystem) of the country's innovative factors SSODE management system (X2ij... X2nm) involves the study and implementation of the following actions: 2.1) calculation of the country's innovative factors SSODE environmental management subsystem indicator using the additive model and maximum and threshold values, built on the basis of correlation-regression analysis of the econometric model; 2.2) comparison of the dynamics of the energy intensity of the country's GDP with individual EU countries, kg n. e. / $ PKS of 2015; 2.3) characteristics of the environmental management subsystem of innovative factors SSORE by analyzing two groups of indicators regarding the rationality of management of the economy and the energy efficiency of production processes; 2.4) analysis of exceeding the intensity of energy use in the country compared to world standards, times; 2.5) analysis of the technological complexity of the country's economy and the structure of energy consumption, %. Methods of assessing the environmental component of the country's innovative factors SSODE management system: trend analysis method, cause-and-effect and system analysis, index method.

3) *The assessment of the economic component (subsystem) of the country's innovative factors SSODE management system (X1ij...X1nm)* involves the study, characterization and measurement of:

3.1) the main trends in the development of the economic component of the management system of innovative factors of a sustainable socially oriented vector of its development, in particular: 3.1.1) the dynamics are being built indicators of the country's innovative factors SSODE economic management subsystem; 3.1.2) an assessment of the population's attitude to privatization in the country is carried out; c) the sovereign index of the economic subsystem (IEP) of the country's innovative factors SSODE management is calculated; 3.1.3) an econometric model is formed based on the results of the correlation-regression analysis of the indicators of the country's innovative factors SSODE economic management subsystem, 3.1.4) the isolation of the group dynamics of the factors of the country's innovative factors SSORE economic management subsystem based on the results of the factor analysis and their interrelationships.

Therefore, the assessment of the economic subsystem of the innovative factors SSODE management system "vertically" involves the analysis of indicators of the development of the noosphere, information, innovation and knowledge economy. Thus, the result of the functioning of the innovative economy is the calculation and dynamics of the index of innovative development, the knowledge economy is the characteristic of the results of patent and licensing activities, the information economy is the trend of the percentage of the population using the Internet, and the noosphere economy is the dynamics of HDI. The result of solving the methodological problems of the economic subsystem of the innovative factors SSODE management system is the analysis of the trend of changes in the economic subsystem based on the calculation of the sovereign integral index containing the input parameters listed above.

3.2) diagnosis of the main problems of innovative development of the economy and activation of its potential in conditions of instability and changes: 3.2.1) calculation and construction of the dynamics of the index of innovative development of the country in additive form; 3.2.2) based on the results of the correlation-regression analysis of the country's innovative development index (IID), the formation of its econometric model; 3.2.3) by the method of cause and effect analysis, the root cause and "bottlenecks" are singled out. Consideration of innovative activity as the main factor of economic growth will contribute to solving the methodological problems of the economic subsystem of the innovative factors SSORE management system. Conditioned by knowledge and investments, it together with them forms a triangle of competitiveness of the national economy (innovations, investments, knowledge), the results of the characteristics of which are a diagnosis of economic development. At the same time, during the evaluation of innovative development, the % of GDP for

R&D was used, and during the forecasting of the MHDI, the total investments of the base year are included in the dynamic model.

3.3) the functioning of the anti-crisis mechanism of the state regulation of life activities of Ukraine as a component of the management system of innovative factors of the sustainable development of a socially oriented economy: 3.3.1) the characteristics of the effectiveness of the functioning of the legislative and regulatory framework, the management of the production system or the activation of industry, financial regulation, redistribution of income (social regulation) by constructing the dynamics of the level of the shadow economy, public external debt (% of GDP), the share of middle class representatives, the share of implemented innovative products, as well as the index of satisfaction of the vital interests of the population, as markers for evaluating the effectiveness of the anti-crisis mechanism of the country's vital activities; 3.3.2) the dynamics of the main indicators of the development of industry in the country's economy and the production of the main types of industrial products; 3.3.3) analysis of innovative activity of industry as a tool for economic renewal and development: anti-crisis management system; 3.3.4) characteristics of the main indicators that determine the quality of life in the country in comparison with other countries of the world in the period of geopolitical stability;

3.4) assessment of the effectiveness of the management system of innovative factors of sustainable development of the national economy from the standpoint of meeting the vital interests of the country's population: 3.4.1) calculation of the MHDI based on 23 indicators, the method of principal components, sliding matrix and additive convolution, construction of its dynamics. The MHDI includes indicators of the social, economic, and environmental subsystems of the innovative factors SSODE management system on the basis of autonomy; 3.4.2) identification of the most significant problems on the way of its development, 3.4.3) identification of groups of factors that affect the level of satisfaction of vital interests of the population thanks to factor analysis; 3.4.4) substantiation of basic innovative factors of socio-economic development of Ukraine; 3.4.5) construction of an econometric model of the management system of innovative factors of sustainable development of the national economy from the standpoint of satisfying the vital interests of the population; 3.4.6) formation of conclusions regarding the effectiveness of management decision-making by state regulatory bodies. Methods of evaluating the economic subsystem of the country's innovative factors SSODE management system: observation, expert, system analysis, synthesis, cause and effect, index, method of principal components, sliding matrix and others.

III) Obtaining the initial parameters of the assessment and forecasting of the innovative factors SSODE management system:

1) substantiation of the initial parameters regarding the evaluation of the innovative factors SSODE management system involves: 1.1. Formation of innovative factors SSODE management system assessment markers: a) comparison of integral indices of social, environmental, ecological as sovereign (independent) subsystems of the IFSSODE management system; b) calculation of the index of satisfaction of vital interests of the population on the basis of UN welfare indicators; c) calculation of the innovative development index based on the competitiveness triangle of the national economy (investments, innovations, knowledge); e) calculation of MHDI based on input parameters. Construction and analysis of their dynamics, formation of conclusions. 1.2. Carrying out on the basis of autonomous integrated indices of the social, economic, environmental subsystems of the innovative factors SSODE management system as components of the MHDI, a comparative two-level (two-level) analysis (on the three target indicators of GDP per capita, HDI, MHDI): in conditions of

stability, apply the first level of analysis, where the objective function will be GDP per capita in the country, and in conditions of instability - the second level where the objective function is HDI (or MHDI, when inequality in society increases and the middle class disappears).

Evaluation methods: correlation-regression analysis, causal analysis, system analysis and synthesis, method of principal components and sliding matrix.

2) substantiation of the compliance of the initial parameters of the innovative factors SSODE subsystem evaluation system as inputs for forecasting (MHDI, investments, stability reserve) to the basic criteria: a) efficiency (K eff 1) – achievement of the planned level of MHDI (Y), where investments min; b) optimality (K opt): {t min, deviation of MHDI from the specified (Am) min}; c) stability is K stability > 61.8% of the population, whose vital interests are satisfied, as well as stability margin (SM max); and defining the group of developing countries (very high, high, medium, low) to which the national economy belongs with the corresponding value of MHDI as the main controlled parameter of the IFSSODE management system. MHDI must simultaneously meet the criteria of stability, optimality (speed of obtaining the desired results), efficiency of management of the economic system. At the same time, the negative value of the stability margin indicates that the country is entering an active phase of financial and economic crisis, a prolonged stay in which will lead to a revolutionary situation, because the basic vital interests of the population are not satisfied.

Forecasting methods: simulation modeling based on the use of the adaptive dynamic model of the innovative factors SSODE control system.

Thus, the tasks of the system, along with the list of input indicators of the social, economic and environmental subsystems of the innovative factors SSODE management system, should be considered compliance with the new technological system (X1), ecologically clean production (X2), the optimal structure of population stratification in the country (X3).

Conclusions. On the basis of complex, interdisciplinary, systemic and selective approaches, methods of analysis and synthesis, the methodic for solving innovative factors SSODE management problems has been developed, which is represented by a structural econometric model for assessing the condition and forecasting of innovative factors SSODE, based on the formed system of socio-economic indicators for evaluating the subsystems of the innovative factors SSODE management system, which meets the criteria of sustainability, optimality, efficiency of management of economic systems, allows to assess the level of satisfaction of the vital interests of the population and to make forecasts based on the MHDI.

It provides a comprehensive analysis of the economic, social, environmental subsystems of the innovative factors SSODE management system based on the index method, factor and correlation-regression analysis on two contours of the economic system that meet the conditions of stability (% of the population vital interests that are satisfied > 61.8% satisfied) and instability (% of the population of vital interests that are satisfied < 61.8%). At the same time, in the first case, GDP per capita is chosen as the objective function, and in the second it is HDI. Successive implementation of the four stages of the developed innovative factors SSODE management problem-solving methodology will allow to single out existing MHDI trends and draw conclusions about the effectiveness of management decision-making by management entities.

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DIVERSIFICATION AS A MECHANISM OF MANAGING THE MULTIFUNCTIONAL DEVELOPMENT OF SOCIO-ECONOMIC SYSTEMS

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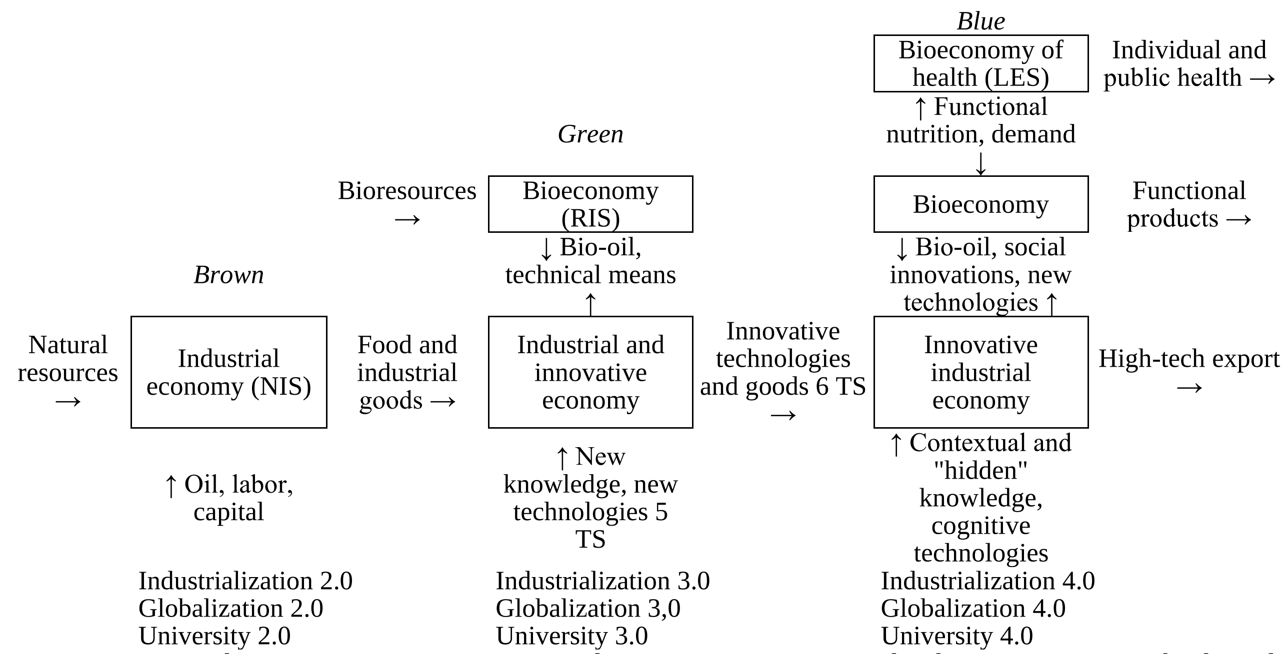
***Abstract**. Diversification as a mechanism of managing the multifunctional development of socio-economic systems. Oleksiy Buluy, Maria Plotnikova, Oksana Prysiazhniuk. The article reveals the evolution of development, considers the directions of diversification of the local and national economy with an emphasis on ensuring the well-being of people and preserving the environment. At the local level, one of the promising areas of business diversification in rural areas is rural tourism. We believe that its development is a key factor that can cause a synergistic effect in combination with other types of entrepreneurial activity in rural areas. The proposed perspective model of the development of society is based on the conditions of self-development and self-realization. The success of the proposed model is based on coordinated cooperation between the state, public organizations and business. The conducted research made it possible to systematize factors influencing diversification on the development of agriculture on the basis of ensuring efficient use of resources. It has been proven that diversification maximizes the effect of synergy, which leads to increased coordination and the creation of an integrated management system to achieve the desired effects.*

Introduction. Under the influence of the mainstream of the current decade, there has been a fundamental change in the focus of socio-economic development from a production-industry vector to an approach focused on nature-centrism and Humanity. This approach demonstrated the transition from exclusive models and proactive strategies to inclusive models of sustainable development in all aspects of life and management of society. Increasing the level and quality of life of the population and multiplying the natural resource potential of the environment has not been achieved so far not only by countries with developing economies, but also by developed states. At the same time, the issue of determining the amount of costs necessary for this remained ambiguous (Arovuori et al., 2005; Zinchuk, Skydan et al., 2021). The implementation of a nature-friendly approach through the harmonization of the relationship between Human and Nature, inclusion and participation is the primary image of the noospheric society of the future (Goncharenko et al., 2021; Zinchuk, Kutsmus, et al., 2021). Under such conditions, prevention and health care turn into investments in human capital and socio-economic development. Only those target communities that are spatially integrated, people-oriented (Khodakovsky et al., 2020; Prysiazhniuk et al., 2018) and able to provide sufficient funding through close and transparent partnership, involving civil society and the private sector in the practice of sustainable development have proven to be sustainable and functional from the point of view of producing values and providing incentives for innovation (Dema et al., 2019, Rashchenko et al., 2020).

The rapid diversification and interdisciplinary integration of modern socio-economic systems, their biotechnological tools, the implementation of environmental conservation practices, the multiplication of sustainability, individual, family, public, regional, national and supranational integrity, stipulate the development of local systems designed to become the new leader of post-pandemic recovery and economic growth. They are focused on anticipatory growth of human capital and new knowledge. In turn, this involves the evolution of educational institutions into the "University 4.0" network (Seniuk, 2018). As a response to modern challenges, it creates prerequisites for innovative changes and new opportunities for the regional economy, science and production. Therefore, the purpose of the research is to develop and deepen the theoretical and methodological foundations and applied provisions of the multifunctional development of socio-economic systems under the condition of diversification of activities, resource provision, sources of their formation and means of activation.

Materials and methods. The research method used in the article is literature analysis and conclusions. The necessary information was obtained by analyzing publications, scientific articles, open data of the State Statistics Committee, the Ministry of Regional Development, Construction and Housing and Communal Affairs of Ukraine, the Ministry of Economy of Ukraine, regional state authorities, the system of local self-government, and associations of the entrepreneurs.

Results and discussion. The national socio-economic system is multifunctional in its structure. It is not limited to a single function - the production of goods, works and services, but also performs technological, distributive, unifying, political, ecological, worldview and other functions, having a system-forming social character (Arovuori et al., 2005). The priority is stimulating the development of depressed regions, overcoming social inequality, ensuring welfare and employment. Its formation took place for a long time (Fig. 1) and is focused on the ability to prepare the necessary personnel for the future, to be a catalyst, accumulator and capitalizer of social and resource potential, as well as a developer of national and regional inclusive development.



*Note. NIS – national innovation system, RIS – regional innovation system, LES – local ecosystem, TS – technological structure

Fig. 1. Conceptual scheme of the evolution of development

Source: author’s research.

The multifunctionality of development has a natural character due to the integration of social-natural, political-technological and other factors, as well as their implementation in social-production processes and their separate spheres. For example, such features characterize agriculture as an integrator of the economy, natural and social environment (Fig. 2). The concept of multifunctional is dominant in the EU, particularly in matters of rural development. It is formed on the basis of a subsidy approach and provides for the simultaneous establishment of agricultural production with the gradual increase of measures to improve the quality of life, provision of public goods, in particular through the strengthening of traditional spheres (education, culture, health care, social, landscape preservation) and new ones (tourism, recreation, ecology, restoration of biological diversity, use of renewable energy sources, formation of a holistic worldview) (Shvets et al., 2019; Skydan, et al., 2019). The restraining factors of development in Ukraine are the decrease in the income of the population (the average monthly salary is 300 USD).

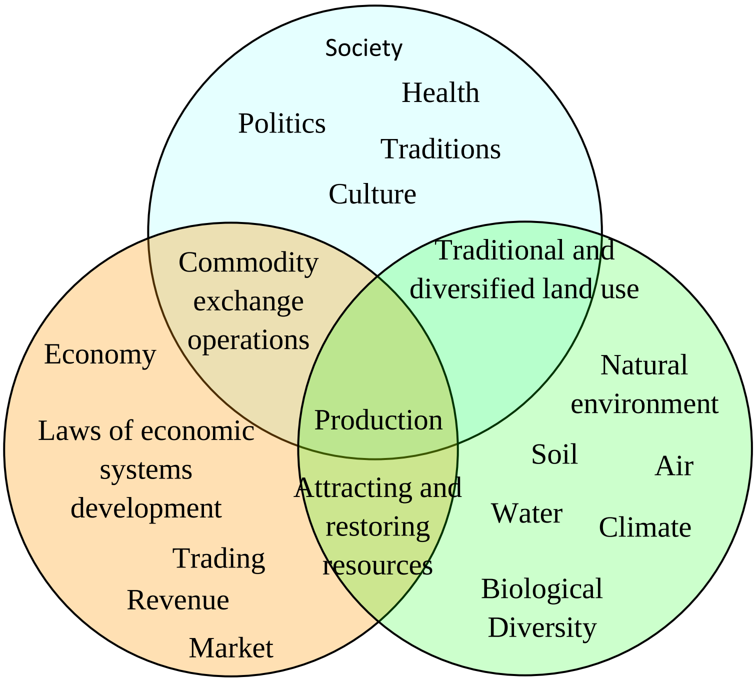


Fig. 2. Integrative role and functions of agriculture

Source: author’s research.

According to experts, the length of life and quality of life are deteriorating (70% of household income is spent on food), the level of unemployment has increased, particularly among peasants (up to 40% of the population aged 15 to 70 is economically inactive), and the availability of public goods is decreasing. Supporting the multifunctional of agriculture should become a strategic direction of national policy, the main component of which is the support of the domestic producer, preservation of biodiversity, protection of the natural environment, landscapes and high quality of products, goods, works and services (Sandal, et al., 2019; Semenets, et al., 2018). We can talk about the diversification of the way of life as a strategy of economic and social growth against the background of understanding the priority of sustainable development in the conditions of the formation of a global and national strategy. Demonstrating the multifunctional of elections, we connect the diversification of the local and national economy with concern for the well-being of people and the restoration of the environment. Therefore, the model of the future society is related to the formation of sustainable communities capable of self-sufficiency and self-development (Fig. 3).

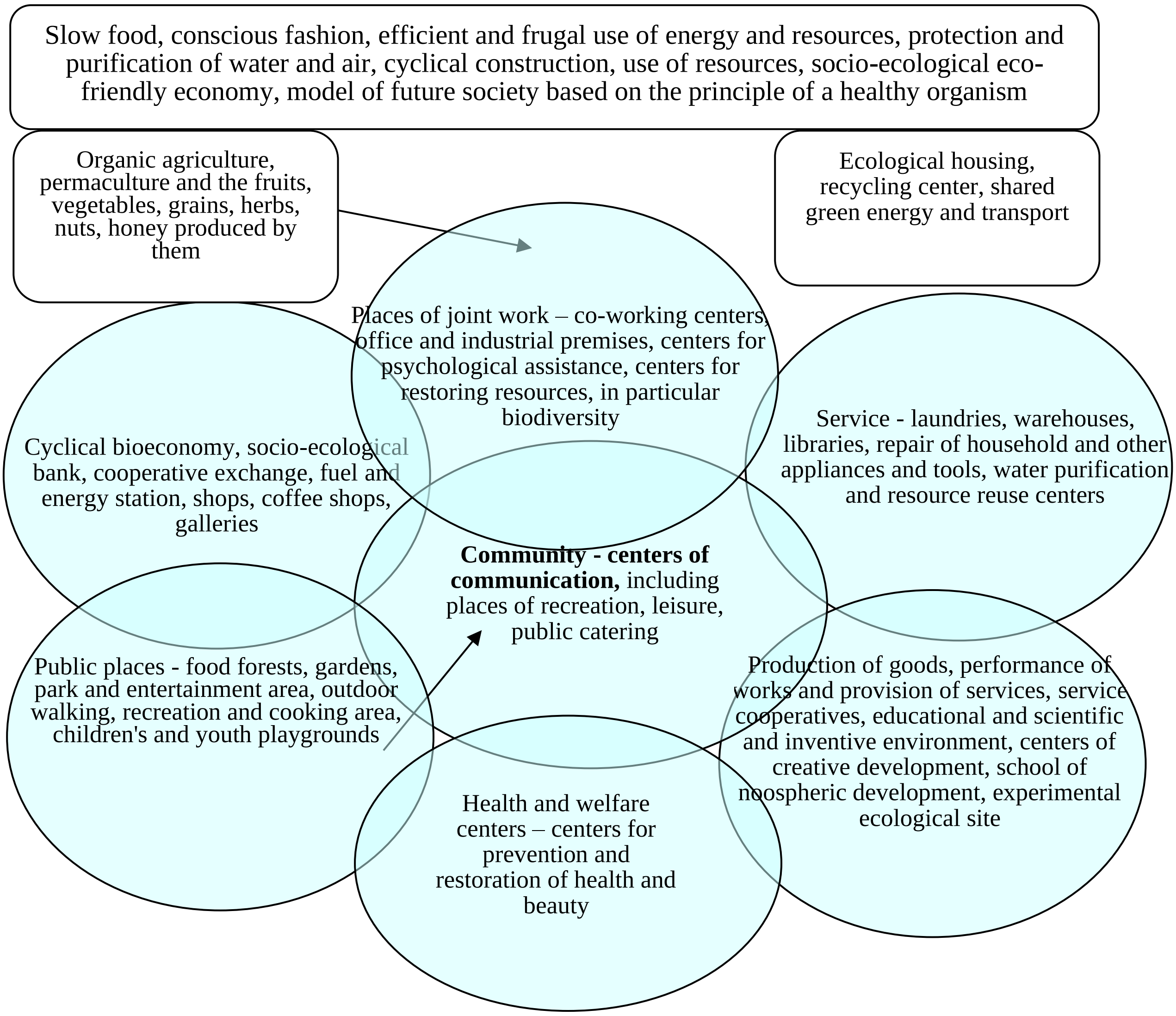


Fig. 3. Model of the regenerative socio-economic system of the settlement

Source: author's research.

In other words, even in rural areas, agricultural production ceases to be the dominant form of management in favour of people-centeredness, bioeconomy of health, orientation to unique resources, in particular natural and human capital, their identification with the area, the ability to develop the nature protection function and ensure the preservation of historical and cultural heritage while simultaneously multiplying creative potential. One of the most promising areas of creative diversification of entrepreneurship in rural areas is rural green tourism. The delayed industrialization of the Ukrainian countryside turned out to be a positive phenomenon from this point of view, as it contributed to the preservation of natural landscapes. According to the results of the survey, the sphere of tourism is on average 10% of the economy of territorial communities of Ukraine and provides up to 16% of employment in the region, which allows it to be classified as a strategic segment of the public sector. It is because of rural tourism and the low industrialization of the village that it has great tourist potential. Tourism as a source of additional income due to its close connection with other branches of the public sector allows to obtain a multiplier synergistic effect from cooperation. For example, when hotels, cafes and other establishments will buy products from local producers or use local craftsmen, contributing to the growth of their production capacity, sales volume of souvenir products, etc.

It is the local economy that is currently becoming a producer of a public product, having a higher level of capacity (due to the flexibility of the local system, the degree of its capacity is 27% higher than the global one), social capital (due to personal ties with consumers) and the main donor of the local budget, which is directed to restore the infrastructure, meet the needs of residents. As a direction of multifunctional sustainable development, the diversification of agricultural producers through the introduction of ecological rural tourism reduces the impact of seasonality and contributes to the restoration of local ecology. The creation of regional service cooperatives with the aim of supporting local initiatives as a format of social entrepreneurship allows expanding the range of services provided. At the same time, the establishment of enterprises on cooperative principles for the purpose of producing a variety of traditional products, such as homemade pasta, cakes, jams, sealed fruit jars, cookies and cakes, can significantly increase the income of commodity producers.

In order to obtain the maximum benefit and increase multifunctional opportunities, a wider cooperation between state structures, local self-government bodies, public organizations and business entities is necessary. In the future, in order to obtain competitive advantages, it is not enough for regional enterprises to have the most modern means of production - it is necessary to possess modern management technologies and constantly increase labour efficiency. Objectively, the process of resource provision administration of both business entities and the management system is becoming more complicated. Diversification is considered by us as a mandatory element of a new business and an attribute of scaling an existing one. A methodological toolkit supplemented by diversification as a mechanism for managing the range of goods, resource areas of business, strategic partners, financial capital management, human resources, investment areas, market geography, sales channels, etc. allows to minimize the risks of the main activity and more intensively attract resource potential.Undoubtedly, diversification, especially in terms of multifunctional and sustainable development, stabilizes business and the public sphere, makes them less vulnerable to external and internal challenges. Thanks to this, diversified structures are more stable and business more competitive than highly specialized ones, including due to greater flexibility and ability to repurpose, delineate processes in space, time and by participants, which contributes to the rationalization of the use of fixed assets. However, in such a case, questions may arise about the limits of diversification, i.e., the optimal ratio between the processes of specialization and diversification (since diversification, along with its positive consequences, creates dispersion of forces, as well as management problems, while in the production segment, the criterion of efficiency is often the reduction of operating costs, for example , due to horizontal diversification - provision of new types of services unrelated to the existing technology, and vertical - through joining the existing activities of previous or subsequent stages and, as a result, optimizing the use of resources). Portfolio analysis of the situation and development of projects of individual processes within the project management program focuses attention on ensuring economic sustainability, in particular, business structures. An important role of management in this case belongs to the logistics approach, which involves coordination of processes related to the movement of material flows, production and marketing.

Multidisciplinary and specialized enterprises differ significantly in the completeness and uniformity of the use of enterprise resources during the year. Diversification, in contrast to specialization, makes it possible to mitigate the disadvantages of seasonality of production due to the expansion of the range of products at the expense of goods for which the main costs of labour and material resources fall in different periods. Redistributing in this way material, technical, financial and labor resources between different types of business during the year, the organization ensures their effective use. In addition, the specialization of the enterprise often makes it impossible to rationally use by-products. In addition, the results of numerous studies confirm that the bottleneck of diversification and specialization is the limitation of human resources in relation to adaptation to new management concepts and tools, which determines the need for the growth of human and social capital. Economic-mathematical modelling makes it possible to obtain a socio-economic structure that is balanced according to the available resource potential. From a mathematical point of view, the modelling of the diversification problem is based on optimization algorithms for the distribution of resources. The task requires taking into account information about the current structure of the socio-economic system and the interrelationship of its individual elements, whether a by-product or waste of one industry is a raw material for another (for example, the grain industry can be considered as the sphere of formation of final products that are sold to various consumers outside the enterprise and as a concentrated feed intended for use in livestock industries). We can come to similar conclusions by considering other processes, considering the optimization of one goal and the release of resources that could be used for the optimization of other areas). Therefore, current goals may conflict with strategic goals, flexibility – with both at the same time.

Typical goals of diversification are economic growth, profitability of the enterprise, reduction of strategic vulnerability from the point of view of technical and market factors, when the goal of diversification is to maximize the efficiency of using resource potential. Then the formulation of the task of diversifying agricultural production can be formulated as follows: achieving the maximum possible result (economic, social, ecological, technological or other effect) under the condition of full use of available resources in the most efficient way at the level of the enterprise, settlement, community, region, country, etc.:

$$K_p \to \max;$$

subject to the following restrictions:

$$\sum_{i=1}^{n} b_{Mi} x_i \le B_M \quad M = \overline{1,m};$$

$$\sum_{i=1}^{n} b_{Ti} x_i \le B_T \quad T = \overline{1,t};$$

$$x_i \ge 0 \quad i = \overline{1,n}.$$

where: K_p – effect, final result (UAH);

b_{Mi} , b_{Ti} – expenses, in accordance with material and labour resources, necessary to obtain a unit of the result of the corresponding *i* type ;

x_i – volume of the obtained result of the corresponding *i* type;

B_M , B_T – the amount of available material and labour resources of the corresponding type (table 1).

Table 1.

Diversification modelling of the Bronikivska territorial community sustainable development with Family Homestead Settlements

Indicator	2020 p. (actually)	Forecast (year)			2025 p. to 2021, %
		2023	2024	2025	
Population, thousands of people	7,99	10,78	10,81	10,82	135,4
Population density, persons / km2	18,00	24,22	24,24	24,27	134,8
Birth rate (per 1000 people)	5,7	6,1	7,6	8,0	140,4
Mortality rate (per 1000 people)	46,4	43,5	34,9	32,1	69,2
Natural growth rate (per 1000 people)	-40,7	-37,4	-27,3	-24,1	16.6 points
Working-age population-total, thousand people	4,16	6,83	7,15	7,23	173,8
including: working age	2,90	5,30	5,66	5,76	198,7
The need of enterprises for employees to fill vacant jobs, vacancies	1	20	21	22	22 times
Average income per person per month, thousand UAH	10,25	22,4	26,6	28,1	2.7 times
Production of gross output in current year prices, millions of UAH	68,24	73,7	92,1	98,9	144,9
Attracting investments, thousands of UAH	6,4	406	1575	1954	

Source: author's research.

Globalization, the influence of international markets, the need to increase agricultural productivity, fundamentally affected the social life of rural residents. To solve this problem, it is advisable to comprehensively develop entrepreneurship in agriculture to develop farms and increase their income. In the conditions of market competition, the creation of new products (goods, services) and processes must be organized as a continuous process. The task may provide for the involvement of additional resources in the event of the impossibility of ensuring the growth of activity efficiency. A new business can cause a synergistic effect, for example due to better use of equipment, raw materials, etc. Undoubtedly, the ultimate goal of diversification remains the stabilization of financial income in the long term, the formation of a normal profit at the enterprise and the reduction of risks, but the diversification of activities, in addition to economic ones, also has a number of social advantages, which are manifested in the management of labour resources: ensuring greater employment of the population, the implementation of a wider range of social and material needs of villagers, new qualified employees can be involved or the potential of existing managers can be better used. The potential for synergy in diversification leads to a reduction in costs when combining different types of business due to a single system of management, control and coordination, as well as due to the acceleration of the turnover of assets and thus, all other conditions being equal, increases the efficiency of production. In addition, it is possible to achieve technological successes thanks to the exchange of technologies and the joint conduct of scientific and research works.

Conclusions. Summarizing the research, we note that the main motives for diversification are the desire to load production capacities, find alternative options for the use of raw materials and materials, master the latest technologies, as well as ensure employment and full use of all types of resources. In general, the achievement of higher business results is possible thanks to the improvement of the organizational structure, the balancing of the production potential, the introduction of new technologies, and the implementation of a scientifically based diversification strategy will open up new directions for the effective use of production factors and ensure obtaining not only an economic effect, but also a social and ecological one.

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INVESTIGATION OF THE DYNAMICS OF INVESTMENT PROCESSES IN UKRAINE IN THE CONTEXT OF ENSURING COMPETENCE OF ORGANIZATIONS ON THE EUROPEAN MARKET

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Abstract. *The article is devoted to the study of the state and dynamics of investment processes (IP) in Ukraine, which is a prerequisite for organizations to acquire competence in the European market. The noted low level of foreign direct investment in Ukraine, the downward trend in investment income and their meager share in GDP (within 5%), which indicates the country's weak integration into the international investment market, cause dubious prospects of achieving a level of competence sufficient for successful activity. Disproportions in the sectoral distribution of investments, their gravitation to industry (33,43% of the total), uneven regional distribution, their concentration in five regions (50%), deprive individual organizations of the opportunity to develop and increase their level of competence. The active participation of EU countries in the supply of investments to Ukraine (over 60%) indicates their interest in cooperation, but the instability of investment trends restrains the renewal of production, the implementation of scientific achievements, and the acquisition of competitive advantages by organizations.*

The peculiarity of the research is the focus on studying the intensity of IP in the context of the impact on the development of organizations by expanding the possibilities of implementing the latest scientific and technical achievements, attracting world experience in the implementation of activities. The results are useful for managers, who, taking into account the main patterns of IP in Ukraine, will be able to assess the prospects of an organization to achieve a level of competence sufficient for successful activity on the European market.

Introduction. The exclusive role of organizations in ensuring the sustainable economic development in the context of active European integration processes actualizes the need to research the prerequisites for ensuring their competence in the market. Scientific research on this topic is relevant, which is confirmed by its active discussion by representatives of the international scientific community. The results of the evaluation of the innovative activity of Ukrainian organizations, as a component of competence, indicate the need to rebuild the national economy in the direction of forming a favorable operating environment, which requires significant financial resources. It is critically important to attract additional investments, which contributes to the introduction of advanced methods of production of unified high-quality products with the possibility of their implementation regardless of geographical, national or other features (Kukharska et al., 2020). This increases the level of competence and competitiveness of Ukrainian producers on the European market (Morhulets, 2015).

The limited participation of Ukrainian organizations in the international movement of capital, causing a shortage of working capital, leads to one-sided dependence on external sources of investment and dubious prospects for functioning and development (Zabarna et al., 2019). The results of the study of the state and dynamics of IP, in particular, the volume of investment resources in

Ukraine, sources of their financing, are needed in practice. This will allow us to understand possible problems, outline the prerequisites for the effective activity of Ukrainian organizations through their restructuring with an emphasis on increasing attractiveness for potential investors, and determine the prospects for acquiring the necessary level of competence in the European economic space.

Literature Review. Researching Ukraine's chances for EU membership, scientists (Boldovska, 2018) considered revitalization of IP by attracting foreign investments, in particular, for the renewal of organizations, to be a necessary condition. Developing this direction, I. Bezzub created a list of benefits from the intensification of IP (Bezzub, 2016), highlighting the activation of the transfer of the latest technologies and know-how, the development of export potential, and an increase in the level of employment. However, the authors, determining the benefits of Ukraine's accession to the European space and forming priority state tasks, ignored the new requirements for organizations and related problems. Other scientists (Huk et al., 2021) focused on solving the problem of technological renewal of organizations, considering foreign investment as a carrier of potential for increasing technology imports and improving practical management skills. Scientists in (Manayenko et al., 2018) focused on the search for ways to ensure the economic development of Ukraine, justifying the need to improve the quality of products on the needs of consumers and the requirement of standards by replacing equipment with innovative ones.

Representatives of the scientific community of other countries did not ignore the problem of investment. The work of Shubita M. F. (Shubita, 2023), which substantiates the feasibility of investing in the development of organizations, deserves attention. However, determining the advantages for investors, the scientist was limited to organizations of the banking sector. The specificity of their activity reduces the level of universality of the recommendations and makes their wide application impossible. The investment experience of Korean organizations is described in (Yoon et al., 2023). Scientists associated the investment inefficiency of organizations with inequality in wages. Shifting attention to the elimination of problems in the organization of labor remuneration means only partial applicability of the recommendations to achieve the goal of the study. Research by experts in (Lestari et al., 2022) dedicated to determining the impact of financial development and corruption on foreign direct investment in developing countries is considered useful. But the limited evidence base ignores the influence of other factors of investment growth as a source of funding for countries.

Without diminishing the value of previous studies, it should be noted that some of them focus on the benefits of investments as a prerequisite for Ukraine's successful accession to the EU (Boldovska, 2018; Bezzub, 2016). Others (Huk et al., 2021; Manayenko et al., 2018) study the role of investment in the technical retooling of production. Foreign scientists are quite logically interested in investment problems in their countries (Shubita, 2023) or in limited spheres of organizational activity (Yoon et al., 2023), which is why they cannot always be used in the practice of Ukrainian organizations. Previous studies (Gruzina, 2023) did not reveal developments aimed at substantiating the importance of IP in the formation of a favorable climate for the development of the competence of organizations, their acquisition of competitive advantages and successful integration into the European economic space. Eliminating the noted gaps and stimulating discussion on this topic requires a study of the state and dynamics of IP in Ukraine, determining the direction of their influence on the likelihood of organizations achieving a level of competence sufficient to ensure competitiveness on the European market.

The aim of the study. The purpose of the article is to study the state and dynamics of IP in Ukraine, as a factor in ensuring the required level of competence of organizations on the European market, which will make it possible to outline the prospects and possible organizational problems on the way to joining the European economic space.

Materials and Methods. The object of the study is the IP in Ukraine. The subject of the study is indicators characterizing the amount of investment resources, sources of their receipt, sectoral and regional distribution, and impact on GDP. The working hypothesis of the study is as follows: the active attraction of investments in Ukraine and their rational distribution is a prerequisite for the acquisition by organizations, regardless of their industry and regional affiliation, of a level of competence sufficient to operate successfully on the European market.

The substantiation of the relationship between the state of IP and the level of competence of organizations was carried out by using the methods of scientific induction and deduction. Generalization of approaches to the analysis of IP, identification of their impact on the ability of organizations to update the production of competitive products and strengthen market positions was carried out using the dialectical method. Methods of content and logical analysis made it possible to form a set of indicators. The methods of system analysis and synthesis have become useful for analyzing the regional distribution of investments, identifying the causes of its imbalance, and the consequences for the successful integration of organizations into the European space. Identification of the dynamics of indicators, comparison of the volumes of investments from different countries in Ukraine was carried out by the methods of grouping and comparative analysis. The explanation of the relationship between the level of indicators and the prospects of Ukrainian organizations on the European market was carried out by the method of descriptive statistics. The substantiation of the conclusions took place by visual presentation of information using a graphic method. Processing and calculation of data for the construction of diagrams and graphs was carried out using a special software and technical tool Microsoft Excel (manufacturer: Microsoft; country of origin: USA).

Results. Statistical information (Official website of the Ministry of Finance of Ukraine, 2023; Official website of the State Statistics Service of Ukraine, 2023) shows a tendency towards a decrease in the indicator of direct foreign investment in Ukraine, which in 2020 reached the worst value in 10 years. 2021 was the year of an investment breakthrough – the value of the indicator was fixed at the level of 2012, but the military invasion of russia on the territory of Ukraine prevented its positive level in 2022. The value of income from direct investments was negative throughout the analyzed period, with the exception of 2015 and 2020 (fig. 1). Thus, the volumes and dynamics of attracting foreign direct investments do not meet the requirements of the Ukrainian economy, which significantly hinders the implementation of driver technologies for its transition to a new technological system (Mostipaka, 2018).

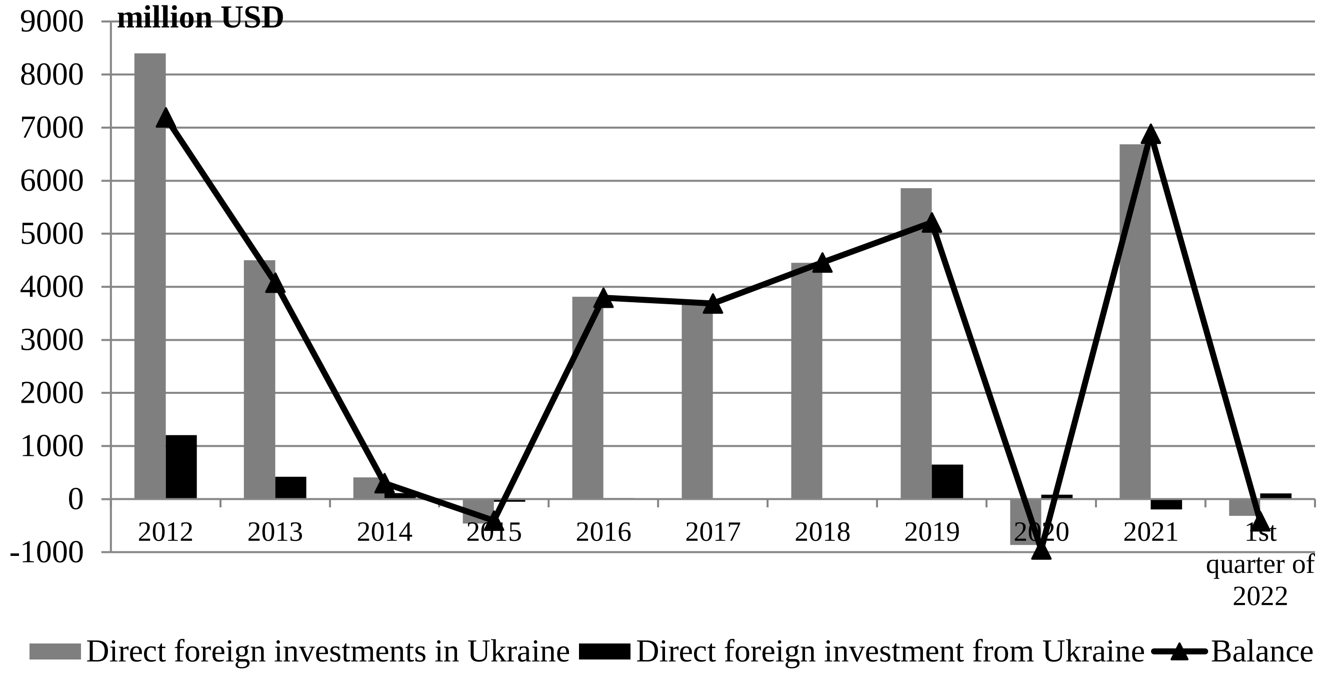

Fig. 1. Dynamics of direct foreign investments in Ukraine

Source: author's development based on (Official website of the Ministry of Finance of Ukraine, 2023; Official website of the State Statistics Service of Ukraine, 2023)

The increase in the volume of investments in absolute terms is most often accompanied by an increase in their share in GDP, which in Ukraine, characterized by chaotic dynamics throughout the analyzed period, remains stably low (within 5%) (fig. 2). This reflects the low level of integration of Ukraine into the international investment market, which is the reason for the inability of capital investments to create a basis for technological modernization and structural changes in the national economy.

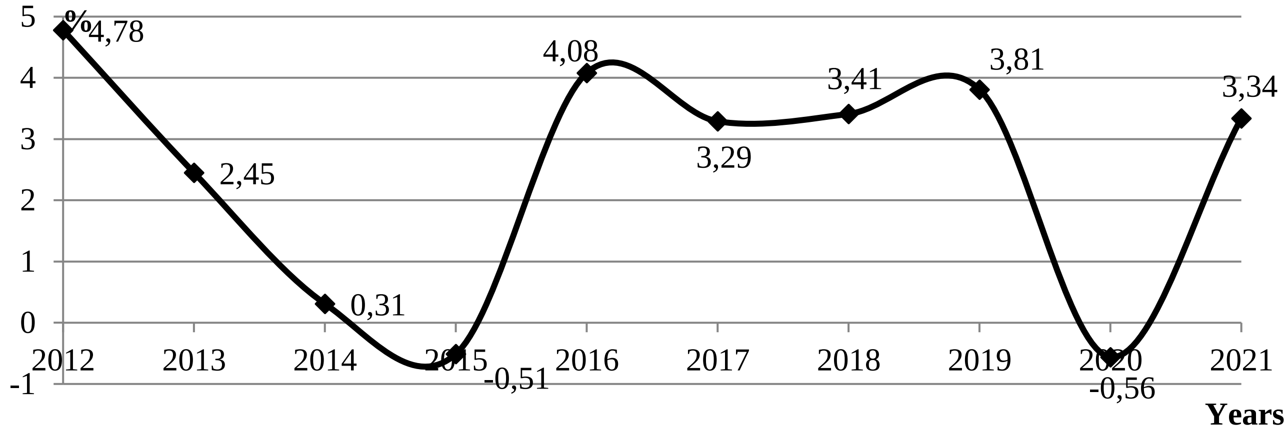

Fig. 2. The share of direct foreign investments in the GDP of Ukraine

Source: author's development based on (Official website of the Ministry of Finance of Ukraine, 2023; Official website of the State Statistics Service of Ukraine, 2023)

The need to determine the prerequisites for the creation of competent Ukrainian organizations, to forecast the prospects of their functioning in the conditions of the intensification of European integration processes, requires an analysis of the sectoral and territorial structure of investments. Investors prefer sectors of the economy with high turnover of capital, territories with natural resource potential and developed infrastructure, unemployed population of working age (Zakarpattia, Ivano-Frankivsk and Chernivtsi regions) (Kukharska et al., 2020; Huk et al., 2021; Kazakova N. A. et al., 2019).

This is explained by the desire for a quick return of capital and obtaining maximum profit at a low level of risk, the availability of the possibility of producing products at low costs with small amounts of investment.

There are serious disproportions in the sectoral distribution of foreign investments in Ukraine. There is an attraction to industry, the share of which in the total volume of investments grew from 33,43% in 2019 to 57,43% in 2021. Agriculture, forestry and fisheries are less attractive for investors – 16,23% in 2021. This is followed by financial and insurance activities, wholesale and retail trade, real estate transactions, the shares of which remained significant compared to other industries – 18,82; 14,21; 5,45%, respectively, in 2019, and 8,6; 6,14; 4,62% – in 2021. That is, the rest of the industries account for 22,47% in 2019 and about 7% in 2021, which is an indicator of serious disparities.

The regional distribution of investments is characterized by unevenness. Direct foreign investment in Ukraine is not only minimal, but concentrated in several regions (Huk et al., 2021; Kazakova et al., 2019). From 6017,4 million c.u. investments in 2019, almost 4 million c.u. mastered the organization of Kyiv (60,32%). The five leading regions – Kyiv, Dnipropetrovsk, Poltava, Luhansk and Lviv regions – mastered almost 95% of the all-Ukrainian volume of investments in 2019. In 2021, there was a redistribution of investments and positions in the top five – it included the Mykolaiv, Rivne, Dnipropetrovsk, Chernivtsi and Kirovohrad regions with shares of 17,83; 10,97; and 3,27%. However, the concentration of investments in a limited number of regions remained at the level of 50%, leaving out the rest.

The sources of investment in Ukraine cover 125 countries of the world. Determining the prospects of the organizations' activities in view of Ukraine's chosen course towards EU membership requires an analysis of investments from participating countries to determine the degree of interest in cooperation. The main investor countries in terms of the share of the total volume of investments in 2019 were: Cyprus (44,22%), the Netherlands (9,79%), Poland (3,51%), Hungary (3,17%), Luxembourg (3,08%). In 2021, their composition changed – Hungary gave way to Germany, however, and in 2021 the EU countries remained the main investors of the Ukrainian economy, providing about 61% of the total volume of investments (fig. 3).

The unstable trend of investment flows, both towards growth (Ireland, Malta, the Czech Republic and others) and decline (Denmark, Estonia, France, Sweden and others) is obvious. This is explained by the dependence of investment volumes on the state of the economy, the speed of its recovery, and the probability of stabilization of the military and political situation (Official website of the State Statistics Service of Ukraine, 2023). As for the dynamics of the volumes of Ukrainian investments, they, while showing an insignificant level, maintain a steady downward trend (more than 90%). Foreign investors focus on industries such as the Internet, software development, network organization and extensive service industries (Kukharska et al., 2020). The Ukrainian side is interested in investments in energy-saving technologies, fuel and energy campaigns, agro-industrial complex, metallurgy, i.e. directions that have the probability of saturation of the domestic market, increase of export potential, promotion of employment of the population.

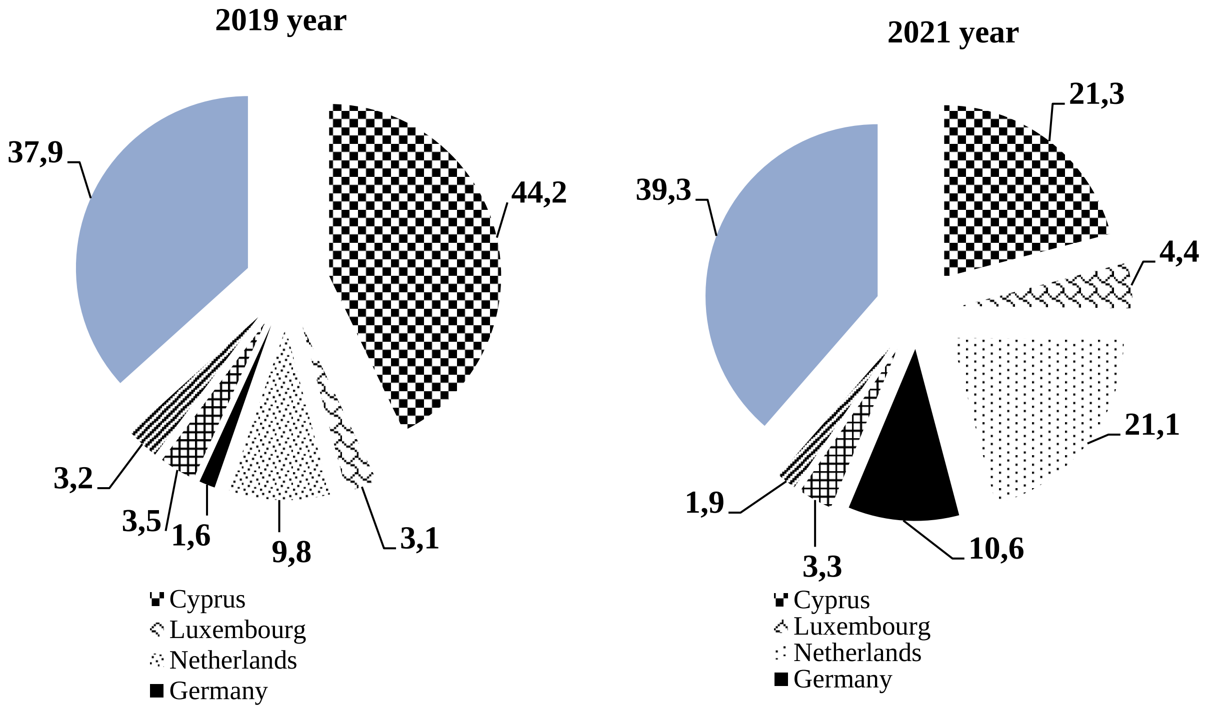

Fig. 3. Distribution of direct foreign investments in Ukraine by investor countries, %

Source: author's development based on (Official website of the Ministry of Finance of Ukraine, 2023; Official website of the State Statistics Service of Ukraine, 2023)

Discussion. The results of the study outlined the problem that prevents the uniform development of Ukrainian organizations, their achievement of the necessary level of competence and successful integration into the European space. We are talking about lagging behind the indicators of the intensity of investment processions from the average European level, deep disproportions in the sectoral and territorial structure of investments. The decrease in the rate of foreign direct investment, the weak activity of Ukraine in the investment market (fig. 1), the excess of investment outflows and inflows limit the access of organizations to modern production and management technologies, inhibit the formation of the national investment market. To determine the depth of the investment crisis in Ukraine, it was useful to analyze the share of investments in GDP, which remained small (fig. 2) compared to the value of the indicator of the EU member states. This confirmed the conclusion about the low level of integration of Ukraine into the international investment market, limited opportunities for technological modernization of production, low chances of organizations acquiring competence in the European market. The effort to understand the reasons for the noted situation led to the identification of factors that significantly complicate it. The uneven regional distribution of investments, their concentration in the five leading regions, creates unequal conditions for the use of investments as a tool for joining the world market by organizations from the rest of the regions. The degree of interest in investment cooperation with Ukraine of the EU member states made it possible to determine the analysis of the sources of investment income. Despite their significant advantage in the total volume of investments (fig. 3), the low activity of investors and the insufficiency of the volume of attracted direct investments (statistics) were noted. This is a sign of the low level of investment attractiveness of Ukrainian organizations, weak international investment interaction and inhibition of the process of economic integration into the European space (Pokataieva, 2009). Monitoring the level of indicators is important for analyzing the state of the country's economy, which explains their active discussion by scientists. The issues of intensification of investment processes (Bezzub, 2016), solving the problems of technological renewal of production and improving the quality of products (Huk et al., 2021; Manayenko et al., 2018), determining the feasibility of investing in the development of organizations (Shubita, 2023), ensuring the effectiveness of their investment activities (Yoon et al., 2023) are relevant. Previous studies (Gruzina, 2023) did not reveal developments aimed at determining the state and dynamics of IP in the country in the context of the impact on the formation of favorable conditions for the development of organizations, increasing their level of competence with a logical increase in competitiveness and operational efficiency. A feature of the research is the determination of the possibility of using the obtained results to determine the probability of positive changes in the conditions of the functioning of organizations. It is about ensuring the equality of doing business, protecting property rights, improving the structure of investment sources and observing transparent principles for the distribution of investments between organizations. This will contribute to the activation of their activities, innovative development, acceleration of knowledge and experience exchange processes with representatives of the international business environment, and the growth of the level of competence in the European market (Boldovska, 2018).

We cannot ignore the consequences of the crisis state of the Ukrainian economy due to the military invasion of russia, which, on the one hand, provoked the intensification of the European integration processes, and on the other hand, crossed out the possibility of any forecasts due to the inability to objectively assess the extent of business losses and damages. But determining the prerequisites for ensuring the competence of Ukrainian organizations on the European market will be the basis for further scientific research into ways of using it to increase the adaptive capabilities of organizations not only on the European market, but also on the post-war Ukrainian market.

Conclusions.1. Foreign direct investment is recognized as an important source of financing Ukraine's investment needs, increasing its chances for sustainable economic development. Contributing to solving the problems of production modernization, the introduction of innovative production and management technologies, ensuring the quality of products in accordance with international standards, they acquire the status of a factor of ensuring the competence of Ukrainian organizations on the European market. This became the reason for the analysis of the dynamics of indicators of the intensity of IP in Ukraine. The critical decrease in the rate of direct foreign investment by more than 20 times during 2012-2014 makes it much lower than the average European level. The lowest value of the indicator in the last 10 years in 2020 (-868 million US dollars) is associated with the COVID-19 pandemic, which provoked an excess of the outflow of foreign investments inflows and a negative balance at the level of -950 million US dollars. Hopes that were based on 2021 – the growth rate of the indicator reached 870% – were crossed out by the military invasion of russia. The investment market reacted by lowering the indicator, which again caused a negative balance (-420 million US dollars). Similar trends led to pessimistic forecasts regarding the possibilities of any development of Ukrainian organizations, the expediency of their modernization in the conditions of military operations and the temporary occupation of a significant part of the territories. However, the intensification of the European integration processes became the impetus for the improvement of the situation in the 2nd quarter of 2022 (+260 million US dollars of direct foreign investment in Ukraine), and the preservation of this trend in the 3rd quarter of 2022 (growth rate of 53,85%). It was logical to change the sign of the balance indicator – +322 million US dollars in the second quarter. Therefore, the tendency to improve the situation is obvious, the confirmation of which required an additional analysis of the level of Ukraine’s integration into the international investment market, the sectoral and territorial structure of investments, and the determination of the degree of interest of EU member states in cooperation with Ukraine.

2. An increase in the volume of investments in absolute terms does not always mean an increase in their share in GDP. In Ukraine, the trends of changing indicators are identical. A decrease in the volume of investments by almost 21% during 2012-2021 was accompanied by a more rapid decline in their share in GDP – by almost 30%. This confirmed the conclusions about the low level of the indicator, therefore, the low level of integration of Ukraine into the international investment market and doubtful prospects for technological modernization of organizations, acquiring a level of competence sufficient for successful activity on the European market.

3. Orientation to determine the perspectives of the functioning of Ukrainian organizations in the conditions of European integration determined the analysis of the industry and territorial structure of investments. This made it possible to assess the probability of ensuring the competence of organizations of various economic spheres and territorial affiliation. Directing investments to industries with high turnover of capital, territories with natural resource potential and developed infrastructure is explained by the desire for a quick return of capital and profit maximization. This creates disproportions in the distribution of indicators. The concentration of investments in industry (57,43%), agriculture, forestry and fisheries (16,23%), financial and insurance activities (8,6%), the development of the vast majority of them (95%) by the five regions of the leaders, leave apart from the organization of other branches and territorial affiliation. Deprived of the opportunity to develop by improving internal properties due to a lack of financial resources, experience, advanced technologies, such organizations demonstrate a low level of their own competence.

4. To assess the level of interaction of Ukraine with the EU member states, to determine the degree of their interest in cooperation, the analysis of the sources of investment in Ukraine helped. The majority of them – more than 60% of the total volume – came to Ukraine from the countries of the European Union. However, the instability of trends, the rapid growth or decline of investment flows, is directly related to the state of the economy, the prospects for its stabilization and recovery, the level of competence of organizations and their investment attractiveness. The insufficient volume of foreign investments, it’s not always effective use restrain the accumulation of entrepreneurial potential by organizations, the introduction of progressive technologies, reducing the level of competitiveness. This is the reason for the weak international investment interaction, inhibition of the process of integration of the Ukrainian economy into the international investment market, which determines the direction of further scientific research. It will be focused on solving the outlined range of problems by improving the quality indicators of the national economy at the micro level. This refers to the formation of a methodological basis for the creation of competent organizations and the development of a practical basis for their successful functioning in accordance with the requirements of European standards.

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PROBLEMATIC ASPECTS OF TAX INNOVATIONS IN UKRAINE DURING THE MARTIAL LAW PERIOD

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Abstract. *To effectively counter Russia's aggression against Ukraine, it is necessary to reform the tax system. In such circumstances, it is relevant to study the current state of Tax Policy and innovations introduced in the Tax Code of Ukraine during the martial law legal regime. Using quantitative methods, the study analyzes tax revenues from the single tax and the single contribution to mandatory state social insurance paid by taxpayers. According to the results of the analysis of laws that introduced amendments to the Tax Code of Ukraine in 2022, it was revealed that almost all of them related to tax preferences. Some problems were also identified as the results of an analysis of the laws adopted in 2022 in the field of preferential tax policy in terms of their harmonization with EU law. Most of the legislative acts in 2022 were adopted without obtaining the conclusion of the Committee on Ukraine's integration into the European Union. Also draft laws were implemented in the presence of a conclusion about their non-compliance with the norms of the "acquis EC". The negative consequences of the Ukrainian preferential wartime tax policy are also the lack of compensatory mechanisms to reduce budget losses from the introduced benefits. Taking into account these circumstances, it is recommended to conduct a mandatory examination of the draft law's compliance with the "acquis EC" standards when preparing legislative acts. The proposed recommendations have a practical focus and can be implemented in rule-making practice in Ukraine.*

Introduction. Effective counteraction to the military aggression of the Russian Federation against Ukraine requires reforming the tax system, which ensures the receipt of tax payments to the budget.

Russian aggression in 2022 reduced Ukraine's GDP by 30 % [27]. The negative factors of the current state of the Ukrainian economy include the imbalance of the national financial system, non-transparency and corruption schemes in certain sectors of the economy, illogicality and inconsistency of government reforms [23].

Against the background of Russian armed aggression, there is an urgent need for balanced strategic state regulation to ensure sustainable development in Ukraine in the short- and long-term periods [10].

Consequently, there is a need for an adequate restructuring of the entire system of state regulation of the economy, including its tax component.

Changes in taxation in Ukraine were made almost in the first days of military aggression – starting from the beginning of March 2022. At the same time, adjustments to preferential policies were carried out mainly intuitively, without their thorough theoretical and methodological justification. This has led to excessive losses in budget revenues and failure to meet the goals of relevant regulatory measures.

At the moment, there are already appeared certain results of research on the ideology, directions and sequence of state regulation against the background of Russian armed aggression [10, 11, 26]. However, there is a need for an in-depth analysis of the impact of legislative reforms on the condition of tax payment receipts in Ukraine and the compliance of adopted legislative acts with EU law. This determines the relevance of the research topic chosen.

The purpose of the article is to research tax innovations introduced into the legislation in Ukraine during the period of the legal regime of martial law and analyze the consequences associated with it, including in the context of harmonization with EU law. The objectives of the study include the following: research of the state and trends of preferential policy development in Ukraine during the martial law, as well as identification of problems and prospects for the development of taxation.

The scientific novelty lies in the formulation of recommendations for making changes to the current legislation, which make it possible to reduce budget losses during the martial law legal regime in Ukraine. Problematic aspects of non-compliance of legislative acts adopted in 2022 in Ukraine with the norms of EU law are identified.

Literature review. The latest scientific works deal with various aspects of the state of the Ukrainian economy during the legal regime of martial law and in the post-war period.

Thus, Lysyak, L. and others (2022) study the reform of tax policy in general and preferential foreign economic policy in particular in the context of creating conditions for the current stabilization of socio-economic processes and the revival of the Ukrainian economy in the post-war period [21].

Voloshyna-Sidei, V. and others (2023) identify strategic guidelines for the development of the Ukrainian economy in the context of global challenges [27].

Romanovskaya, Yu. and others (2022) refer to the challenges to the economic security of Ukraine as an imperfect legislative framework, fragmentation and imperfection of the laws of Ukraine in the development of modern spheres of the economy [23].

Ivanova, V. and others (2022) hold the position that drivers for ensuring sustainable development are both financial and non-financial in nature [10].

Argevitin, S. and others (2023) determine in a study of the impact of martial law on the productivity of the banking sector of Ukraine that in order to ensure credit activities, it is advisable to develop credit support for ESG's goals of diversification of energy production, housing and Infrastructure Construction [1].

The overwhelming majority of experts note the need to adopt reforms in the field of tax policy in order to ensure the functioning of the Ukrainian economy during the active phase of military operations and in the post-war period. At the same time, it should be noted that the adopted legislation in Ukraine should be harmonized with EU law, which is stipulated in the terms of the association agreement between Ukraine and the European Union [2]. Researchers draw attention to certain problems in the application of EU law. In Particular, Doeleman R. (2023) examines the problems of applying the "arm's length" principle in EU member states and draws attention to the fact that although all EU member states have implemented the "arm's length" principle in their internal transfer pricing rules, differences regarding the application of this principle persist [7].

Jeroen Bijl, Joël de Vries (2023) in their study conduct a critical analysis and categorization of EU legislation regarding the VAT regime when purchasing goods and services by businesses, when third parties (also) have benefit from these purchases [4].

Thomas Bieber, Denise Schmaranzer (2023) recearch the provisions of the EU Directive 2020/262, which are aimed at linking Excise and customs legislation and further promoting the digitalization of excise processes. The authors argue that, despite the revision of the directive, harmonization has not yet reached its full potential due to the numerous options provided to member states [3].

Therefore, it can be concluded that the provisions of tax legislation in Ukraine need harmonization with EU law. At the same time, based on the results of the research, experts draw attention to the imperfection of the norms of EU law regarding the regulation of direct and indirect taxes (value added tax, excise duty, customs duties).

Materials and methods. The methods of analysis, synthesis, comparison, and generalization were used to study problematic aspects of taxation of single tax payers in Ukraine. The abstract-logical method is used to substantiate the directions of development of the Ukrainian legislation in wartime and in the postwar period.

The method of statistical analysis are used to analyze tax revenues from the payment of a single tax and a single contribution to mandatory state social insurance from individuals who pay a single tax and the structure of legislative acts adopted in 2022. Calculations were performed using Excel based on data from the Ministry of Finance of Ukraine.

Results and discussion. To overcome the negative phenomena in the economic, social and defense spheres caused by the military aggression of the Russian Federation against Ukraine, it was urgently necessary to make changes to the tax legislation. The first innovations were adopted on March 3, 2022 by Law No. 2118-IX [12]. In the future, legislative changes to the Tax Code of Ukraine [24] were introduced repeatedly. 22 of 26 legislative acts that amended the Tax Code of Ukraine in 2022 [24], concerned tax preferences, 13 laws regulated changes in the tax administration process, and only 4 laws had a fiscal orientation (fig. 1).

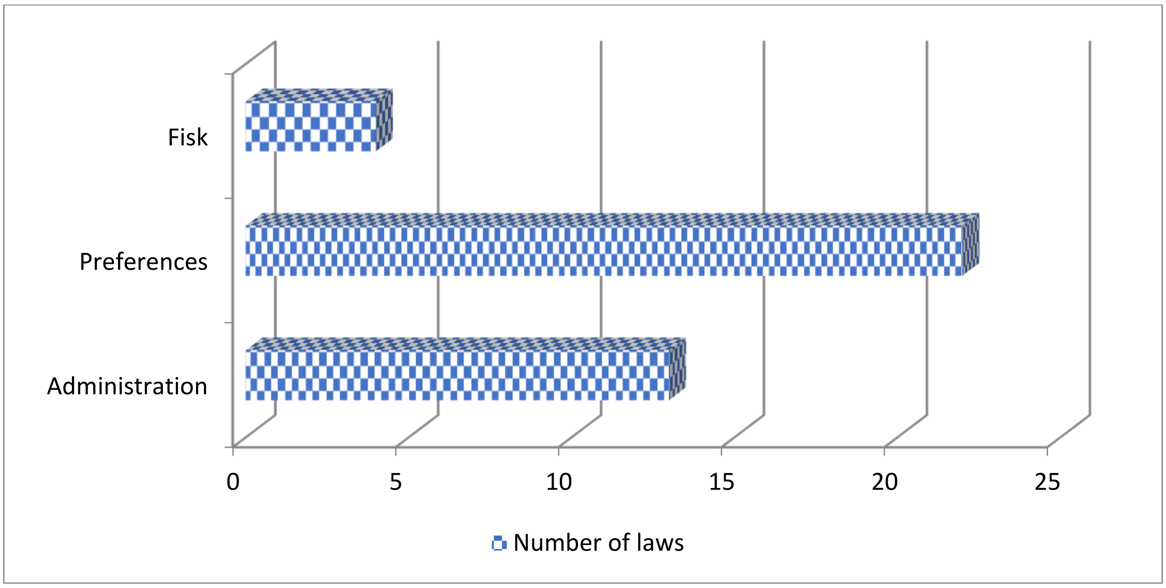

Fig. 1. Quantity of laws that amended the Tax Code of Ukraine in 2022 by directions.

Source: Developed by the authors based on the analysis of the Tax Code of Ukraine [24]

At the same time, the accelerated introduction of changes to the legislation led to shortcomings that had to be corrected later. Thus, in the accompanying materials to most of the draft laws, there was no financial, economic and scientific justification for the feasibility of adopting certain changes. The analysis of the risks and consequences that the proposed innovations may lead to, wasn't carried out, this negatively affects the rule-making practice.

The analysis of legislative acts shows that there is no systems approach to the introduction of tax benefits. For example, there were no systematic preferential rules for transactions related to the taxation of charitable assistance, which were repeatedly introduced by separate laws of Ukraine and subsequently adjusted. Moreover, some problematic issues in the application of preferential norms regarding the taxation of charitable assistance, despite the large number of adopted legislative acts, have not been resolved yet.

The research revealed some preferential norms that were implemented without proper justification and subsequently canceled. In particular, this applies to the benefits introduced by Law No. 2142-IX [13] in VAT-exempt transactions involving the import of certain goods into the customs territory of Ukraine under the customs regime of import by business entities and individuals. These benefits were abolished by Law No. 2325-IX [15] in a few months.

As it's indicated in the Explanatory Note [9] according to the results of customs clearance of vehicles by citizens during the validity period of Law No. 2142 [13], benefits for customs clearance of customs payments amounted to more than 13 billion UAH, in particular, benefits for customs clearance of phones reached the amount of more than 270 million UAH; of clothing and footwear – the amount of more than 850 million UAH. Taking into account the above, the introduced benefits for the import of goods that are not essential goods and at the same time are budget-forming, were abolished by Law No. 2325-IX [15].

A similar situation also occurred with zero excise tax rate on transactions of supply in the customs territory of Ukraine and import of motor gasoline, heavy distillates and liquefied gas (paragraph 41 of the subs.5 of Section XX of the Tax Code of Ukraine [24]), establishment by Law No. 2120-IX [16], which was repealed by Law No. 2618-IX [17].

Given the above, the implementation of some specific tax benefits during the period of martial law raises certain doubts. In particular, this applies to the benefits introduced by Law No. 2273-IX [14] regarding VAT exemption for transaction involving the supply, preparation, and distribution of audiobooks voiced in Ukrainian, except for erotic publications (Art. 197.1.251 of the Tax Code of Ukraine [24]), as well as benefits established by Law No. 2330-IX [18] for industrial parks activities in Ukraine. After all, the introduction of such benefits may lead to additional budget losses, and the urgent need to support these transactions under martial law is not obvious.

The most significant adjustments to the current taxation procedure in 2022 were made by Law No. 2120-IX [16], which defines the specifics of the administration of taxes and fees during the legal regime of martial law.

Special attention should be paid to innovations regarding the exemption of individual entrepreneurs - single tax payers of the first and second groups from paying a single tax and a single contribution to mandatory state social insurance (paragraph 9^{19} of Section VIII "Final and transitional provisions" of Law No. 2464 – VI [19]).

According to the Tax Code of Ukraine, the first group of single tax payers includes registered as an entrepreneurs individuals who do not have employees, which carry out exclusively retail of goods from trading places on the markets and/or carry out economic activities for the provision of household services to individuals under conditions that the amount of their income during calendar year does not exceed 167 times the minimum wage established by law on January 1 of the tax year (in 2023 - 1118900 UAH – over 280 00 EUR). The second group of single tax payers includes individuals - entrepreneurs who carry out their economic activities for the provision of services to single tax payers and/or individuals, production and/or sale of goods, activities in the field of restaurant business, provided that during the calendar year they meet the set of the following criteria:

the number of employees at the same time does not exceed 10 people;

the amount of income does not exceed 834 amounts of the minimum wage established by law on January 1 of the tax (reporting) year (in 2023 - 5587800 UAH – approximately 139700 EUR).

This approach is accompanied by the risk of losing budget revenues. After all, unconditional exemption from taxation will inevitably lead to budget losses, and in the context of the legal regime of martial law, funds are needed to maintain the combat capability of the Armed Forces of Ukraine.

The dynamics of single tax payment for 2020-2022 is shown in Fig. 2:

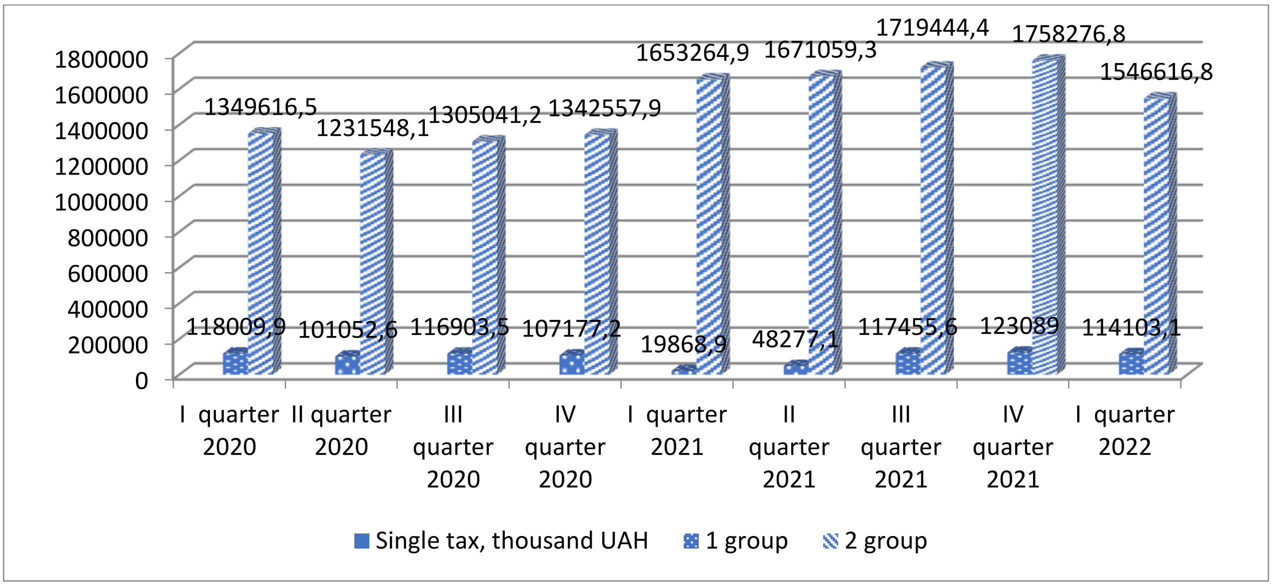

Fig. 2. Dynamics of single tax payment by group 1 and 2 taxpayers in 2020-2022.

Source: calculated by authors according to the data of the Ministry of Finance of Ukraine

As evidenced by the data of fig. 2, 1660719.9 thousand UAH were received from single tax payers of group 1 and 2 in the first quarter of 2022. Under the conditions of maintaining such a trend of paying a single tax to the budget, for 2022, 6642879.6 thousand UAH should have been received according to the forecast data. However, since these payers were given the opportunity not to pay a single tax, according to the forecast data due to the implemented benefits, the budget in 2022 theoretically may not receive 4982160 thousand UAH of a single tax.

The dynamics of a single contribution payments by group 1 and 2 payers is shown in Fig. 3:

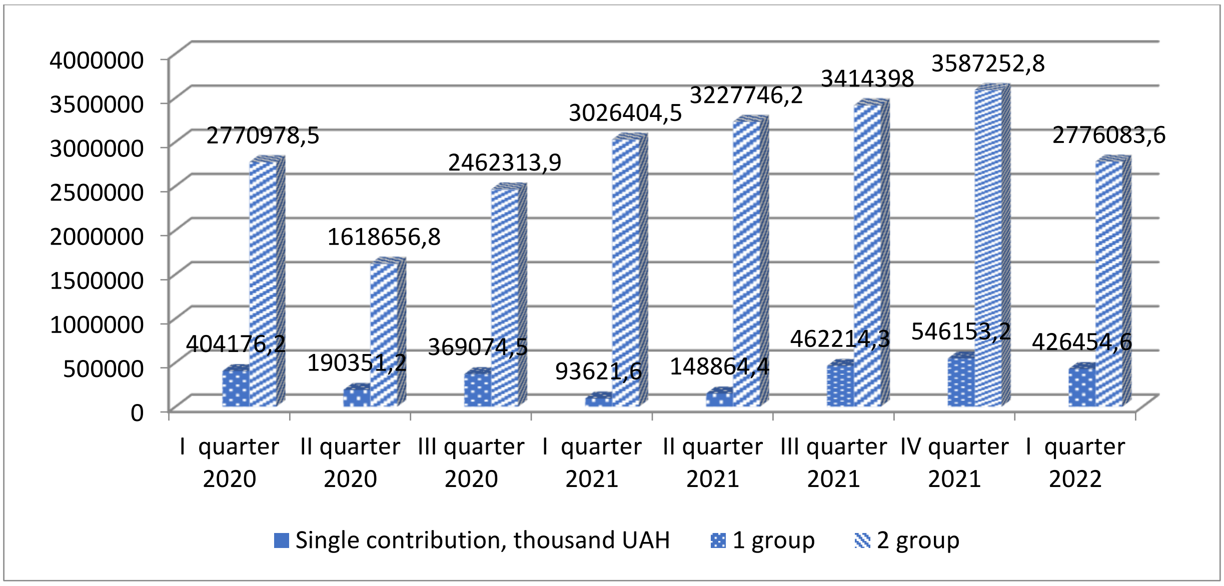

Fig. 3. Dynamics of payment of a single contribution by Group 1 and 2 single tax payers for 2020-2022.

Source: calculated by authors according to the data of the Ministry of Finance of Ukraine

According to Fig. 3 it can be seen that during 2020-2021 and the first quarter of 2022, the amount of a single contribution for group 1 single tax payers did not change significantly and reached UAH 426,454. 6 thousand in the first quarter of 2022, on average, this amounted to UAH 240 per quarter.

The amount of the single contribution for group 2 single tax payers during 2020-2021 was more significant and amounted to UAH 2776083.6 thousand in the first quarter of 2022, and on average for one single tax payer – UAH 544 per quarter.

In total, in the first quarter of 2022, single tax payers of groups 1 and 2 received UAH 3202538.2 thousand of a single contribution. Under the conditions of this trend maintaining, the payment of a single contribution to the budget for 2022 should have received, according to forecast data, 12810153 thousand UAH. At the same time, since these taxpayers are given the opportunity not to pay a single contribution, according to forecast data, , due to the introduced benefits, the budget may not receive in 2022 theoretically 9607615 thousand UAH of a single contribution.

Taking into account these losses of tax revenues to the budget, we consider that the goals declared in the Explanatory note for the Draft Law No. 2120-IX [16] will not be fully achieved. This problem can be solved by establishing a condition according to which these payments (single tax and single contribution) will not be paid by individual entrepreneurs of the first and second groups only for those months in which they do not carry out business activities in connection with the martial law introduction.

One of the most important requirements established by the association agreement between Ukraine, on the one hand, and the European Union, the European Atomic Energy Community and their member states, on the other hand [2], is the approximation of Ukrainian legislation to EU law. The document of the European Commission "Opinion on Ukraine's application for membership of the European Union" [8] on Ukraine's application for EU membership, notes the huge work that Ukraine has done in the framework of the implementation of the association agreement between

Ukraine and the EU, in particular regarding the regulatory approach to EU law acts and the implementation of a number of reforms.

The recommendations for Ukrainian public authorities on approaching EU law [22] (hereinafter referred to as the Recommendations) emphasized that Ukraine is obliged to harmonize national legislation with hundreds of EU normative legal acts (the so-called "EU acquis") from many branches of law. The Recommendations note that one of the most important procedural problems in approximating legislation is compliance verification.

In Ukraine, the Committee on Ukraine's integration into the European Union provides conclusions on the compliance of draft legislative acts.

The analysis of the laws adoption process on changes in the tax legislation of Ukraine in the field of preferential policy during the period of martial law showed the following results of their compliance to EU law (fig. 4).

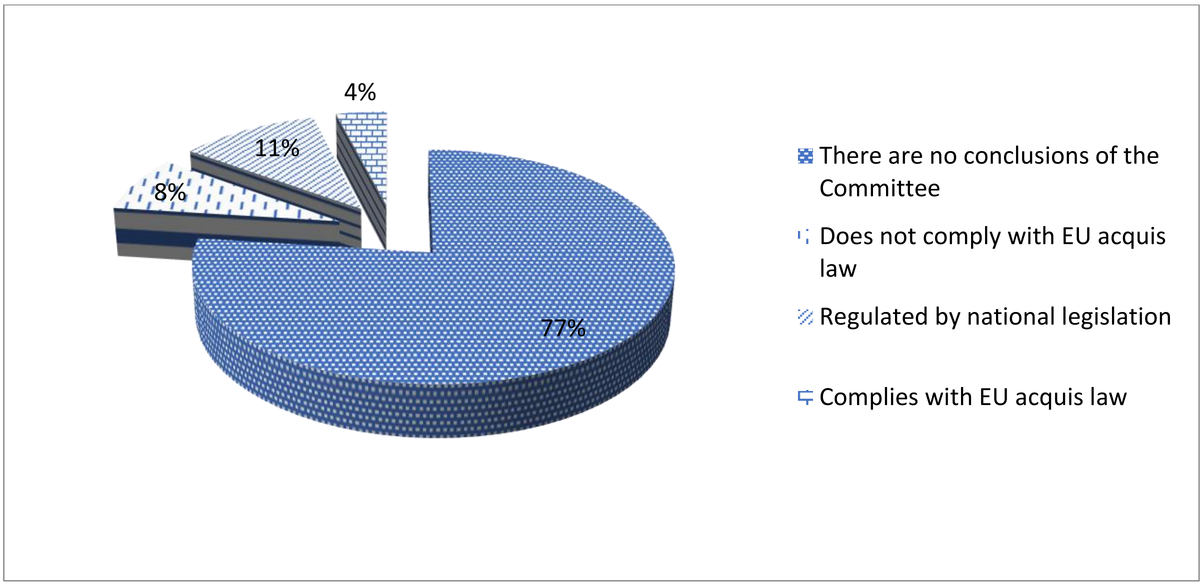

Fig. 4. Structure of the conclusions of the Committee on integration of Ukraine into the European Union on the adopted laws of Ukraine in the field of preferential policy in 2022

Source: developed by the authors based on the analysis of the Tax Code of Ukraine [24]

Figure 4 shows that 77 % (20 draft laws) did not receive the conclusions of the committee on integration of Ukraine into the European Union at all, 8 % (2 draft laws) received a negative opinion of the Committee, 11% (3 draft laws) received the conclusions of the Committee on the regulation of the draft norms by national legislation. And only 4% (1 conclusion) was positive and confirmed the compliance of the draft law with EU acquis law. This situation is unacceptable and does not meet the obligations assumed by Ukraine in the association agreement.

Thus, in the Conclusion of the Committee on the Integration of Ukraine into the European Union [5] to Law No. 2273-IX [14], it was noted that the state support for audio books provided by the provisions of the draft law, distorts economic competition. Therefore, the conclusion of the Antimonopoly Committee of Ukraine regarding the impact on competitive environment and contradicts the EU acquis was necessary. However, despite this inference, the Law was adopted.

In the Conclusion on the Draft Law of Ukraine on Amendments to the Tax Code of Ukraine on Facilitating the Restoration of the Energy Infrastructure of Ukraine [6] it was noted that according to Article 98 of Directive No. 2006/112, the basic VAT rate for EU countries is not less than 15% and the provisions of Regulation 1186/2009 do not provide for exemption from import duty of goods specified in the draft law. Taking into account the above, the Committee on the Integration of Ukraine into the European Union concluded that the provisions of the draft law contradict the acquis of the European Union, but at the same time they can be applied during the period of martial law in accordance with Articles 472 and 143 of the Association Agreement.

However, despite this conclusion, this draft was adopted and implemented in Law No. 2836-IX [20].

Taking into account the above, the norms of our laws, which have not received the opinion of the Committee on Ukraine's integration into the European Union, should be carefully analyzed for compliance with the norms of EU acquis law. After all, based on the conclusions of the main scientific and expert Department of the Verkhovna Rada of Ukraine and the Committee on finance, tax and customs policy of the Verkhovna Rada of Ukraine, two laws do not comply with the EU acquis law, since they violate the principle of legal certainty. In accordance with the requirements of Article 282 of the Association agreement (ensuring legal certainty), legal norms must be sufficiently clear and free from contradictions.

Conclusions. At the first stage of the study, all legislative acts that amended the Tax Code of Ukraine No. 2755-VI of 02.12.2010 [24] since the introduction of the legal regime of martial law in Ukraine in 2022 were analyzed. Based on the results of the analysis, the total number of legislative innovations was determined. All legislative changes are distributed according to some essential characteristics: tax preferences, tax administration process, and fiscal orientation.

At the second stage, a detailed analysis of the content characteristics of legislative acts that amended the Tax Code of Ukraine during the period of the legal regime of martial law was carried out As a result of it there were identified the shortcomings of legislative work such as: the lack of a systems approach to the establishment of benefits and proper justification of legislative innovations, which led to further cancellation of some adopted changes.

At the third stage, the consequences of preferences introduced by the Law of Ukraine "On amendments to the Tax Code of Ukraine and other legislative acts of Ukraine regarding the duration of norms for the period of martial law" of March 15, 2022 No. 2120-IX [16] in the Tax Code of Ukraine regarding preferential taxation of single tax payers of the first and second groups for the duration of the legal regime of martial law in Ukraine were investigated.

Possible budget losses from the introduction of these benefits were predicted and recommendations were given for adjusting the current legislation in order to eliminate the identified shortcomings.

At the fourth stage, the legislative acts adopted during the period of apply the legal regime of martial law in the field of preferential tax policy in terms of their harmonization with the norms of EU law were analyzed. It is revealed that most of the legislative acts adopted in 2022 did not receive the estimation of the Committee on Ukraine's integration into the European Union. In this regard, it was proposed to observe a certain balance of losses of state and local budget revenues and conduct a mandatory examination of the draft law's compliance with the EU acquis standards when developing legislative acts that amend the current legislation.

According to the results of the analysis of legislative acts in the field of preferential tax policy adopted during the period of martial law, a number of shortcomings were identified. In particular, the establishment of preferential norms regarding the unconditional exemption of single tax payers of the first and second groups from paying single tax and single contribution to mandatory state social insurance will inevitably lead to budget losses. Taking into account the above, it is proposed to establish restrictions in the application of preferential norms, in particular, to provide that single tax payers of the first and second groups do not pay only for those months in which they do not carry out business activities in connection with the introduction of martial law.

It is also noteworthy that the implemented laws do not establish any "compensatory" tools that would offset the impact of preferential norms on non-receipt of budget revenues.

The analysis of legislative acts for compliance with the norms of the EU acquis law revealed that 20 draft laws not passed through the appropriate expertise and received the conclusion of the Committee on Ukraine's integration into the European Union.

Two laws were adopted despite the existence of a negative conclusion of the Committee, which indicates shortcomings in legislative practice.

In the latest Analytical report to the Communication of the Commission to the European Parliament, the European Council and the Board of Conclusions of the European Commission regarding Ukraine's application for membership in the European Union [25], it was noted that Ukraine demonstrates a certain level of training in the field of taxation. Although Ukraine has made progress in coordinating VAT legislation with the EU acquis, there are certain legislative gaps.

Taking into account the above, we can conclude that now it is necessary to analyze why in most cases in 2022 the draft laws were adopted without conducting an expert examination of the Committee on Ukraine's integration into the European Union and in some cases were considered after receiving a negative opinion of the Committee, while the identified shortcomings were not eliminated.

In addition, official authorities should listen to the guidelines set out in the recommendations for Ukrainian public administration bodies on approaching EU law and analyze draft laws for compliance with EU acquis law even at the stage of their development. It also makes sense to provide in regulatory acts the special mechanisms that would not allow the adoption of draft laws without obtaining a positive opinion of the Committee on Ukraine's integration into the European Union. This is due to the fact that after the adoption of the relevant laws, it is very difficult to adjust them and harmonize them with the norms of EU acquis law, so it is necessary to prevent the occurrence of such situations.

These recommendations can be applied in the process of regulatory acts developing on amendments to the current tax legislation in order to overcome the negative consequences of the armed aggression of the Russian Federation against Ukraine, which will be the direction of further research.

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ENERGY SECURITY OF UKRAINE IN THE CONTEXT OF EUROINTEGRATION

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Abstract. *In the face of asymmetric effects in the global market, characterized by financial, investment, technological, production, and trade challenges, renewable energy emerges as a potential catalyst for transformative changes. Its primary goal is to rejuvenate economic activity and enhance energy security for nations. Energy security plays a critical role in this discourse, as reliance on non-renewable fossil fuels exposes countries to geopolitical vulnerabilities and environmental issues. In contrast, utilizing renewable energy sources such as solar, wind, hydro, and geothermal power provides a sustainable alternative, reducing dependence on finite resources and mitigating the adverse impacts of climate change. The authors explore the potential of renewable energy and demonstrate how transitioning to clean energy sources can enhance national energy security within the context of post-war economic recovery, while also minimizing the economic and environmental risks associated with a fuel-hydrocarbon model of public production. The adoption of renewable energy sources offers additional benefits beyond diversification and resilience. Renewable energy investments have a positive socio-economic impact by creating job opportunities and stimulating local economies. In addition, the utilization of renewable energy sources promotes technological innovation and fosters a culture of sustainability. By investing in R&D, countries can drive advancements in renewable energy technologies. These innovations can then be shared globally, accelerating the transition to a low-carbon future and fostering international cooperation. The promotion of renewable energy aligns with the SDGs. By integrating renewable energy strategies into national development plans, countries can contribute to multiple SDGs, including affordable and clean energy, climate action, sustainable cities and communities, and economic growth.*

Introduction. In the wake of a global crisis, nations are confronted with the task of revitalizing their economies while also addressing urgent challenges such as intensifying global competition, geopolitical uncertainties, energy security, and the imperative for sustainable development. One approach gaining prominence is the adoption of a green economy framework that aligns with the principles of the United Nations Sustainable Development Goals (SDGs). This approach emphasizes the integration of economic growth, social inclusion, and environmental sustainability to shape a more resilient and equitable future.

The green economy principles focus on fostering sustainable development by decoupling economic growth from environmental degradation. By shifting towards cleaner and more efficient production processes, countries can mitigate the negative impacts on natural resources and ecosystems, while simultaneously promoting economic prosperity. This transition involves adopting renewable energy sources, enhancing resource efficiency, promoting circular economy practices, and investing in green technologies and infrastructure. Additionally, the principles of the United Nations SDGs provide a comprehensive framework for countries to address a wide range of social, economic, and environmental challenges. These goals, encompassing areas such as poverty eradication, education, healthcare, gender equality, and climate action, offer a roadmap for nations to achieve sustainable development holistically. By aligning their policies and actions with the SDGs, countries can contribute to the global agenda while addressing their unique development priorities.

The historic example of the Marshall Plan, officially known as the Program for the Reconstruction of Europe after World War II, serves as a remarkable precedent for international cooperation and effective utilization of financial resources. Spearheaded by the United States, this initiative successfully revitalized economies, promoted political stability, and fostered transatlantic alliances among nations. Drawing inspiration from this historic endeavor, countries today can leverage similar collaborative efforts and financial mechanisms to implement green economy principles and advance sustainable development goals.

Materials and Methods. In this study, a systematic approach was employed to analyze and compare various factors related to the subject matter. The research methodology incorporated elements of comparison, analysis, synthesis, and abstract-logical reasoning to ensure a comprehensive and rigorous investigation. To begin with, a systematic review of expert resources was conducted to gather relevant information and insights from existing studies and scholarly works. In addition, the use of a systematic approach, combined with comparison, analysis, synthesis, and abstract-logical reasoning, ensured a rigorous and comprehensive methodology for this study. Overall, these methods provided a solid foundation for collecting, analyzing, and interpreting data, ultimately leading to reliable and valid conclusions.

Results and Discussion. On June 23, 2022, the leaders of 27 EU member states decided to grant Ukraine the status of a candidate for EU membership. Further preparation for membership will involve the commitment to harmonize national policy with EU standards, to carry out a comprehensive transformation of socio-economic development. The country’s status as a candidate for EU membership can contribute to the formation of an attractive business space for foreign investors through increased stability and the introduction of international regulatory standards. The specific impact of the status of a candidate EU member state on the management of changes in the state economic policy will depend on many factors, and this situation may change over time. At the level of international organizations, this requires the standardization of management decisions, in particular, the implementation of EU recommendations aimed at supporting Ukraine in the key direction of harmonization, standardization, unification, implementation in support of the development of political and regulatory measures to increase energy sovereignty, which will also contribute to its achievement of the Sustainable Development Goals (SDGs), declared by the UN General Assembly Resolution No. 70/1 of 09/25/2015, namely: universal access to affordable, reliable and modern energy supplies, including renewable energy sources (SDG 7) (UNDP, n/d). Additionally, the program for integration with the European Union, with a budget of up to $1 billion, focuses on harmonizing Ukrainian legislation with European standards. This harmonization process will foster closer cooperation and interaction between Ukraine and the EU, promoting stronger ties and facilitating smoother integration efforts.

According to the reform course of the government of Ukraine, the development of renewable and low-carbon energy sources is foreseen in the coming years in order to achieve energy independence. To this end, in 2019-2021, Ukraine successfully separated the operators of the gas transportation network and the transmission system, which was confirmed by their certification, and makes changes to corporate governance approaches in state-owned companies in the energy sector. NEC Ukrenergo, as a Ukrainian transmission system operator (TSO), has taken measures to prepare our power system for synchronization with ENTSO-E since 2017, when the Agreement on the conditions of future unification was signed. Since then, testing of power units of Ukrainian NPPs, TPPs, CHPs and HPPs has been carried out, a mathematical model of the energy systems of Ukraine and Moldova has been created, on the basis of which the ENTSO-E OSP Consortium has conducted a study of the static and dynamic stability of the energy systems of Ukraine and Moldova when working with the network of continental Europe. As a result, Ukraine joined the ENTSO-E continental Europe unified energy system a year earlier than planned, thereby fully synchronizing with the ENTSO-E continental European energy network (Cabinet of Ministers of Ukraine, 2022).

Ukraine has yet to enact the necessary legislation to align with the Governance Regulation mandated by the Energy Community, as well as its domestic energy and climate plan. As a signatory to Annex I of the United Nations Framework Convention on Climate Change, Ukraine has established a comprehensive legal framework for the development of a national greenhouse gas inventory system. It diligently conducts annual greenhouse gas inventory assessments, formulates policy initiatives, biennially reports on its progress and future projections to the UNFCCC, and maintains a rigorous system for quality assurance and quality control (European Commission, 2023).

One of the key mechanisms introduced in the program is the Carbon Border Adjustment Mechanism (CBAM). This mechanism will set tariffs on goods imported into the EU, the production of which is associated with carbon emissions. The Council decided to progressively strengthen CBAM rules over a period of 10 years between 2026 and 2035. The European Green Deal (EGD) package of initiatives was adopted by the EU at the end of 2019. The goal of the strategy was to transform the economy into a low-carbon, sustainable, and therefore more suitable for future generations. According to the plans of the EEC developers, the EU member states should achieve climate neutrality by 2050.

Ukraine became one of the first countries to support the EWC. The Ukrainian authorities argued for the strategy of “early joining” the agreement with the possibilities of influencing the processes of minimizing potential threats with the help of joint projects on decarbonization and climate protection. However, with the beginning of full-scale Russian aggression, the situation in the country changed. The founding document of the European Commission on EWC states that “climate change and biodiversity loss are global in nature and are not limited by national borders, so the European Union can use its influence, experience and financial resources to mobilize its neighbors and partners”. Thus, the EU called on other countries to join the EWC on the way to sustainable development (UA Energy, 2023).

RePowerEU envisions the annual production and import of at least 20 million tons of hydrogen derived from renewable energy sources. However, it is anticipated that EU member states may only fulfill half of this target through their own hydrogen production capacities. Nevertheless, direct exportation is not the sole promising avenue for harnessing Ukraine’s hydrogen potential. Valuable prospects include the advancement of “green” hydrogen-based metallurgy and, potentially, the manufacture of ammonia and fertilizers using “green” hydrogen as a feedstock. The establishment of a “hydrogen cluster” in the Zaporizhia and Dnipro regions is a viable possibility. This geographic region boasts optimal access to essential resources such as water, iron ore deposits, and a promising renewable energy potential, facilitating the development of hydrogen production and its application in “green” direct reduced iron (DRI) and steel production. Additionally, hydrogen can serve as a means of storing surplus electricity generated from renewable sources when production surpasses demand. Nonetheless, the cost-effectiveness of this hydrogen utilization is not expected until at least 2030, owing to the inherent inefficiencies in the process.

The founding document of the European Commission on EWC states that “climate change and biodiversity loss are global in nature and are not limited by national borders, so the European Union can use its influence, experience and financial resources to mobilize its neighbors and partners”. Thus, the EU called on other countries to join the EWC on the way to sustainable development.

In autumn 2020, the Ukrainian authorities presented “Vectors of Ukraine’s economic development until 2030”. However, according to the assessment of environmental experts, this strategy did not consider the economic model of Ukraine in the context of the integration of environmental and climate aspects into all spheres of the economy, climate neutrality and circular economy. At the same time, a sociological survey of public opinion conducted by the Resource-Analytical Center “Society and Environment” at the beginning of 2023 showed that reconstruction on ecological grounds is not among the top priorities of Ukrainians.

The survey showed that 95% of Ukrainians believe that the restoration of nature is important in the post-war reconstruction of Ukraine. At the same time, only about 26% are ready to pay for the environmental friendliness of basic services, such as access to high-quality drinking water, public transport, and proper waste management. And about 54% of respondents said that they would not participate in government programs to improve the energy efficiency of buildings if this would lead to an increase in the cost of utility services (UA Energy, 2023).

The goal of the reconstruction of Ukraine should not be a return to the pre-war state, but a full-fledged development and integration into the European community on the basis of sustainable development and taking into account what is also a requirement of the Copenhagen criteria for joining the EU. The need to speed up the implementation of European environmental legislation is caused by the need to comply with international obligations, as well as changes in the status of Ukraine as a candidate country for joining the EU. The need to speed up the implementation of European environmental legislation is caused by the need to comply with international obligations, as well as changes in the status of Ukraine as a candidate country for joining the EU. The too slow process of implementation of European directives in the “green” sphere in Ukraine was noted in the February 2023 report compiled by the expert group of the European Commission. Analysis of Ukrainian legislation shows that the country is showing significant progress in the implementation of energy reforms, but is still at the initial level of preparation in the field of environment and climate change. The report summarizes that Ukraine has done a lot to build its environmental regulatory framework and relatively little to reform its regulatory framework and align with climate law. But European experts noted that the gaps in the level of legislative coordination have grown with the expansion and deepening of the EU acquis (EU law) in these areas. The European Commission recommends solving problems with the ability to adopt the relevant EU acquis, taking into account the provisions of the European Green Course in all policy areas and effective implementation and enforcement of legislation.

The war with Russia made the problem of energy dependence of European states on the import of traditional energy resources even more acute. The reaction to this aggravation was the renewed “green” program RePowerEU, which raises the main goals of the Green Deal and Fit for 55 to an even higher level. The central goal of the program is to replace gas imports from Russia. Potential instruments for ensuring the EU’s demand for gas in the event of a refusal to import gas from Russia until 2030.

The Parliament of Ukraine has registered draft law No. 6004 dated 04.01.2023 "On integrated prevention and control of industrial pollution", which should introduce Directive 2010/75/EC on industrial emissions into Ukrainian legislation. This draft law is important within the framework of the European Union as a signal to international partners and investors that the same environmental regulations apply in Ukraine as in the EU. Therefore, it will be possible to create factories here or invest in the restoration of Ukrainian industry in accordance with EU policies. And for Ukraine, this draft law will be a guarantee that investments will be environmentally sustainable without harming people's health" (Verhkovna Rada, 2023). After all, this will contribute to the creation of a new permit system for industry in the form of an IT system, which will combine separate permits for emissions into water, air, soil, noise pollution, which will help calculate the cumulative impact on the environment, as well as the introduction of European emission standards for all types of industry in accordance with the indicators of the best available technologies (BAT – best available techniques), will contribute to the modernization of production and its growth.

Also, we cannot ignore the Draft Plan for the Recovery of Ukraine, which was prepared by the National Council for the Recovery of Ukraine from the Consequences of the War for the materials of the "Energy Security" working group, in particular with emphasis on such blocks as (Fig. 1) (Cabinet of Ministers of Ukraine, 2022).

Recommendations for the implementation of goal 3 "Decarbonization, optimization of the energy mix and development of low-carbon generation" in the context of the implementation of the Recovery Plan of Ukraine "Energy Security"

3.1: Updating the estimation of the optimal generation structure, taking into account the state after the end of hostilities
3.2: Nuclear generation: Modernization and optimization of the use of installed nuclear capacities (increasing the KVVP), extension of the operating period of existing units, development of new capacities at the Khmelnytskyi NPP
3.3: Hydropower: Completion of the construction of a new hydropower plant (Kakhovska-2 HPP, Kanivska HPP, Dnistrovsk HPP – completion)
3.4: Solar and wind energy: restoration of capacities taking into account new conditions and opportunities due to integration with ENTSO-E
3.5: Increasing the production of biomethane (up to 2 billion cubic meters per year) and connecting the installations to the GRS/HTS
3.6: Hydrogen: Launch of 1-2 GW pilot projects with the prospect of building up to 15 GW in combination with RES (mostly at the expense of private investors)

Fig. 1. Recommendations regarding the implementation of goal 3 "Decarbonization, optimization of the energy mix and development of low-carbon generation" in the context of the implementation of the Recovery Plan of Ukraine "Energy Security"

The estimated €750 billion Marshall Plan for Ukraine will serve as a foundation for rapid and sustainable economic development in Ukraine and throughout Europe in the 21st century. To ensure the success of this plan, it is crucial to promote structural changes in the economy, foster integration with the European Union, and address challenges in key strategic sectors (United4Ukraine, 2022). By diversifying the implementation channels, the Marshall Plan for Ukraine aims to create a comprehensive framework for economic development and facilitate the country's integration into the European community. Presented in Lugano, the new Marshall Plan encompasses a comprehensive set of strategic areas that will drive the economic and social development of Ukraine. With the plan consisting of 15 national programs spanning various sectors, each program includes a range of key projects scheduled for implementation as early as 2022 (ICPS, 2023). By strategically addressing defense and security needs and actively pursuing integration with the EU, the new Marshall Plan sets the stage for Ukraine's advancement in crucial areas, ensuring a more secure and prosperous future.

The program dedicated to the environment and sustainable development, with a budget of approximately $20 billion, encompasses several notable projects. These include the restoration of salt mines in the village of Solotvino in Zakarpattia, the reduction of the Chornobyl nuclear power plant exclusion zone from 30 km to 15 km, the establishment of 142 waste processing complexes, the creation of ten natural parks, the construction of 15 eco-friendly houses, and the establishment of ten centers for wildlife rehabilitation. The energy security program, allocated a budget of around $130 billion, focuses on various initiatives. These include the construction of hydroelectric power plants (HPP) and nuclear power plants (NGP), the development of renewable energy-based power plants with a capacity of 5-10 GW, the completion of additional units at the Khmelnytskyi NPP, the modernization of existing nuclear power plants, and the construction of infrastructure for the production of 'green' hydrogen.

Based on the OECD research, here are some recommendations on the measures to be taken for the development of the green economy in Ukraine (OECD, 2022):

1. Strengthen data collection and analysis: continue conducting comprehensive studies and analyses, similar to the ones carried out by the OECD, to provide robust evidence on energy subsidies. This will enhance transparency and provide a solid analytical basis for future policy reforms.

2. Raise awareness and build a case for reform: utilize the available reports and data to raise awareness among policymakers, stakeholders, and the general public about the negative impacts of fossil fuel subsidies. Highlight the economic, environmental, and social costs associated with such subsidies, and emphasize the potential benefits of subsidy reforms.

3. Establish a clear roadmap for subsidy reform: develop a well-defined plan and timeline for phasing out fossil-fuel subsidies. This roadmap should include specific targets, policy measures, and implementation strategies to gradually reduce and eventually eliminate subsidies. Ensure that the roadmap aligns with the country's energy transition goals and commitments to international agreements.

4. Promote alternative energy sources and energy efficiency: invest in renewable energy technologies and energy-efficient practices to reduce dependence on fossil fuels. Encourage the development and deployment of clean energy solutions, such as solar, wind, and hydroelectric power, and incentivize energy-efficient practices in industries, buildings, and transportation sectors.

5. Enhance coordination and cooperation: foster collaboration among Eastern Europe and Caucasus countries, regional organizations, and international partners to share experiences, best practices, and lessons learned in subsidy reform. Exchange knowledge on successful subsidy phase-out strategies and explore opportunities for joint initiatives and projects.

6. Strengthen institutional capacity: provide technical assistance and capacity-building support to relevant governmental agencies responsible for subsidy reform. Enhance their ability to design and implement effective policy measures, monitor progress, and evaluate the impact of subsidy reforms.

7. Monitor and evaluate progress: establish a robust monitoring and evaluation framework to track the progress of subsidy reform efforts. Regularly assess the effectiveness and efficiency of

policy measures, identify challenges and barriers, and make necessary adjustments to ensure successful implementation.

8. Promote international cooperation and peer learning: engage with international organizations, such as the OECD, and participate in regional and global forums focused on subsidy reform and energy transition. Learn from the experiences of countries that have successfully phased out fossil-fuel subsidies and seek opportunities for collaboration and knowledge-sharing.

By implementing these measures, Ukraine can gradually reduce its reliance on fossil fuel subsidies, promote sustainable energy practices, and contribute to global efforts in mitigating climate change and achieving sustainable development goals.

Addressing the public finance implications of the net-zero transition (OECD, 2023). It is essential to recognize the potential magnitude of these implications, especially when considering the indirect effects that carbon pricing can have on other sources of public revenue, such as fossil fuel taxes. In light of this, governments should undertake the following measures:

(i) Implement prudent fiscal planning to ensure a resilient net-zero transition. This requires a comprehensive assessment of both the direct and indirect effects of policy instruments on emissions. While policies may directly impact tax rates, they also have implications for tax bases. It is important to note that most indirect effects tend to exert downward pressure on public revenues.

(ii) Conduct a thorough analysis of the implications of national policy mixes on public finance, taking into account that non-price-based policies generally require increased government expenditure. Additionally, the national economic structure plays a pivotal role in determining fiscal outcomes. Therefore, a careful examination of the fiscal consequences of different policy combinations is imperative.

(iii) Develop plans to gradually implement alternative tax instruments, such as distance-based fuel charges, to mitigate the risk of tax base erosion. This risk becomes particularly significant for the country's fiscal balances, especially concerning excise duties on fossil fuels in the transport sector. As the transition to a net-zero economy gains momentum, these excise duties are expected to decline.

Maintaining investment flows amidst rising costs of capital (OECD, 2023). To address the challenges posed by the escalating costs of capital in the net-zero transition, it is crucial to ensure the continuity of investment flows and safeguard the economic viability of low-carbon projects. The government should take the following actions:

(i) Uphold the ambition and rigor of core climate policies to send a clear and compelling message to investors and financial institutions regarding the future significance of low-carbon assets. By maintaining strong climate policies, governments can instill confidence and provide long-term certainty for investments in low-carbon initiatives.

(ii) Continue providing fiscal support for low-carbon investments whenever possible, while exercising caution when phasing out subsidies for clean technologies. It is important to strike a balance between nurturing the growth of the low-carbon sector and managing the gradual reduction of subsidies in a manner that does not impede progress.

(iii) Implement policies aimed at reducing investor risk, such as promoting the inclusion of risk insurance or guarantees in financing arrangements for renewable energy projects. The government can also bolster governance structures by ensuring high-quality and predictable regulatory frameworks. Additionally, streamlining the permitting process for renewable energy projects can help alleviate barriers and facilitate timely project implementation.

(iv) Support the development of market products and measurement methodologies that enable investors to align their portfolios more effectively with climate objectives. However, it is essential to design these approaches carefully to avoid unintentionally diverting investment away from developing countries. Measures should be taken to ensure a balanced distribution of investment opportunities.

In addition to government actions, central banks can consider implementing ‘green’ monetary policies to safeguard low-carbon investments in the face of challenging investment conditions. This may involve offering preferential refinancing rates for low-carbon technologies or adopting green quantitative easing strategies, such as purchasing green bonds exclusively, to maintain low-interest rates specifically for climate-friendly sectors.

By adopting these measures, Ukraine could proactively address the public finance implications associated with the net-zero transition. Through careful fiscal planning, analysis of policy mixes, and the introduction of alternative tax instruments, they can ensure a resilient and sustainable pathway to a net-zero future. It is crucial to anticipate the challenges that arise from changes in revenue streams and fiscal balances and to take proactive steps to manage them effectively. The government and central bank can foster an environment conducive to sustainable investment flows, despite the rising costs of capital. Sustaining investor confidence, providing targeted fiscal support, mitigating risks, and promoting innovative financial instruments will contribute to the successful realization of the net-zero transition and the achievement of climate objectives.

Conclusions. In conclusion, the transition towards renewable energy sources is a vital step towards a more sustainable and resilient future. By diversifying energy portfolios, stimulating economic growth, fostering technological innovation, and promoting environmental stewardship, nations can lead the way in addressing global challenges and creating a better world for future generations. Moreover, aligning the development of renewable energy with the Sustainable Development Goals (SDGs) established by the United Nations offers a comprehensive framework to address global challenges, including eradicating poverty, implementing climate change measures, and ensuring access to clean energy resources. By integrating renewable energy strategies into national economic recovery plans, countries can simultaneously foster economic growth, promote social justice, and uphold environmental sustainability. The convergence of the Marshall Plan, the importance of green energy, and the potential of renewable energy is realized through a series of measures designed to support small and medium-sized enterprises, enhance infrastructure development, strengthen energy efficiency, modernize the healthcare system, and improve the quality of education. These elements are reflected in the plan for national economic recovery. In summary, the Marshall Plan for Ukraine stands as an essential strategic document and a valuable experience in formulating effective strategies to achieve economic growth, enhance national security, improve citizens’ quality of life, and uphold democratic and legal values.

We believe that the development and formation of proposals for the doctrinal model of the Energy Security Strategy project in the context of European integration for the medium-term perspective until 2030, which should be based on a holistic integrative model of the system of principles of the rule of law and sectoral legal frameworks, one of the components of which should be vector of further cooperation with international partners. Proposals for key stakeholders within the framework of the doctrinal project of the Energy Security Strategy in the context of European integration for the medium-term perspective until 2030 are presented in Fig. 2.

Proposals for key stakeholders within the framework of the doctrinal project of the Energy Security Strategy in the context of European integration for the medium-term perspective until 2030

(1) FOR THE GOVERNMENT OF UKRAINE, which should formulate the government's priorities, taking into account the opportunities and threats of the EEC; to invite the European side to start a dialogue on the development of a Road Map for Ukraine within the framework of the EWC; to support the further European integration of Ukraine in the spheres of EEC, which are a priority for Ukraine; to formulate the climate policy of Ukraine; to support the integration of Ukrainian manufacturers into EU industrial production chains, in particular to ensure the signing of the ACCA as soon as possible; use and promote new opportunities for financing and attracting green investments, continue digitization; inform business about the role of the carbon footprint in future exports to the EU.

(2) FOR THE SUPREME COUNCIL OF UKRAINE, which, first of all, should ensure the process of full implementation of the requirements of European legislation related to the EWC, in particular through the strengthening of control mechanisms for compliance of draft laws with the requirements of European legislation and consideration of climate change issues at all stages of law-making.

(3) FOR BUSINESS, which must take into account the goals of the EWC in the process of strategic planning of its development and use the financial instruments of the EWC; to look for opportunities for integration into new industrial production processes on the EU market; take into account that access to the EU markets in the future will depend significantly on the compliance of goods and services with the climate and environmental requirements of the EU.

(4) FOR CIVIL SOCIETY, which, first of all, should contribute to better informing all interested parties about the opportunities and challenges of the EWC, as well as continue the process of monitoring the implementation of European integration reforms in Ukraine.

(5) FOR THE EUROPEAN SIDE, which should consider Ukraine as a necessary partner in the implementation of the EUC, develop together with the Government of Ukraine a road map for Ukraine based on the example of the Roadmap for the Balkan countries provided for by the EUC; promote Ukraine's integration into new "green" production processes in the EU by initiating an industrial dialogue; strengthen control over the sustainability of goods and services imported into the EU from Ukraine, in particular wood, agricultural products, etc.; support investments from the EU aimed at the production of "green" goods, decarbonization of the economy; continue to provide assistance to Ukraine in the approximation of legislation in the field of environmental and climate protection, agriculture, energy, and transport;

to form flagship initiatives for the integration of Ukraine into the EU environmental sphere, in particular, to start a dialogue on the elimination of barriers in the implementation of the bird and habitat directives and the integration of Ukraine into the NATURA 2000 network.

Fig. 2 Proposals for key stakeholders within the framework of the doctrinal project of the Energy Security Strategy in the context of European integration for the medium-term perspective until 2030 (Dixigroup, 2020)

For each of the outlined directions, it is necessary to define strategic goals, the implementation of which will be directed by the efforts of the main manager of financial resources in the country, as well as quantitative and qualitative indicators that will testify to their achievement, which will contribute to the formation of the Strategy-2030, which will form the basis for sustainable and inclusive development international cooperation and the national economy in general, improving the well-being of Ukrainian citizens. During the development of new strategic documents, attention should be paid to the main aspects of the real picture of cooperation with international financial institutions in the field of energy security, while respecting national interests. It is advisable to continue making efforts to increase the effectiveness of joint programs. First of all, it is about drawing up domestic norms and rules and harmonizing them with European ones (taking into account the chosen development vector) in order to more effectively avoid risks and manage them, monitor the processes of preparation, implementation and evaluation of the effectiveness of such proposals.

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STRATEGIC PLANNING OF THE INDUSTRIAL RECOVERY IN UKRAINE BASED ON SUSTAINABLE DEVELOPMENT

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Abstract. *The article substantiates the importance of incorporating the principles of sustainable development into the strategic planning of Ukraine's post-war recovery. The authors noted the importance of the full Sustainable Development Goals implementation into the national strategic documents of Ukraine for recovery economic growth and integration into the European community. It made possible to determine the levels of support for sustainable development in Ukraine and the tools for their implementation. These include the introduction of a flexible strategic planning system and associated institutional arrangements; developing funding strategies and creating databases to track progress towards achieving the SDGs. These tools include in-depth interaction with foreign partners in the EU. The primary task is to develop National Plans for Post-War recovery, aligning the goals of recovery with the SDG goals and indicators. The goals and objectives mandatory for the post-war recovery of industrial development in Ukraine are substantiated, namely energy efficiency, ensuring efficient, safe and environmentally friendly production according to the sustainable development principles, a future without a carbon footprint and a circular economy in accordance with the European strategic vector. The action of these instruments is aimed at creating favorable conditions for eco-innovative transformations and is implemented at the level of interstate cooperation, state institution, regional public institution and enterprises. Areas of consolidation with the European agenda have been identified, namely strengthening cooperation in the field of green economy: decarbonization, waste management; harmonization of industrial policy, creation of alliances and promotion of international cooperation.*

Introduction. European society is a model of sustainability and democracy. It confirmed by a system of values and a well-developed infrastructure aimed at achieving sustainable development in all EU countries - rational models of consumption and production, ecological use of natural resources to meet the needs of the current and future generations of people. Adherence to the European principles of socio-economic development is a strategic goal of Ukraine, which, despite being tested by the war for its independence, freedom and national identity, continues to carry out the necessary reforms for joining the EU. The consequences of russia's war with Ukraine go far beyond Europe and affect almost all aspects of sustainable development for all countries. First of all, the war could cause a global food crisis that would last for years. The decline in the global food supply has led to a sharp rise in food prices. In addition, the introduction of a ban on the export of Ukrainian food by some countries increases the risk of a global food crisis. This distorts the direction vector of a civilized society towards the achievement of the Sustainable Development Goals. The second important aspect of threat to achievement of the Sustainable Development Goals is the ecological catastrophe caused by military actions and threats to nuclear security of world. The situation in Ukraine showed how unstable global energy security is, which is directly related to oil and gas. Therefore, war in the heart of Europe has reinforced the importance of coordinated actions of democratic world in strategic planning of events and development of responsible policies to overcome threats not only to the economy and climate, but also to security of every citizen.

Materials and methods. To achieve this goal, the following methods of scientific research are applied: system analysis, content analysis, methods of scientific generalization, induction and deduction. Scientific publications and reports of international organizations in the relevant fields, normative legal acts, in particular regulations, work programs and documents of the European Commission, draft plans for the recovery of Ukraine, scientific works of foreign and domestic scientists were used. In particular, through the approaches of the Economic Analysis and Policy Division of the United Nations Department of Economic and Social Affairs (UN DESA), published in the Sustainable Development Outlook 2021, the relationships between selected DGs are identified, which helps to understand and explain the results of progress and tools towards achieving these goals.

Results and Discussion. At the current stage, achieving sustainable economic growth has become an important item on the global agenda. Harmonious coordination of the components of sustainable development, which ensures economic growth, social stability and ecological balance in long term, can be ensured with the help of concept of green economy, which has recently received increased attention around the world. The transition from the traditional model of economic development to green growth is becoming a worldwide global trend, in which the green economy acts as a tool for achieving sustainable development. In 2015, at the Summit on "Sustainable Development" in New York, 17 global goals were approved, the achievement of which is to reduce poverty, protect the planet and ensure that by 2030 all people live in peace and prosperity. 17 Goals are priorities for achieving a balance between the three elements: social, economic and environmental sustainability. They are complementary: actions in one area also affect results in others, combating climate change is one of the 17 goals that currently require active action [1].

Issues of sustainable development and its implementation into development of civil society are at the center of the foreign and domestic scientific discourse. So, A. Balaskas, E. Lima, T. Sid and others from the School of Engineering at Blackinge Institute of Technology, Sweden, developed the Framework for Strategic Sustainable Development Assistance (FSSDA). The program is based on a five-level strategic planning framework, which includes the following stages: system-wide measurement; identification of strategic development goals; guidance to the strategic management process; development initiatives, projects and programs; tools for monitoring, measurement, evaluation, analysis, capacity building, etc. Dr. Mousumi Roy provided policy recommendations in developing and implementing sustainable development strategies. In his book “Strategy for Sustainable Development. Technology, culture and economics”, he combined social, economic and environmental goals, taking into account their consequences for different socio-economic groups and future generations [3].

Drawing on the concept of externalities, I. Montiel, A. Cuervo-Casurra and others have argued how multinational companies can contribute to the implementation of the UN Sustainable Development Goals as part of their regular investments. The authors grouped 17 sustainable development goals into six categories based on whether they increase positive externalities or reduce negative externalities and placed these categories in an expanded value chain to facilitate their implementation. This allowed them to prove the dependence of profitable corporate growth on the integration of environmental or social sustainability issues [4].

Ukrainian researchers Yu. Petrushenko, V. Aleksandrov and others conducted a bibliometric analysis in the VOS viewer software and identified the main scientific clusters of the connection between the theory of sustainable development and the strategic planning of local communities [5].

The Sustainable Development Outlook 2021, prepared by the Economic Analysis and Policy Division of the United Nations Department of Economic and Social Affairs (UN DESA), selected individual DGs, analyzed progress in the years preceding COVID-19, examined the impact of the pandemic on them, and generated scenarios for achieving these SDGs and identifying policies that can help realize these scenarios. The Sustainable Development Outlook (SDO 2021) aims to facilitate the process of revitalizing efforts to achieve the 2030 Agenda [6].

In national sustainable development strategies of individual countries, ecological component is mentioned in connection with economic growth, and solution for tasks of greening complex and economic growth is envisaged within the framework of implementation of the green economy concept. The result of applying the concept of green growth should be a transition to a low-carbon economy. It should be based on socially responsible business conduct, which involves the implementation of complex programs and mechanisms for increasing resource efficiency, developed taking into account the technologies available at the enterprise (waste management programs, energy efficiency improvement programs, etc.). Its integral component is also socially responsible consumption, which involves changing people's views, thinking and values in relation to nature. The concepts of sustainable development, green and circular economy are similar in many respects: these concepts are global; they emphasize the importance of better integrating environmental and social aspects with economic progress; they emphasize intra- and intergenerational obligations due to environmental hazards; and also signal the importance of expanding the participation of authorities and the public. Therefore, when considering the concepts of sustainable development, green and circular economy, it is necessary to emphasize a similar approach to their formation, caused by the growth of environmental risks, the general focus on ensuring development based on economic growth, as well as the importance of partnership and cooperation between interested parties to achieve the set goals. The solution to Sustainable Development Goals 12 "Responsible consumption and production" in the field of sustainable development is the transition to a circular economy, which represents a system of production and consumption with maximum efficiency in the use of resources, waste management and minimization of external negative effects on the environment. Sustainable development goal 12 "Responsible consumption and production" provides for achievement of reducing the resource intensity of economy and ensuring environmental safety. That is, the prerequisites for its achievement are industrial development with a simultaneous reduction of burden on the environment, i.e. achieving a balance between economic development and preservation of natural resources. And this, in turn, will contribute not only to reducing resource consumption, but also to reducing the cost of manufactured products and increasing their competitiveness. As well as Goal 12 achievements will allow to fulfill the tasks set in the Goals 6, 7, 8, 11, 13, 14, 15 and positively influence the decisions of others. This is also confirmed by analytical assessments of the Institute of Social and Economic Research of Ukraine, confirming the synergistic impact of SDG 12 on other important goals. The 12th SDG objectives related to reducing the resource intensity of the economy, reducing the volume of waste generated and deepening their recycling (SDG 12.1 and 12.4) are quite fully reflected in the state strategic documentation concerning the development of economic sectors. However, A significant disadvantage is the lack of the specific resource intensity indicators that should be achieved in the process of completing the assigned tasks [7]. That is, to assess the implementation of the 12th SDG in Ukraine, we will consider how we managed to achieve the appropriate level of indicators for 2015-2021 and the estimated results in 2025 and 2030. (Table 1).

Table 1

Indicators of achievement of the SDGs in Ukraine, % to the level of 2015

Indicator	2015	2016	2017	2018	2019	2020	2021	2025 (mark)	2030 (mark)
Energy intensity of GDP	100	102,3	94,7	95,2	88,5	88,9	- [1]	80	60
Material capacity of GDP	100	100,0	98,2	97,2	100,4	99,9	108,2	80	60
Carbon capacity of GDP	100	105,8	85,1	83,8	77,9	72,8	72,2	80	60
Water capacity of GDP	100	98,2	91,7	95,1	91,6	94,2	77,3	80	60
Waste capacity of GDP	100	92,5	111,6	103,9	126,1	137,3	141,6	80	60

1 The calculation of the indicator for 2021 will be renewed after the deadline for submitting statistical and financial reports established by the Law of Ukraine "On the protection of the interests of subjects submitting reports and other documents during the period of martial law or a state of war".
Source: data of the State Statistics Service of Ukraine [8].

The given data confirm that Ukraine has long been actively supporting the implementation of the 2030 Agenda for Sustainable Development, an international document adopted in 2015 to overcome poverty, protect the planet, and ensure peace and prosperity for all people by the end of this decade. In 2019, the President of Ukraine, V. Zelenskyy, adopted the Decree on the integration of 17 Sustainable Development Goals (SDGs) into state policy [9], as a basis for achieving sustainable economic and social development for all Ukrainians based on the principle of "no one will be left behind without attention".

Until the start of a full-scale war in February 2022, Ukraine made steady progress in achieving 15 of the 17 Sustainable Development Goals, and moreover, it achieved the greatest success precisely in reducing poverty. The Voluntary National Survey of Ukraine for 2021 showed a decrease in poverty from 58.3% in 2015 to 43.2% in 2018 [10]. Reduction of resource intensity of GDP in 2021 compared to the level of 2015 by components: energy intensity of GDP to 88.2%; carbon capacity of GDP up to 72.2%; water capacity of GDP up to 77.3%. The dynamics of most of its components (except for the material intensity of GDP 100.4% and the waste intensity of GDP 141.6%) are positive and there is a high probability of achieving the defined target guidelines for 2025. Therefore, when discussions begin regarding the recovery of the country and the economy, the SDG are used as a reference point to ensure the most effective recovery in Ukraine.

The transition to sustainable development is a complex and long-term process that requires painstaking work at all levels, taking into account the experience of developed countries that have passed similar tests and achieved a high level of development. The creation of prerequisites for the introduction of the green economy model, first of all, by focusing on resource-efficient and clean production and consumption (including energy saving) requires the improvement of legislation. In particular, we are talking about the introduction of a new hierarchy of waste management in Ukraine and the expansion of producer responsibility, a system of long-term waste management planning at the national, regional and local levels; implementation of measures to prevent or reduce the generation of waste, promote preparation for reuse as secondary raw materials and energy resources; creation of cost-effective technologies for the processing of solid household waste with the receipt of a final product useful for society; improvement of existing logistical approaches to household waste management at the national and regional levels.

An effective institutional framework for sustainable development at all levels is the basis for the full implementation of the Principles of Sustainable Development and the principles of the Rio Declaration on the Environment, including the provisions of the Millennium Declaration, taking into account the Monterrey Consensus and relevant outcomes of other major United Nations conferences and international agreements since 1992 [11]. This should lead to the strengthening of international institutions and organizations involved in sustainable development, following their existing mandates, as well as the strengthening of relevant regional, national and local institutions. The action of these instruments is aimed at creating favorable conditions for eco-innovative transformations and is implemented at the level of interstate cooperation, government agencies, regional institutions and enterprises, as shown in Table 2.

Table 2

Characteristics of levels of support for sustainable development in Ukraine

Level of influence	Characteristic
International cooperation	Fulfillment of the country's international obligations within the framework of international agreements, in particular the European Green Course
State management agencies	The formation of an effective industrial policy, the modernization of the institutional infrastructure, which involves the systematic implementation of reforms in all spheres of the economy, the creation of an innovative ecologically oriented infrastructure
Regional level	Implementation of effective support measures at the level of regions and local communities to transform ecologically "dirty" regions into "green" growth points. Inventory of land damaged by military shelling, demining, restoration and creation of new environmental sites
Enterprises	Innovative renewal of the material and technical base of production based on energy-efficient technologies; introduction of new methods of processing, technologies and new materials; improvement of existing methods of production and management, development and introduction new types of products, introduction new production facilities, reorganization of the organizational system.

Source: compiled by the authors on the basis of the Plan of Implementation of the World Summit on Sustainable Development [11].

Measures contributing to sustainable development include such elements as the formation of an institutional structure and management system (a system of agencies and organizations); legislation (holding public hearings before proposing new legislation); innovation policy (support for eco-innovations); support of small and medium enterprises; awareness campaigns.

The government's role is to use a variety of financial instruments: taxation of fossil fuel use and emissions in various sectors; the transformation of energy subsidies, which lead to wasteful and environmentally harmful economic activity; supporting clean technologies and sustainable production through tax incentives; consideration of potential social consequences (for families with low incomes, pensioners); mapping environmental impacts by estimating the full cost of energy and transportation services.

Implementation the principles of "green transition" to the strategic planning of sustainable development of Ukraine should be based on a model of public governance that involves constructive interaction between government institutions, communities, academics, and private entities. Implementation of such a model is associated with a number of complex management tasks, such as forming a common vision of the country's development, industries and regions; defining strategic goals and development priorities; strengthening institutions aimed at stakeholder participation in decision-making, inter-sectoral and inter-regional cooperation and long-term planning that takes into account the interests of future generations; making coordinated decisions with the participation of stakeholders, etc. To realize these tasks, the following are used a strategic approach is used to realize these tasks, which makes it possible to coordinate actions and development planning to coordinate actions and harmonize interests of different ministries and agencies and other stakeholders.

The strategic approach to sustainable development has been successfully applied in European countries that have not only adopted national sustainable development strategies have not only adopted national sustainable development strategies, but also regularly review them. The EU has solid experience in the field of industrial development strategizing, aimed at creating the conditions for the economic development of industry in the EU, as well as fulfilling the tasks set in the Sustainable Development Goals and responding to the threatening challenges of today. In May 2021, the European Commission updated the Industrial Strategy adopted in March 2020 - a comprehensive document that approved the dual transition of European industry to green and digital transformations. It is a growth strategy focused on the idea of "competitiveness". This was followed by the announcement of the updated European Green Deal [12], which aims to reduce greenhouse gas emissions by 2050 according to the principles of decoupling for the transition to a climate-neutral circular economy. A year later, in April 2021, the European Commission published the Updated Industrial Strategy, which is a response to overcoming the losses from the COVID-19 pandemic and ensuring the recovery of industry and the EU economy [13].

Over the past 30 years, the lack of modernization of industry and the construction of business processes on russian gas, coal and old technologies have played against Ukraine in all aspects: political, economic and environmental. Formation of pro-russian forces, monopolization of key industries, loss of working places, devastating impact of pollution on the environment and health of population - this is a strategic loss for the state that has not formed its own plan for high-tech industrial development.

EU partners are already offering successful experience and tools for post-war recovery, taking into account the principles of sustainable development. In the Communiqué adopted by the European Commission on May 18, 2022 it is noted that the reconstruction must comply with the

European green and digital agenda, and the support mechanism will have a specific management structure that will at the same time ensure full ownership of Ukraine and ensure that investments will be brought into line with climate and environmental policies, as well as EU standards [14]. That is, the economy should be low-carbon and energy-saving, nature-oriented, have efficient and clean production, balanced consumption and be based on the principles of joint responsibility, innovation, cooperation, solidarity, flexibility and interdependence. The implementation of the European Green Course for Ukraine, a candidate for EU membership, is becoming mandatory.

This confirms Ukraine's steadfastness to follow the course of the "green transition", laying a solid foundation for strategic planning of country's recovery on basis of sustainable development. Ukraine is supported in this by the partner countries, in particular the EU. In the joint statement of the Group of Seven (G7) on support for Ukraine (June 27, 2022), the heads of state clearly stated their readiness to support a strategic recovery plan that would promote sustainable, sustainable, inclusive and green economic recovery [15]. The Organization for Economic Cooperation and Development believes that in the long term, the post-war green recovery should be considered as an economic necessity for the deep transformation of Ukraine on the way to a green and climate-neutral economy [16].

Approach to sustainable development for Ukraine depends on the implementation of European legislation and its transfer to the status of national. For this, we need to make appropriate changes to a number of regulations, introducing European principles from the standards of the products to be produced to cultural values and rules. It is primarily about the development of key strategic documents of post-war recovery, namely the introduction of changes to the National Recovery Plan regarding tools for supporting domestic business (especially SMEs) in the process of their adaptation to European requirements in accordance with the principles of "green" and "digital" transition. Martial law forces Ukrainian society to act in extremely difficult conditions, therefore the implementation of European standards and principles requires appropriate state attention. It is expedient to prepare the National Strategy for the Integration of Ukraine into the EU (like the Polish National Strategy for Integration into the EU) as a comprehensive vision of a consistent government policy that integrates European principles; approves goals, mechanisms and means of implementing the strategy, mechanisms of adaptation of key stakeholders to requirements and standards; providing information to society about the opportunities and threats that arise as a result of these changes.

Conclusions. Strategic planning for post-war recovery should implement the principles of sustainable development. This is an urgent task for Ukraine as a candidate for EU membership. In a difficult economic situation and limited resources, achieving 12th SDG “Responsible consumption and production” by using additional sources of reducing the resource intensity of GDP is extremely important.

Ukraine has long been an active supporter of the implementation of the 2030 Agenda for Sustainable Development. An assessment of indicators for achieving the SDGs by Ukraine was carried out using such indicators as: GDP energy intensity, GDP material intensity, GDP carbon intensity, GDP waste intensity showed a partial level of progress. Thus, the achievement of 12th SDG “Responsible consumption and production” has a positive trend in reducing the resource intensity of GDP in 2021 compared to the level of 2015 in terms of components: energy intensity of GDP to 88.2%; carbon intensity of GDP up to 72.2%; water intensity of GDP up to 77.3%. At the same time, there is also a negative trend – an increase in GDP waste intensity by 41.6% over the same period. All this reinforces the importance of introducing a flexible system of strategic planning in the field of implementing sustainable development in Ukraine at all levels: interstate cooperation, government agencies, regional institutions, business and SMEs. It is important to create favorable conditions for eco-innovative transformations, namely the formation of an institutional structure and management system (system of organizations); legislation (holding public events before new legislation is proposed); innovation policy (support for eco-innovations, transfer of domestic scientific R&D); support for small and medium-sized enterprises; awareness campaigns.

The post-war recovery and further development of Ukraine should be considered as a "green transition" based on sustainable development. This will ensure more economic efficiency and competitiveness of Ukraine in the European and world markets. This will enable Ukraine to transition to affordable green technologies, reduce dependence on fossil fuels and strive towards a zero-emission economy. The primary objectives of the industrial development post-war recovery should be energy efficiency, ensuring efficient, safe and environmentally friendly production based on the principle of green development, a "future without a carbon footprint" and a "circular economy" in accordance with the European vector. All this should be carried out on the basis of strategic documents for industrial development operating in EU countries.

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APPLICATION OF DUALITY THEORY IN THE ANALYSIS OF LINEAR PRODUCTION PLANNING PROBLEMS

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Abstract. *The paper presents the relevance of developing new methodological approaches for application of duality theory for more in-depth analysis of linear production planning problems. The theory of duality allows to find solutions to a dual problem in several ways, one of which is based on the construction of an inverse matrix. This matrix is obtained either from a simplex table involving the optimal plan or by algebraic methods from a matrix constructed on the basic vectors (corresponding variables are included in the basic of the optimal solution). In practice, finding an optimal solution to a linear programming problem by the iterative simplex method is a cumbersome process, the application of duality theory is possible only for problems in a small number of variables and constraints. In this paper we propose an algorithm that avoids routine calculations and finds an inverse matrix for further study of the production planning process. The algorithm is based on the reports of solving a linear programming problem built in MS Excel using the "Solver" add-in and the properties of the simplex method for solving linear programming problems. Studies have shown that this algorithm allows us to analyze the optimal production plan for linear problems in a large number of products, given production and demand constraints. The presented algorithm has a number of drawbacks, which in general do not significantly affect the process of finding the inverse matrix. Scientific research has shown that it is possible to further develop such methodological approaches to getting more complete information about the optimal solution of problems by the simplex method.*

Introduction. Linear programming methods allow to obtain not only optimal values of variables. Any business entity is primarily interested in studying dynamic changes in economic systems, which may affect the development and functioning of companies. Changes in the conditions under which the model was built lead to a loss of its relevance. Companies face and overcome a constant set of challenges such as: changes in resource inventory, introduction of new technologies or equipment replacement, changes of pricing policy, a new product launch and/or termination of unprofitable type of products, etc. In these situations the optimal production plan will become either suboptimal or not applicable at all in a new environment. To study the impact of such economic situations on the optimal plan, experts use such mathematical tool as the theory of duality. It makes possible to determine the status of resources and the stability intervals of dual variables due to changes in scarce resources or the replacement of one scarce resource to another. The dual variables provide the opportunity to measure product profitability. Also, during mathematical modeling and sensitivity analysis, it will possible to identify changes in the parameters of the original model on the previously obtained optimal feasible solution in linear programming problem.

The development of new algorithms for solving the optimization problems based on the duality theory is considered in the paper (Auslender & Teboulle, 2003). The authors (Daskalakis, Deckelbaum & Tzamos, 2015) apply a duality-based framework for revenue maximization in a multiple-good monopoly. Elements of duality theory in game theory are used by the authors (Bagan, Calsamiglia, Bergou, & Phys, 2018).

In the paper (Gozlan, Roberto, Paul-Marie & Tetali,, 2017) the researchers prove a Kantorovich type duality theorem to minimize the overall transport costs. Khrushch L. (2018) provided economic and ecological production functions investigating the appropriate dual problems explicity to the deduced one-criterion problems. The group of researchers (Chernova, Titov, Chernov, Kolesnikova, Chernova & Gogunskii, 2019) focused attention on the generalization of the operations of conversion of the primal problem to the dual problem. In the paper (Vybrani pytannia kompiuternoho modeliuvannia protsesiv i yavyshch, 2022) the authors consider the application of mathematical modeling in different fields of science, social and economic relationship and the use of computer mathematics and digital applications to solve practice-oriented problems.

In the paper (Moroz, Zahorianskyi, Haikova & Kuziev, 2022) the researchers formulated a defect algorithm for a special transportation problem applying optimality conditions from the theory of duality in linear programming. In the paper (Kuzmychov, Chernetska & Shestakov, 2022) the researchers investigate two tools of sensitivity analysis for the solution of a transportation problem, determining the advantages of the SolverTable in comparison with the Solver add-in in MS Excel.

The scientists Blaga N. and Priyamak I. (2019) noted the application of the dual simplex method and elements of the duality theory to select an effective strategy for the development of an enterprise. Yushchenko N. (2021) conducts a study of the network to solve linear problems of minimizing the total cost of the project and applies elements of the duality theory to define dual variables as flows in a network with limited bandwidth.

Researchers (Martynova & Shevchenko, 2022). prove that any matrix game can be transformed to the dual linear programming problems, which allows to obtain an optimal solution to a direct problem for one player, and the solution of the dual problem will be the optimal strategy for the second player.

Stepanova (2019) uses elements of the duality theory to identify bottlenecks in the combined production flows of metallurgical production. The authors (Aloshyn, Panchenko & Prykhodko, 2021) show that the principle of duality can be used to reduce the time of analysis and calculation of an information-measuring system. The researchers (Zhurbenko & Chumakov, 2021) use the dual simplex method to solve a problem related to planning the modernization of the transport system.

Thus, having studied the papers of domestic and foreign scholars, we determine the relevance of further development of new algorithms based on the duality theory in order to use them for a deeper analysis of economic models. Simplex method is suitable for solving linear programming problem. It is possible to obtain the optimal solution using tabular form. However, in practice, specialists must take into account more than a dozen different types of products. Usually, the solving of a linear programming problem is carried out according to the following scheme (Fig. 1). The implementation of the algorithm shown in Fig. 1, even using formulas in MS Excel, is quite cumbersome, since the algorithm is iterative in nature and requires a large amount of calculations and computations. This paper proposes an algorithm developed by the authors that avoids the drawbacks of solving a linear programming problem by the simplex method, but provides an opportunity to conduct an economic and mathematical analysis of the impact of objectively determined estimates on the optimal plan using only the built-in "Solver" in MS Excel.

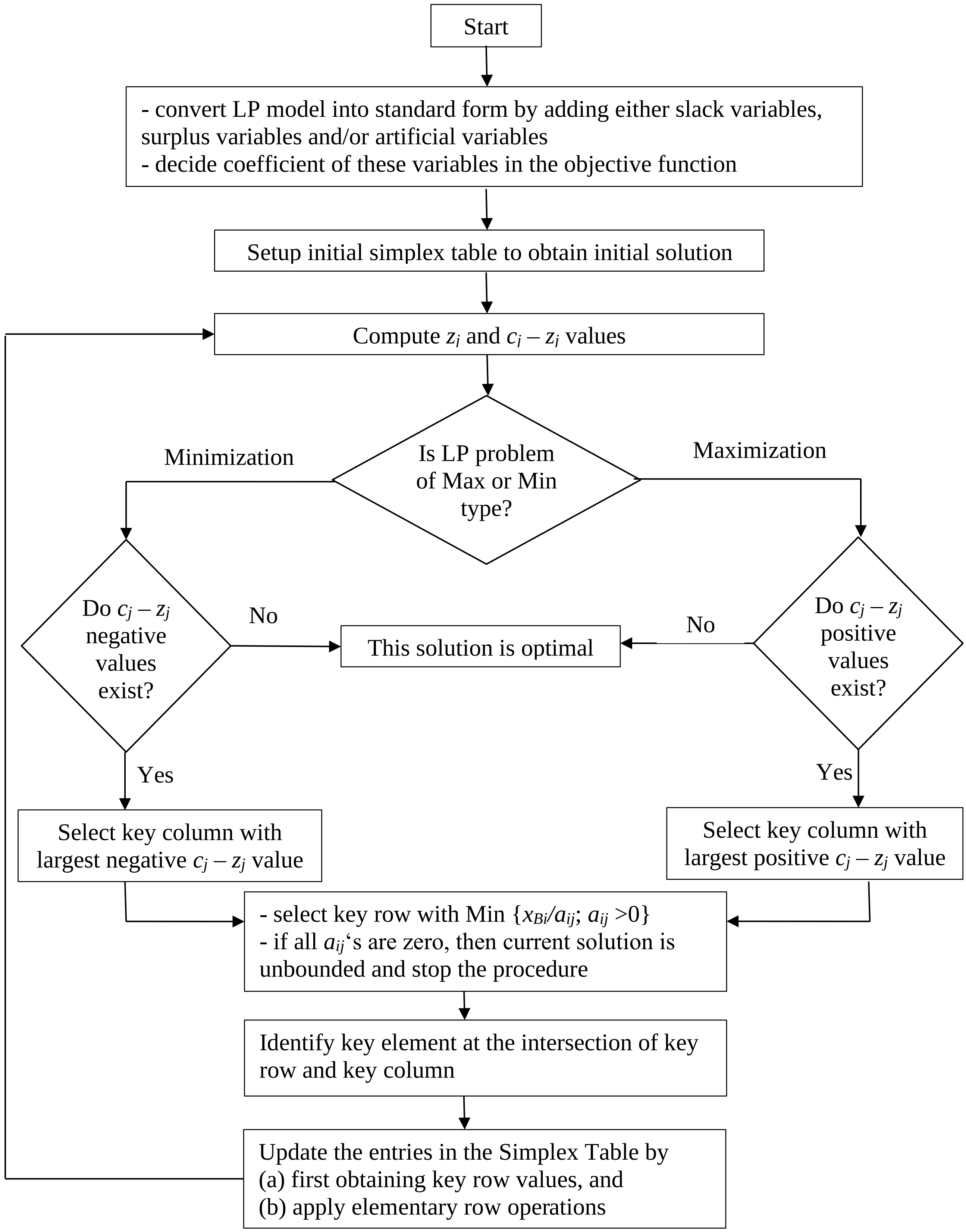

Fig. 1 Flow Chart of Simplex Algorithm

Source: (Sharma, 2017, p. 113)

The capabilities of the built-in functions of MS Excel spreadsheet application allow to conduct only an initial analysis of optimization problems and their results. Application of the duality theory with the capabilities of MS Excel allows to conduct an analysis that determines the impact of all hidden factors on the economic process under study, and as a result, to identify its negative aspects and develop ways to solve them.

Materials and Methods. Each linear programming problem can be compared to some other linear programming problem, called a dual. A dual problem is composed in accordance with the following rules:

- if the primal problem is a maximization problem, the dual to it is a minimization problem;
- the number of variables of the primal problem is equal to the number of constraint solutions of systems of inequities;
- the constraint system of the maximization problem has all inequalities of the type « ≤ », the minimization problem has inequalities of the type « ≥ »;
- matrix of the coefficients with unknowns in an inequality of both problems are transposed (the rows of one matrix correspond to the other columns);
- inequalities of primal problem are equal to the coefficients of the objective function of other problem. With a pair of symmetric dual problems, we have n + m related pairs of conditions.

If the constraint system of a problem contains an equality (one or more), then the dual problem to it also exists and is solved according to the same rules with one difference (Ladohubets & Finohenov, 2019).

In the duality theory, there are several ways to obtain solutions to a dual problem if there is a solution to a primal problem, one of them is: the vector of the optimal solution of the dual problem (Y*) is calculated due to the duality relation using first theorem as follows (Vitlinskyi, Tereshchenko. & Savina, 2016, p. 73):

$$Y* = \bar{C}_b D^{-1}, \tag{1}$$

where $\bar{C}_b$ – a row vector, which consists of the coefficients of the objective function of the primal problem with the variables that are basic in the optimal solution;

D^{-1} – matrix inversed to matrix D, consists of the basis vectors of the optimal solution, the components of which are taken from the initial plan of the problem.

This inverse matrix D^{-1} allows us to analyze the impact of changes in resources on production. In other words, an economist does not need to implement a rather cumbersome iterative process of the simplex method in order to find a simplex table, containing an optimal solution of a linear production planning problem with a large amount of initial data and given resource constraints. In Fig. 2 shows a block scheme of the algorithm for obtaining the inverse matrix, which eliminates the cumbersome process of solving a linear programming problem by the simplex method. According to the flowchart above (Fig. 2), the researcher must perform the following steps:

1. Find the solution of a linear model in MS Excel using the Solver add-in and generate Answer report and Sensitivity report.
2. Identify the unprofitable types of products, in the optimal solution such types of products have zero values (Answer report). Identify inequalities in the model as a separate type of constraints on the admissibility of the solution for the unprofitable products and take them into account when building the canonical form.
3. Represent the canonical form of the linear programming problem.

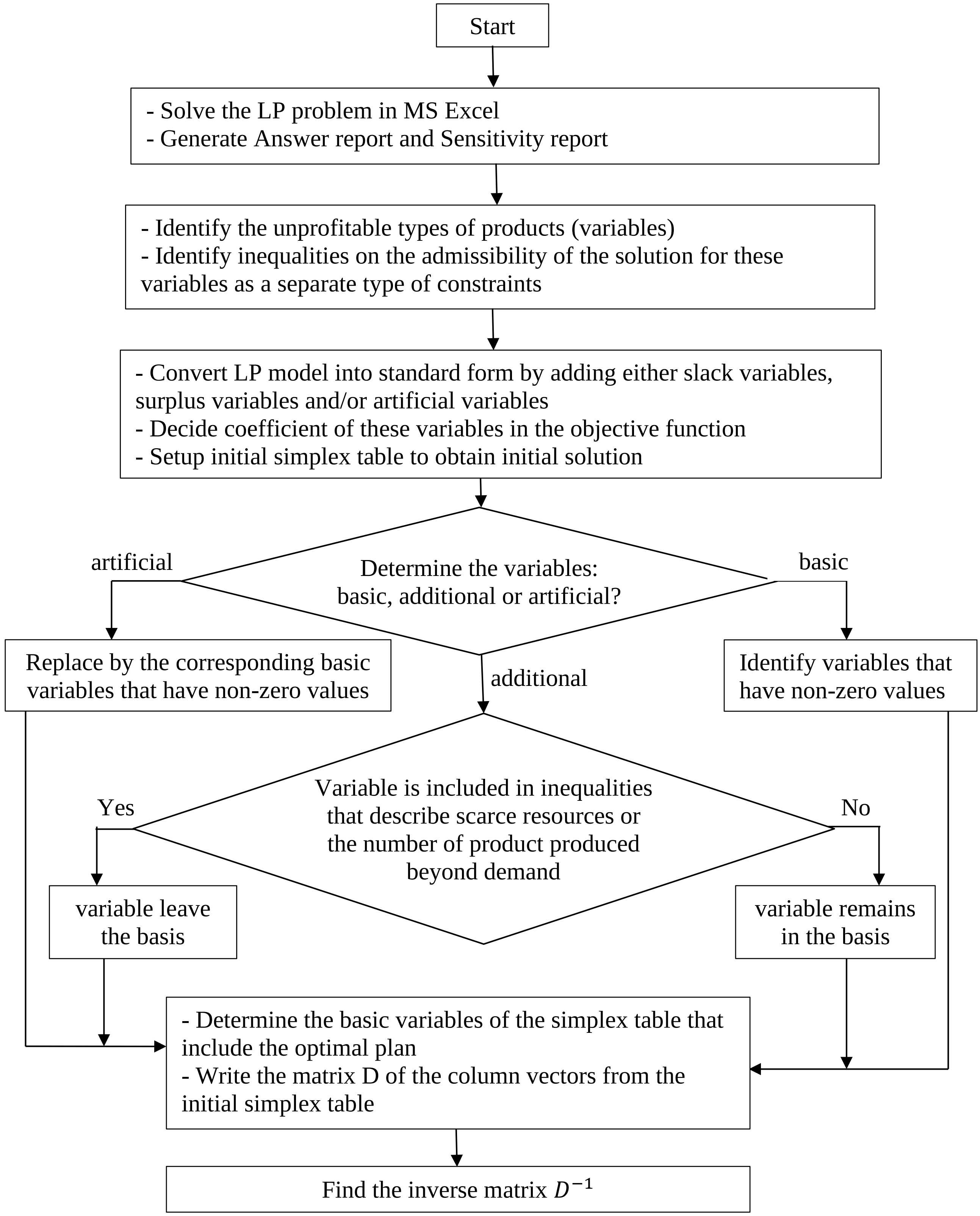

Fig. 2 Block scheme of the algorithm for finding the inverse matrix

Source: created by the authors

4. Write initial simplex table.

5. Determine the basic variables of the simplex table that include the optimal plan (the order doesn't matter if the model is linear):

5.1. Identify additional variables that correspond to scarce resources, unprofitable products in the constraints with artificial variables. Identify additional variables that correspond to the types of products that are produced at the upper bound on demand (the most profitable products for the enterprise). The identified variables will not be the basic in the simplex table containing the optimal solution and will be equal to zero.

5.2. The artificial variables are replaced by the corresponding basic variables of the problem that have non-zero values in the equations of the canonical form.

5.3. Identify additional variables that correspond to non-scarce resources and types of products whose production does not equal the upper bound on demands. The variables will remain basic.

5.4. The basic will also include the basic variables of the problem that have non-zero values and are not defined in the previous stages of the algorithm.

6. Write the matrix D of the column vectors from the initial simplex table in accordance with the system of basic variables.

7. Find the inverse matrix D^{-1}.

8. Check if an inverse matrix is correct by calculating the system of objectively determined estimates using formula (1) and comparing it with the shadow prices in the Sensitivity report.

9. Analyze the impact of objectively determined estimates on the value of objective function and the impact of simultaneous changes in multiple constraints.

The proposed algorithm can be applied only to non-degenerate dual linear programming problems that have a nonempty set of feasible solutions.

Results and Discussion. Authors implement the proposed algorithm to the different types of production planning regarding resource limitation and existing demand.

Suppose it is required to make a production plan of four types of products (P_1, P_2, P_3, P_4) regarding the existence of three types of raw materials (RM_1, RM_2, RM_3) in order to maximize the product revenue (Table 1).

Table 1

Data for a linear production planning problem

Types of resources	Raw materials usage per unit				Raw materials inventory, conventional units
	P_1	P_2	P_3	P_4	
RM_1	2	3	4	3	220
RM_2	3	2	2	2	250
RM_3	4	3	1	2	270
Product revenue, monetary units	17	16	15	12	

Source: created by the authors

Suppose that there is 11 units per pre-order for the fourth type of product. Construct the economic-mathematical model of this problem.

Firstly, introduce the notation:

x_i - the amount of products of the i-type, i = 1,2,3,4.

Then the objective function that expresses the maximization of revenue will be as follows:

$$Z = 17x_1 + 16x_2 + 15x_3 + 12x_4 \rightarrow \max$$

Subject to the constraints:

$$\begin{cases} 2x_1 + 3x_2 + 4x_3 + 3x_4 \leq 220 - raw\ material\ RM_1 \\ 3x_1 + 2x_2 + 2x_3 + 2x_4 \leq 250 - \ raw\ material\ RM_2 \\ 4x_1 + 3x_2 + x_3 + 2x_4 \leq 270 - raw\ material\ RM_3 \\ x_4 \geq 11 - production\ plan\ of\ the\ fourth\ type\ of\ product \end{cases}$$

$$x_i \geq 0,\ i = 1, 2, 3, 4.$$

Firstly, according to the algorithm, we find the solution of the linear model in MS Excel using the built-in "Solver" and generate Answer report (Fig. 3) and Sensitivity report (Fig. 4).

Objective Cell (Max)

Cell	Name	Original Value	Final Value
$G$12	Revenue Total	0	1379,5

Variable Cells

Cell	Name	Original Value	Final Value	Integer
$B$10	Production 1	0	57,5	Contin
$C$10	Production 2	0	0	Contin
$D$10	Production 3	0	18	Contin
$E$10	Production 4	0	11	Contin

Constraints

Cell	Name	Cell value	Formula	Status	Slack
$G$13	Raw material 1	220	$G$13<=$I$13	Binding	0
$G$14	Raw material 2	230,5	$G$14<=$I$14	Not Binding	19,5
$G$15	Raw material 3	270	$G$15<=$I$15	Binding	0
$B$10	Production 1	57,5	$B$10>=$B$11	Not Binding	57,5
$C$10	Production 2	0	$C$10>=$C$11	Binding	0
$D$10	Production 3	18	$D$10>=$D$11	Not Binding	18
$E$10	Production 4	11	$E$10>=$E$11	Binding	0

Fig. 3. Answer report

Source: compiled by author's calculations

Secondly, we determine from the data in Figs. 3 and 4, that according to the optimization result, the second type of product is unprofitable and its forced inclusion in the production plan will lead to a decrease in total revenue by 1,36 monetary units per unit. The fourth type of product is unprofitable for the enterprise, since it is produced in amount of minimum bound of the production plan and the growth of its production volume will also lead to a decrease in total revenue of the enterprise by 2,64 monetary units per additional unit. Raw materials of the first and third types are scarce under this production plan and a further increase in their volumes per unit can lead to an increase in revenue by 3,1 and 2,7 monetary units. In this case, these volumes will vary between [157; 274,6] for raw materials of the first type and [68,75; 304,125] for raw materials of the third type.

6	Variable Cells						
7			Final	Reduced	Objective	Allowable	Allowable
8	Cell	Name	Value	Cost	Coefficient	Increase	Decrease
9	$B$10	Production 1	57,5	0	17	43	2,111111111
10	$C$10	Production 2	0	-1,35714286	16	1,357142857	1E+30
11	$D$10	Production 3	18	0	15	19	3,166666667
12	$E$10	Production 4	11	-2,64285714	12	2,642857143	1E+30
13							
14	Constraints						
15			Final	Shadow	Constraints	Allowable	Allowable
16	Cell	Name	Value	Price	R.H. Side	Increase	Decrease
17	$G$13	Raw materials 1	220	3,07142857	220	54,6	63
18	$G$14	Raw materials 2	230,5	0	250	1E+30	19,5
19	$G$15	Raw materials 3	270	2,71428571	270	34,125	201,25
20							

Fig. 4. Sensitivity report

Source: compiled by author's calculations

Thirdly, we construct the canonical form for the written model, where we forcefully add an inequality of an admissible solution for the second unprofitable product. Thus,

$2x_1 + 3x_2 + 4x_3 + 3x_4 + x_5 = 220$

$3x_1 + 2x_2 + 2x_3 + 2x_4 + x_6 = 250$

$4x_1 + 3x_2 + x_3 + 2x_4 + x_7 = 270$

$x_4 - x_8 + y_1 = 11$

$x_2 - x_9 + y_2 = 0$

$x_i \geq 0,\ i = \overline{1,9};\ y_1, y_2 \geq 0.$

$Z - 17x_1 - 16x_2 - 15x_3 - 12x_4 - M\,(y_1 + y_2) = 0.$

Fourthly, we write down the initial simplex table (Table 2).

Table 2

The initial simplex table of the resource utilization problem

Basic variables	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9
x_5	2	3	4	3	1				
x_6	3	2	2	2	0	1			
x_7	4	3	1	2	0	0	1		
y_1	0	0	0	1	0	0	0	-1	0
y_2	0	1	0	0	0	0	0	0	-1
Z	–17	–16	–15	–12	0	0	0	0	0
–M	0	–M	0	–M	0	0	0	M	M

Source: compiled by author's calculations

The constructed basic of the initial simplex table contains five variables: x_5, x_6, x_7, y_1, y_2.

Fifthly, we determine the basic variables that will be in the optimal solution. The additional variables x_5, x_7, corresponding to the scarce resources RM_1 and RM_3, will be removed from the basic variables and will have values equal to zero. The variables x_8 and x_9, which demonstrate how more than the minimum output is produced, are also equal to zero and will not be included in the basic. The artificial variables y_1 and y_2 will be replaced by the corresponding variables that remain in the canonical form equations and will become the basic variables, i.e. $y_1 \leftrightarrow x_4$ and $y_2 \leftrightarrow x_2$. The variable x_6 will remain basic, as it corresponds to a non-scarce resource. And the basic variables will also include the two main variables that have non-zero values in the optimal solution. Thus, the basic variables will be as follows: x_1, x_2, x_3, x_4, x_6.

Sixthly, we build the matrix D from the vectors of the initial simplex table (Table 2) corresponding to the basic variables of the optimal solution (Table 3).

Table 3

The matrix *D*

	x_1	x_2	x_3	x_4	x_6
D =	2	3	4	3	0
	3	2	2	2	1
	4	3	1	2	0
	0	0	0	1	0
	0	1	0	0	0

Source: compiled by author's calculations

Accordingly, the inverse matrix will be presented in Table 4.

Table 4

The inverse matrix D^{-1}

D^{-1} =	–1/14	0	2/7	–5/14	–9/14
	0	0	0	0	1
	2/7	0	–1/7	–4/7	–3/7
	0	0	0	1	0
	–5/14	1	–4/7	3/14	11/14

Source: compiled by author's calculations

Multiplying the row vector (17; 16; 15; 12; 0), which consists of the coefficients of the objective function of the direct problem with the set of basic variables that we found in the optimal plan, we obtain the solution to the dual problem: Y* = (53/14; 0; 19/7; –37/14; –19/14) or convert to decimals (3,071; 0; 2,714; –2,643; –1,357), which completely coincides with the shadow prices given in sensitivity report (Fig. 4). The columns of a matrix correspond to additional variables x_5, x_6, x_7, x_8, x_9. Thus, the matrix is obtained, which can be used for a more detailed analysis of the impact of changes on the optimal solution of the linear planning problem.

It is necessary to ensure that the proposed algorithm allows us to find the correct set of basic variables. We present a simplex table (Table 5) which contains the optimal solution to the linear resource utilization problem for the developed canonical form. The optimality criterion for the simplex method assumes that the last row should contain non-negative numbers. The values in the columns correspond to the positive variables that are included in the canonical form with a minus sign and should have opposite signs.

Table 5

A simplex table of the optimal solution of a resource utilization problem

Basic variables	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9
x_1	1	0	0	0	–1/14	0	2/7	5/14	9/14
x_2	0	1	0	0	0	0	0	0	–1
x_3	0	0	1	0	2/7	0	–1/7	4/7	3/7
x_4	0	0	0	1	0	0	0	–1	0
x_6	0	0	0	0	–5/14	1	–4/7	–3/14	–11/14
Z	0	0	0	0	53/14	0	19/7	37/14	19/14
Y	y_6	y_7	y_8	y_9	y_1	y_2	y_3	y_4	y_5

Source: compiled by author's calculations

This remark should be taken into account when conducting economic analysis of the solution of linear programming problems obtained by the simplex method, and implementing the proposed algorithm, this situation does not arise. In Table 5 is presented the solution to the dual problem. Given the above, we can conduct a more in-depth analysis of the obtained optimal solution to the linear programming problem of resource utilization.

According to the table 5, it can be concluded that an increase in the stocks of raw materials of the first type by one unit will cause an increase of revenue by 53/14 monetary units due to (column x_5) a decrease in the output of the first type by 1/14 units; an increase in the output of the third type by 2/7 units will lead to a decrease in the stocks of raw materials of the second type by 5/14 units. The production of an additional unit of unprofitable second and fourth types of products (for example, an additional unit of the fourth type of product (column x_8) will lead to a decrease in total sales revenue by 37/14 monetary units, while production of the first type of product will decrease by 5/14 units and the third type of product by 4/7 units and the unused raw material stocks of the second type will increase by 3/14 units.

Conclusions. The theory of duality is a powerful tool in the study of optimization problems. It provides a possibility to design the new algorithms for solving problems.

It should be noted that given algorithm can be applied only to non-degenerate dual pair of coupled linear programming problems that have a nonempty set of feasible solutions. The drawback of the algorithm is the implementation of artificial restrictions on the inalienability of unprofitable products to the canonical form, which leads to the identification of an additional dual variable and, accordingly, the determination of its value. However, such situation may arise if the constructed linear programming problem is solved by the simplex method with the calculation of all simplex tables. The proposed algorithm does not involve the use of the simplex method, and therefore this situation will not affect the economic analysis of the obtained solution. Despite the identified drawback, the proposed algorithm can be effectively used to conduct a more in-depth analysis of the solution of linear programming problems in order to determine the impact of changes in the given constraints on production in general.

The constructed inverse matrix can also be used to study the overall impact on the optimal solution when the right-hand sides of the constraint system are changed, a new type of product is included, or a new constraint is imposed on a new type of raw material, etc.

Thus, a specialist without any additional mathematical tools can conduct a more in-depth analysis of the production planning problem applying all the possibilities of the duality theory.

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THE IMPACT OF ARTIFICIAL INTELLIGENCE IN LOGISTICS MANAGEMENT ON SUSTAINABILITY DEVELOPMENT OF E-BUSINESS

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Abstract. *In the conditions of all-encompassing transformational changes in the economic system of Ukraine, the key to the success of the functioning of domestic trade enterprises in the long term is ensuring their sustainable development. At the same time, in recent years, domestic trade enterprises have been operating in the face of global challenges, such as the COVID-19 pandemic, and now they are facing the consequences of the ongoing large-scale armed aggression of the Russian Federation against Ukraine.*

In particular today, a significant number of trade enterprises faced problems relocation, deterioration of supply conditions and disruption of logistics chains, complication of product sales processes, outflow of highly qualified personnel for border, the need to transfer employees to remote work, loss property, lack of sufficient equity, which is directly negative affects their effectiveness and efficiency and complicates (makes it impossible) further development.

For many years, the logistics industry remains to be one of the most actively growing industries. However, there are some barriers that prevent many logistics companies from their expansion and growth, including the lack of access to real-time data that can demonstrate the most relevant road conditions, low control over delivery processes, low transparency of supply chain stages, and inaccurate route planning.

Nowadays, among the factors that prevent the industry from further development, we can name the lack of access to real-time data that can demonstrate the most relevant road conditions, low control over delivery processes, low transparency of supply chain stages, and inaccurate route planning.

Introduction. The object of research is the process of digitization of logistics services through the impact of AI in logistics management on sustainable development of e-business. Analysis of the current state of logistics services and trends of digital transformation in logistic processes.

Materials and Methods. The study used general scientific and special research methods, in particular, methods of critical and scientific analysis for analyzing AI trends in logistics management, abstract and logical methods for theoretical generalizations (systematization of directions for using AI in logistics) and formulation of conclusions. The research was based on statistical data, data from analytical publications, and expert opinions of market experts and companies in the industry. The research aim is to analyze the AI trends of logistics management and the impact AI on e-business in the world.

Results and Discussion. However, today it is not possible without sustainable logistics and transportation aim to improve profitability and reduce the ecological impacts of logistics activities.

Seeking a balance among economic growth, environmental care, and societal health, sustainable development in logistics has drawn tremendous attentions from different aspects.

Supply chain agility is set to become one of the focuses of logistics trends in 2023 as businesses strive to satisfy the ever-increasing demand for products and services. Agility will enable businesses to quickly and efficiently respond to fluctuations in supply and demand while also reducing costs and increasing efficiency and is therefore an essential part of staying competitive in today's ever-changing market [1].

E-business promotes sustainable development in the fields of economic prosperity, poverty reduction, social development, international cooperation, etc. It provides people with decent work and increases economic growth in short and long-run. It is now important to use more advanced technologies such as data management, data engineering, data science and machine learning to work with data that is profitable [2].

Since sustainable logistics is characterized by the use of artificial intelligence, we have analyzed modern trends in detail in Table 1.

Table 1.

Analyze the AI trends of logistics management

(constructed by the authors based on sources [1, 3 – 9])

Modern trends	**Description of trends**
The Internet of Things (IoT)	enables multiple resource-constrained embedded devices, objects, and humans to connect through the Internet protocol for a ubiquitous data exchange in real-time data. In addition, the valuable information extracted and transformed from the IoT data can be exploited to create intelligent services and applications to improve the logistics activities as well as the overall performance of logistics operations [3].
AI algorithms	combined with machine learning support companies to be proactive in dealing with demand fluctuations. For example, AI-based forecasting solutions allow managers to plan supply chain processes and find ways to reduce operating costs. Self-driving AI and smart road technologies are affecting a positive shift towards delivery service automation. In addition, AI-based cognitive automation technology brings intelligence to automate administrative tasks and speeds up information-intensive operations [1].
An automated storage and retrieval system (ASRS)	can deliver high efficiency but may be limited in flexibility when it comes to dealing with order disparities in size, shape, weight, volume and mechanical properties. The ASRS may not offer adequate scalability to adapt to growth and cope with increased seasonal demands, or deal with facility breakdowns and carry out technical maintenance. Robotics promises to strike a balance between efficiency, scalability and flexibility [4].
Last-mile delivery	is a defining service in logistics as it is directly related to customer satisfaction. However, last-mile delivery faces various problems including delays due to traffic congestion, customer nuances, government regulation, and delivery density [5].
Warehouse automation	increases efficiency, speed, and productivity by reducing human interventions. Warehouse automation technologies can be broadly categorized into devices that assist the movement of goods and those that improve their handling. In the first group, we've already seen automated guided vehicles (AGVs) that move cases and pallets. New twists are the equipment and software needed to

	retrofit standard forklifts and make them autonomous. The new gear can be switched on whenever needed—peak seasonal shifts, say—and the forklift can remain manual when demand is slower [6].
Blockchain	is an emergent technology concept that enables the decentralized and immutable storage of verified data. Over the last few years, it has increasingly attracted the attention of different industries. Especially in Fintech, Blockchain is hyped as the silver bullet that might overthrow today's payment handling. Slowly, the logistics and supply chain management community realizes how profoundly Blockchain could affect their industry[7].
Big data analytics	provide actionable insights for improving warehouse productivity, performance management, and utilization of logistical resources. The data obtained from monitoring position and weather along with fleet schedules help optimize routes and delivery planning. The analysis of market data supports the further optimization of supplier pricing, inventory levels, and the generation of risk management reports. Moreover, advanced analytics provide insights that help identify anomalies and offer predictive maintenance solutions [5].
Autonomous vehicles	improve vehicle safety and deliver goods safely by eliminating human errors while driving. They increase the efficiency in the first and last-mile delivery as they are designed to work all day and all night. Moreover, autonomous vehicles improve fuel efficiency by using platooning techniques for long-haul routes, reducing traffic jams, and optimizing travel routes by taking advantage of AI-enhanced technology [5].
Elastic logistics	refers to a company approach that is adaptable and flexible enough to scale up or down in response to market demands. This enables supply chain activities to expand or contract in near real-time in response to foreseen (and even unpredicted) market events. Picking and packing are automated in elastic logistics, forcing warehousing and logistics to make more supply-driven decisions. This never-ending supply-driven expansion and contraction of warehouse activities allows for more reliable financial control. Companies may run supply chains more efficiently in the face of volatility with elastic logistics, which allows for scalable upscaling and downscaling based on seasonal activity and other changes. The balance of supply and demand has swung heavily in favour of demand [8].
Digital voice assistants	is a software program that can perform simple tasks or services, and is generally controlled by voice command. According to a forecast, around 200 million of these smart speakers will be sold worldwide in 2023 . The best-known language assistants are Amazon's Alexa, Google Assistant and Apple's Siri [9].

For a deeper investigation of the role of AI in the logistics process in our view, it is necessary to consider logistics management practices and examples of the use of AI in E-business.

At IBM, the researchers estimate that relatively moderate investments generate a much larger ROI than before. The complexity of AI is growing: more unstructured data, complicated algorithms, high-level tasks, etc. And the output of AI to amplify transportation services and global supply chains increases as well. Over the past years, AI in supply chain and logistics has proved to be effective [10].

Artificial intelligence gives machines and systems the capability to analyze their environment and make decisions with some degree of autonomy to achieve specific goals [11].

That is why the use of artificial intelligence focused on sustainable development is relevant in conditions of uncertainty. It can provide solutions to many challenges, such as treating diseases or minimizing the environmental impact of farming. Artificial intelligence (AI) is an area of strategic importance and a key driver of economic development.

As a result, logistics specialists lose a lot of time fulfilling monotonous repetitive paperwork tasks instead of devoting time to more creative and intellectual activities.

The global TMS (Transportation Management Systems) market is expected to grow at a CAGR of 14.5% and almost double over the next five years, from USD 2.5 billion in 2019 to USD 4.3 billion by 2025 [12]. The development arc of these systems mirrors the exponential growth in data sources, such as IoT sensors, actuators, RFID, GPS, and barcodes. As a result, modern transportation management systems need to do more than record time and place of shipments. Today, a digital TMS needs to facilitate smart functionalities like dynamic routing and automation across the transportation lifecycle to enable businesses to optimize transportation performance in real-time. Dealing with the volume and the diversity of this new data will be next to impossible without embedded ML and AI. An ML/AI-enabled intelligent TMS can automate almost every process across the transportation value chain, starting with load tendering. In fact, smart systems that combine advanced analytics and embedded intelligence are able to autonomously handle 25% [13] or more of load tendering and automate related activities, including booking, approval, routing, and alerts.

TMS applications can save money and help operators to increase service performance. They can do this by:

- helping resource planners to optimize routes for truckload and less-than-truckload shipments
- identifying when and where multi-stop routes prove more economical than single-stops
- highlighting the comparative performance of carriers
- analyzing data to answer questions such as "Which specific geographic areas are impacted most often by late deliveries?" [14]

Technologies like AI and ML are facilitating a new generation of transportation management solutions that continuously learn by comparing inputs with outcomes. They also introduce innovative capabilities such as real-time fleet tracking, improved vehicle utilization, and more cost-effective and proactive approaches to fleet maintenance. Most important of all, intelligent TMS allows companies to come up with the best transportation and logistics strategies that perfectly balance the competing priorities of shippers, drivers and fleets without compromising service levels [15].

According to McKinsey: «The future of supply chain: digital and AI will enable end-to-end transparency and faster decision making». Logistics and distribution will have the following impact: «Dynamic optimization of routing, freight contracting, and vessel sharing, reducing costs and environmental impact» [16].

AI, according to a Deloitte report [17], is helping to drive more value from rules-based automation. Among survey respondents, 78% use AI to drive more value from rules-based automation (or are planning to do so in the future). Among manufacturers, this figure jumps to 93%. For example, Walmart and Procter & Gamble have collaborated to create an automated re-ordering system. Walmart utilizes satellite communications, which are then sent to Procter & Gamble whenever an item is needed. Procter & Gamble then fulfills the order and delivers the item. This helps Walmart form more accurate forecasts and react more efficiently to customer needs.

Predicting product demand and planning logistics can improve service, decrease transportation costs, and save money. AI predicts the market, modifies orders and reroutes products in warehousing. These estimates help your enterprises alter orders and deliver in-demand commodities to local warehouses. AI can connect warehouses to discover the optimal inventory transfer solution [18].

The systematization of directions for the use of AI in logistics is shown in Figure 1.

AI can assist a company in more efficiently planning its hiring and training processes. It will be useful if you are a startup company looking to hire employees. Even established businesses can use it to hire suitable employees effectively. This enables efficient day-to-day operations on the organization's floors. Also, it results in better-suited work assignments, which makes employees happier. Thus, it becomes a win-win situation for both.

The presence of these AI trends in the development of logistics service use cases in the transport and logistics industry worldwide has 2020 «Global AI use cases transport and logistics industry 2020» [19], according to a study on the Statista website, with 40 percent of respondents stating that artificial intelligence can help improve inventory management. By implementing AI, businesses can create smarter production and distribution centers. Thus, AI can understand the complex dynamics of real-time inventory management, predict scenarios, recommend actions, and act accordingly.

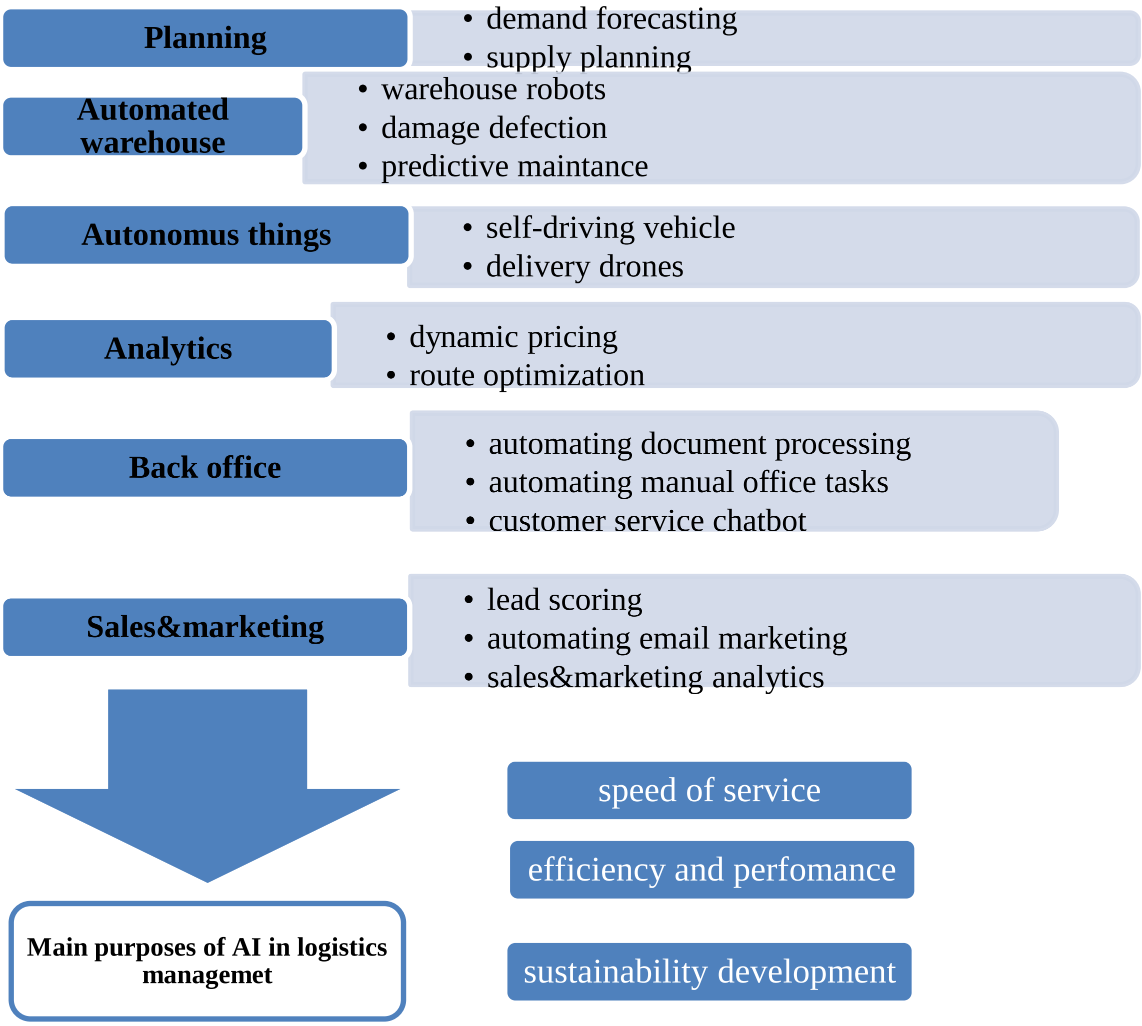

Fig. 1. Use cases of AI in logistics management

(constructed by the authors based on sources [16-18])

Predictive Capabilities of AI have made demand forecasting [20] easier. When inventory is behind the demand schedule, businesses lose money. Network planning and demand planning [20] are becoming more efficient thanks to AI, which enables merchandisers to be more proactive. Knowing what to anticipate allows them to modify their stock levels and guide inventory to areas where they expect the most demand, resulting in lower operational costs.

Use Case «Shell Inventory Optimiser», a product that uses advanced analytics on historical data to optimize operational spare part inventory levels, was created in a collaboration between Shell and Equinor. Equinor expects this tool to reduce inventory inflow by as much as 13%, saving millions.

The goal is for energy companies to have better control over available equipment and to optimise stock levels. Since first deployment in 2017, this proprietary solution has been deployed across Shell's Upstream, Manufacturing and Integrated Gas assets globally, generating millions of dollars in value through optimized stock levels. Dan Jeavons, General Manager Data Science at Shell, says:

The collaboration to co-develop the next stage of Shell Inventory Optimiser with Equinor is an important milestone for both our companies; it speaks to the digital cultural and technical strengths we share, and our history of successful collaborations in the supply chain domain and the value we can achieve working in partnership. I look forward to further collaboration with Equinor in the supply-chain and decarbonization domain, with the continued support of our mutual partner Microsoft [21].

Smart Warehouse Systems are able to recognize patterns, regularities and dependencies from unstructured data by using the Internet of Things, artificial intelligence and cloud computing. They can then adapt, independently and dynamically, to new circumstances throughout the entire logistics system. As a result, monotonous jobs become simpler, and operations become more efficient and cost-effective.

Use Case Cainiao [22], the logistics division of Chinese e-commerce behemoth Alibaba, has declared the opening of business at its brand-new smart warehouse in Huiyang, Guangdong province. The warehouse has more than 100 self-charging, Wi-Fi-equipped AGVs (automated guided vehicles) to oversee transporting products. Alibaba claims that since the warehouse started operating in July, employee productivity has tripled.

In the last two years alone, the demand for smart warehouse solutions has soared to an all-time high. In fact, the smart warehousing market size [23] is expected to almost double, growing from US$ 14.8 billion in 2021 to US$ 25.4 billion by 2026.

To strengthen its logistic services under its «asset-light» business strategy, Alibaba invested $807 million, to increase its stake in logistics platform firm Cainiao Smart Logistics to 51 in Sep 2017 [24]. Instead of creating a courier service company, Cainiao Smart logistic is a Cloud and Big Data powered platform that connects 3rd party logistic partners with E-commerce Merchant to improve the overall delivery efficiency. Its goal is to fulfill orders on the mainland within 24 hours and within 72 hours globally [24].

By connecting logistic partners and the E-commerce Merchant – Cainiao platform feed real-time information to small merchants to choose the most efficient delivery option within a pool of delivery firms based on its location and type of goods. Cainiao's smart routing and sorting service also reduce logistics firm's delivery errors by 40%. In addition, it provides a real-time tracking system to enhance the information synchronization and transparency among logistic partners, Merchants, and Consumers. [25].

AI-Powered Route Planning can help the transport and logistics industries integrate data from various sources and make intelligent judgments regarding travel routes.

Use Case UPS developed Dynamic On-Road Integrated Optimization and Navigation technology (ORION) that uses advanced algorithms, artificial intelligence and machine learning and offers precise delivery time estimates, dependability and responsiveness. UPS has saved around 100 million miles and 10 million gallons of gasoline annually since ORION's first deployment in 2012.

UPS route optimization software (ORION) helps make many deliveries without any hassles. UPS delivers around 5.5 billion packages a year with the help of the 125,000 vehicles in its delivery fleet. The fleet consists of 10,300 «alternative fuel and advanced tech vehicles», representing a little under 10% of its entire fleet size.

Conversational Artificial Intelligence is present in user-interactive virtual assistants or chatbots [26]. The technology mimics human interactions by identifying speech and text inputs and translating their contents into other languages using massive amounts of data, machine learning and natural language processing.

Conversational AI provides regular updates and all relevant information about any delays, allowing for comprehensive visibility of the shipment. Additionally, by providing a 24/7 conversational interface, conversational AI is always available to provide users with the information they require.

Use Case BearingPoint, in collaboration with DHL [27], developed ‘Marie’ using Salesforce Service Cloud and Einstein AI to automatically resolve customer requests coming through chat. Customers got a seamless experience while agents were able to handle inquiries more effectively. Nearly one-quarter of respondents trust virtual assistant recommendations for product purchases rather than a human salesforce. 87.2% of consumers report having a neutral or positive customer experience with chatbots [28].

Computer Vision: The Computer Vision trend is set to highly impact logistics in the coming years. Its technology will underpin and drive future logistics, enabling more efficient processes as well as sustainable and safe operations.

However, more investment is needed for this trend to be fully realized. As experienced in the early days of sensor adoption, computer vision applications must be scalable for logistics organizations to maximize benefits.

HCL: Emerging from AI as a trend in its own right, Computer Vision has developed in conjunction with the advancement of deep machine learning, leveraging the rising quality and decreasing cost of camera devices. In 2020, the computer vision market globally was worth 9.4 billion USD and – as AI, vision systems, and computer processing continually improve – it is anticipated this market will more than quadruple to 41.4 billion USD in 2030.

Today, advanced computer vision technology is perfecting depth perception, 3D reconstruction, and dark and blurred image interpretation, all of which will unlock more opportunities in supply chains [29].

Autonomous Vehicles. DHL is working on autonomous vehicles on three fronts, including the development of intelligent robotic workers in its own warehouses and air freight centers; the use of semi-autonomous trucks in the line-haul business; and “follow-me” robots used for last-mile route delivery in urban settings.

One of the more interesting uses of AI is the development of truck platoons in Europe, where anywhere from one to four autonomous semi-trucks follow a lead truck with a human driver down the road. By synchronizing acceleration, braking, and steering among the trucks, the platoon can boost freight capacity while minimizing costs, all without handing total control over to the AI program. DHL will be involved with testing a truck platooning in the UK next year with the British Transportation Research Laboratory and truck manufacturer DAF Trucks [30].

Resilience 360. DHL plans to infuse this cloud-based risk management tool with AI capabilities that will give its customers an early warning that something is amiss in their supply chains. This product uses sentiment analysis to monitor 8 million sources of data on the Internet, including social media, for anything that could signal a disruption, including unhappy customers and even labor unrest.

«For a lot of our B2B or automotive or manufacturing customers, they have very vast supplier networks», Gesing says, «we proactive identify risky parts of the supply chain so our customers can plan downstream more effectively».

Supply chain tracking. AI has been increasingly applied in supply chain management to improve performance in an Agile and Lean perspective. Many companies are investing in digital solutions to optimize their supply chain operations, depicting the global AI adoption rate in supply chain and manufacturing businesses. Literature has shown that AI can provide companies with the ability to respond quickly to changes in demand, reduce waste, and improve collaboration and customer satisfaction. The AI in 2022 was 11% adaptation and in 2025 it expects to be 38% [31]

Drone-based deliveries. The use of drones for deliveries looks very promising, especially for streamlining and automating goods transportation. At the moment this segment is being actively studied. Nevertheless, today is definitely not the best time to speak about the full-scale adoption or mass use of drones in this industry when it comes to long distances. Drones are good for in-house deliveries but with the growth of distances, it is not always reasonable and feasible to use drones. Moreover, many drones are simply not able to carry very heavy boxes and packages which also limits their use to some specific cases only.

The retail industry could become the first to start using such solutions as a standard delivery method. It is also forecasted that drones will make it possible to reduce operational costs and staff while increasing the quality of services and customer satisfaction. But with the growing interest in the application of drones from the side of companies working in many industries, including logistics, we can make an assumption that in the future, the situation will change.

Commercial Drone Market Worth USD 47.38 Billion by 2029 Increasing Demand for Small Drones in Commercial Applications to Propel Market Growth: Fortune Business Insights™, Growth Rate is CAGR of almost 28.58% 2022-2029, Revenue forecast is expected in 2029 USD 47.38 Billion [32].

Fleet management tools. Solutions of this type are often integrated into more complex systems. As companies can operate a huge number of vehicles, it’s very important for them to accumulate a great deal of real-time information about the availability and state of each vehicle. Fleet management tools help companies better organize the entire workflow.

Fleet management solutions have a lot in common with software products that are built for location tracking. However, they can be used not only for monitoring the exact real-time location of trucks but also for tracking their technical state. Special sensors and devices can be installed on trucks and can continuously estimate the chosen parameters. Based on these parameters, logistics specialists can receive regular reports on the state of vehicles and on recommended timeframes for tech maintenance services.

The data from smart devices is sent to the defined servers where the company's employees can get access to them.

Ford is offering a new van fleet management service to large operators of its vehicles for free, claiming it can improve uptime by up to 60%.

Ford Telematics Essentials is the latest development of the FordLive system [33], which delivers 'smart maintenance' alerts based on real-time vehicle health data. The alerts help businesses to maximize uptime by reducing the number of breakdowns and achieving quicker servicing and repair times, it says.

Connecting vehicle data from the fleet, FordLiive also links businesses to the support available from the Transit Centre network through 'smart diagnostics' so that the productivity of each individual vehicle can be optimized.

Small business customers have already been benefiting from the FordLiive service through FordPassPro [33], which is generating 20,000-plus proactive service messages to customers every month.

Ford's larger fleet customers can now benefit from that same capability for free with the launch of Ford Telematics Essentials.

Mark Harvey, director for enterprise connectivity at Ford of Europe, said: "Ford Telematics Essentials is a desktop software tool that enables fleet managers to understand more about the health of their vehicles [34].

Enterprises can use fleet management to track and repair their cars in a cost-effective, timely, and accessible manner. Vehicle tracking and diagnostics, finance, driver management, and other activities are all part of it. It enables businesses that rely heavily on transportation to reduce or eliminate the risks connected with staffing, operations, and other factors. Fleet management benefits include lower fuel and overall operating costs, improved safety, and better fleet operations, as well as real-time fleet tracking and monitoring. According to the Automotive Fleet, sales of automobiles to business fleets in the United States climbed by 2.1 % to 69,145 in May 2019 compared to the previous year, according to Maximize market research statistics from the Automotive Fleet [34]. Rising operational expenses, owing to increased demand for utility vehicles, rising maintenance costs, and constant growth in compliance costs, have had a significant impact on the fleet management business

Conclusion. The study analyzes the application of AI in e-business logistics, characterizes the main trends in logistics management, and systematizes the directions for the effective use of AI in logistics. The result of research demonstrates that globalization is breaking all barriers and boundaries, enabling e-businesses to flourish. The industry that has benefitted and also been affected the most is logistics management. For it to operate seamlessly across the nations, it is important to keep up with the pace of technological advancements. Contributing greatly to the economy and increasing bilateral trade, the logistics management must be efficient enough to transport products so they are smoothly and quickly sent across.

The role of AI has become so prominent that it is almost indispensable to specific industries. According to Gartner [35], by 2026, more than 75% of commercial supply chain management application vendors will deliver embedded advanced analytics (AA), artificial intelligence (AI) and data science.

The future of AI in logistics management is likely to see several trends. AI is expected to become more widely adopted in logistics management as e-business recognizes its potential to improve efficiency and reduce costs. AI systems are expected to become more seamlessly integrated with existing logistics management systems, allowing for more accurate data analysis and decision-making.

AI will play an increasingly important role in predictive analytics, enabling e-business to anticipate and respond to logistics disruptions and manage risk more effectively.

Today, in the conditions of war, it is important for Ukraine to apply the latest information technologies in the logistics of goods and services, which will ensure the sustainable development of the enterprise.

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SUSTAINABLE FINANCIAL ECOSYSTEMS IN TERMS OF DIGITALISATION

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Abstract. *The article is devoted to the transformation of financial sector in terms of digitalization and creating sustainable financial ecosystems. The global financial ecosystem includes global, regional and national associations of financial institutions, regulators and other stakeholders, as well as financial ecosystems of individual countries. Creating a sustainable financial ecosystem on the national level is an important task and requires participation of the central bank as a regulator. Digitalisation of the economy as a whole and the financial system in particular contributed to the emergence of fintech companies and their rapid development. Nowadays remote technologies are widespread all over the world and there is growing demand for fintech services. In terms of digitalisation central banks need to be up-to date to improve national financial ecosystems. They are responsible for creating an adequate regulatory framework for regulation of fintech activities and at the same time stimulation of their development. Modern tendencies of the financial sphere regulation are analysed in the article. There is a trend among regulators worldwide to prioritize the development of fintech and to implement a 'supportive' regulation as well as introducing central bank digital currencies. The author outlines the main tendencies of the investments in fintech in the world. The main principles of sustainable financial ecosystems functioning in terms of digitalization are highlighted. On the basis of conducted analysis the author provides recommendations for the development of the sustainable financial ecosystem in Ukraine in modern economic conditions*.

Introduction. One of the current global trends in the circular economy is modernization of financial ecosystems. The global financial ecosystem includes global, regional and national associations of financial institutions, regulators and other stakeholders, as well as financial ecosystems of individual countries (fig.1). The issue of creating a sustainable financial ecosystem is of very importance nowadays. Lots of researchers (Frolov, S. et al., 2021; Maslii, N. et al., 2022; Somin, S. et al., 2020) pay attention to financial ecosystems and their transformations in modern economic conditions. Bose, S. et al. (2019) analyse global financial market players functions in the financial ecosystem and highlight their specific capacities to improve the sustainability of the broader ecosystem. Aldhanhani, N. and Nobanee, H. (2021) outline the need to build a sustainable financial ecosystem based on innovative strategies and provide the five-factor framework of such an ecosystem that include a deep pool of ESG investors, a strong pipeline of ESG fund raisers, a highly regarded and talented human capital pool, strong awareness of ESG by different stakeholders and robust mechanisms for ESG verification. It should be mentioned that the described approach concentrates on ESG factors but does not explain the essence of the ecosystem, its basic participants and key elements.

Fig. 1. Participants of the World Financial Ecosystem

Researchers also underline the importance of a sustainable financial ecosystem functioning on the national level in order to have progress in achieving sustainable development goals and creating finance ecosystems that systematically mobilize SDG-aligned investments at the required scale. The in-depth analysis of available financing instruments, in close collaboration with the public funding agencies as well as private funding actors is at the core of ecosystem process (Halonen, M. et al., 2022). According to the above mentioned approach sustainable financial ecosystem is considered as a part of other ecosystems that enables allocation of required resources and makes SDG-investments easier due to its instruments and innovations.

It worth noting that sustainable financial ecosystem aims to satisfy consumers' needs in terms of vulnerable environment, digital transformation and meet customers` demand, as well as support country`s progress towards sustainable development. At the same time sustainable financial ecosystem should take into consideration not only modern situation and customers demand but also needs of future generations. So the role and importance of creating a sustainable financial ecosystem is realized by economists and researchers but it worth mentioning that authors do not focus enough on the key actors, their interactions and processes within a sustainable financial ecosystem.

In terms of digitalization new technologies are implemented, financial services have to be constantly improved. The key role in creating a sustainable financial ecosystem in the state is played by the central bank as a regulator, which must ensure the necessary conditions for the functioning of all financial market players. Digitalization of the economy as a whole and the financial system in particular contributed to the emergence of new members of financial ecosystems - fintech companies and their rapid development. Due to the increasing spread of remote technologies and the growing demand for fintech services, the need to regulate fintech ecosystems has arisen.

An important role in building a sustainable fintech ecosystem at the national level is also played by regulators, who are responsible for creating an adequate regulatory framework for regulation of fintech activities and at the same time stimulation of their development. There is a trend among regulators worldwide to prioritize the development of fintech. It should be noted that the first countries where such 'supportive' regulation was introduced were Great Britain and Singapore. According to the KPMG Report 'Pulse of Fintech' (KPMG, 2021), the Monetary Regulatory Authority of Singapore issued the first two digital banking licenses to the Grab-Singtel consortium and the technology giant SEA in 2020, as well as two digital wholesale bank licenses for such market participants as Ant Group and the consortium, which includes Greenland Financial Holdings Group Co. Ltd, Linklogis Hong Kong Ltd and Beijing Co-operative Equity Investment Fund Management Co. Ltd.

In terms of digitalisation central banks need to be up-to date to improve national financial ecosystems. So they pay attention to innovative technologies and tools that can be used in monetary sphere, such as digital currencies. In October 2020, the Bank for International Settlements and seven central banks, including the Fed, the ECB and the Bank of England, published a report 'Central Bank Digital Currencies: Foundational Principles and Core Features' outlining the main requirements for central bank digital currencies (CBDC) (BIS, 2020). The document states that CBDC should complement the legal means of payment in the country, and not replace cash or non-cash forms of payment. In addition, they must maintain monetary and financial stability, as well as be safe and as cheap or free as possible. It is assumed that the CBDC will play a significant role for the private sector.

As it is mentioned in the KPMG report 'Pulse of Fintech' (KPMG, 2021) in 2020, China's central bank launched a project to use the central bank digital currency, introducing digital yuan into circulation in one of the country's regions. Many well-developed countries of the world, such as Singapore, Canada, Sweden, Norway, the Netherlands, Finland, Australia, etc., are working on the development of central bank digital currencies. As part of the partnership, the regulators of Singapore and Canada carried out the first cross-border operation using the CBDC.

The National Bank of Ukraine is also working towards the introduction of its own digital currency. In 2018, a pilot project was conducted (NBU, 2019). It included the introduction of the "Electronic Hryvnia" platform, the issuing of the e-hryvnia into circulation, and the testing of operations using it. The results of the project are highlighted in National Bank of Ukraine Analytical Report on the E-hryvnia Pilot Project (2019). During the period of the project, e-hryvnias were issued in the amount equivalent to UAH 5,443. The project participants carried out a number of operations with e-hryvnia:

- creation of e-wallets;
- installation of e-hryvnia wallets mobile applications on own devices with Android or iOS operating systems;
- cashless refilling of e-wallets using National Payment System "Prostir";
- P2P transfers of e-hryvnia between wallets;
- replenishment of mobile phone balance with e-hryvnias;
- making charitable contributions;
- exchange of e-hryvnias for cashless funds, using cards of National Payment System 'Prostir'.

Materials. Despite the assistance of regulatory authorities, business participation is also important in the development of the fintech ecosystem as a part of a financial ecosystem. The basis of fintech development is investments in innovations, and especially venture capital investments, which is one of the incentives for the creation of new companies and technologies. In recent years, the world has developed a tendency to grow investments in fintech (fig. 2).

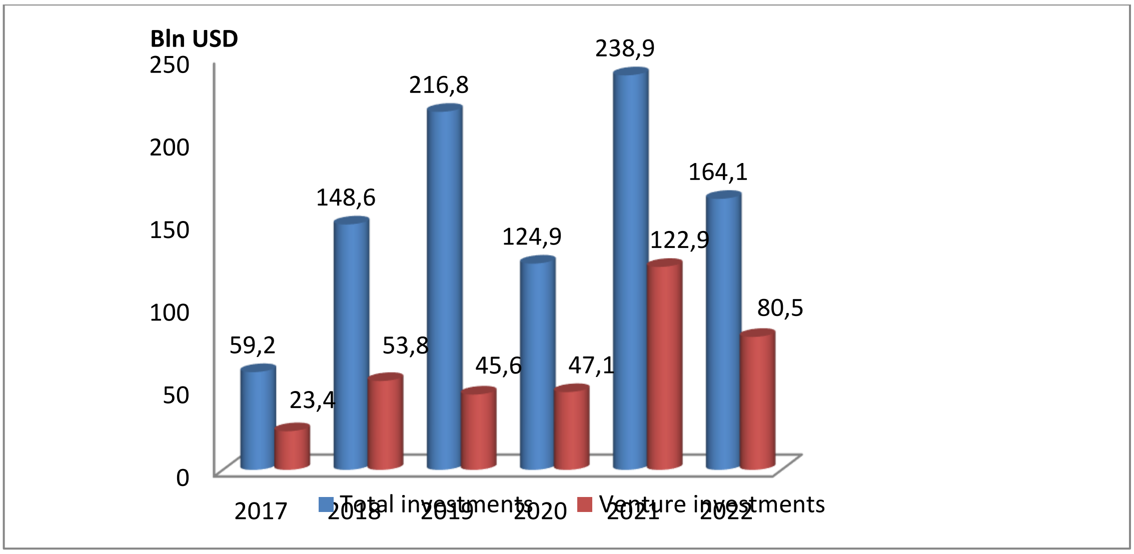

Fig. 2. Global Investments in Fintech from 2017 to 2022.

Source: KPMG (2021). Pulse of Fintech. H2 2020. 72 p. Available at https://assets.kpmg.com/content/dam/kpmg/xx/pdf/2022/02/pulse-of-fintech-h2-21.pdf. Retrieved 28 May 2023; KPMG (2023). Pulse of Fintech. H2 2022. Available at https://veri-media.io/wp-content/uploads/2023/02/kpmg-pulse-of-fintech.pdf. Retrieved 28 May 2023.

According to fig. 2 the volume of total investments in fintech increases but, it dropped to $124.9 billion in 2020 compared to $216.8 billion in 2019. This was partly caused by a decrease in the number of mega M&A deals, such as the 2019 acquisition of WorldPay by FIS worth $42.5 billion (KPMG, 2021). At the same time, the volume of venture capital investments in fintech increased in 2020 compared to the previous year. Fintech funding increased by $1.4 billion in Europe and by $500 million in North America. At the same time, Asia showed a drop in financing volumes by $3 billion, despite the rapid recovery of the region from the negative impact of the pandemic. Funding of South American fintech companies increased by 64% from 2016 to 2020. About 40% of the deals during this period are financing deals for alternative lending and settlement companies (Janowski, 2020). 2021 was a remarkable year for investments in fintech. Total volume of investments was $238.9 billion, volume of venture investments in the fintech companies was also the highest in 2021 – $122.9 billion. Following 2021's record high level of total global fintech investment and deal volume 2022 saw both total investment fall — to $164.1 billion. While low by comparison, it was the third best year for fintech investment ever (KPMG, 2023).

Over the last 5 years 2020 was marked by a record number of mega funding rounds. The leader among countries was the USA, where more than 50% of megarounds took place (54 of 97). The second place was occupied by China, with 7 megarounds two years in a row. During 2020, there was a 13% year-over-year increase in the number of financing deals for fintech companies that provide services to small and medium-sized businesses, while other segments saw a decrease in the number of deals (Janowski, 2020). Deals fell 8% year-over-year to reached 5,048 in 2022. Africa was the only major region to see deals increase compared to 2021. Banking funding declined 63% YoY – the sharpest drop across fintech sectors analysed — to return to pre-Covid levels. Despite the drop, 2022 was the second-highest funding year for US fintechs on record. Africa-based fintechs saw a record 227 deals in 2022, a 25% increase YoY. Insurtech M&A exits reached a new high, rising 40% in 2022 to 81 deals (CBInsights, 2023).

There were no significant changes in the structure of financing agreements for fintech companies during 5 years (Fig. 3).

According to the data of fig. 3, a slight decrease in the share of seed deals was observed - by 5 pp. compared to 2019 due to an increase in the share of series B deals (by 3 pp.), series C (by 1 pp.) and megarounds (series E+ by 1 pp.).

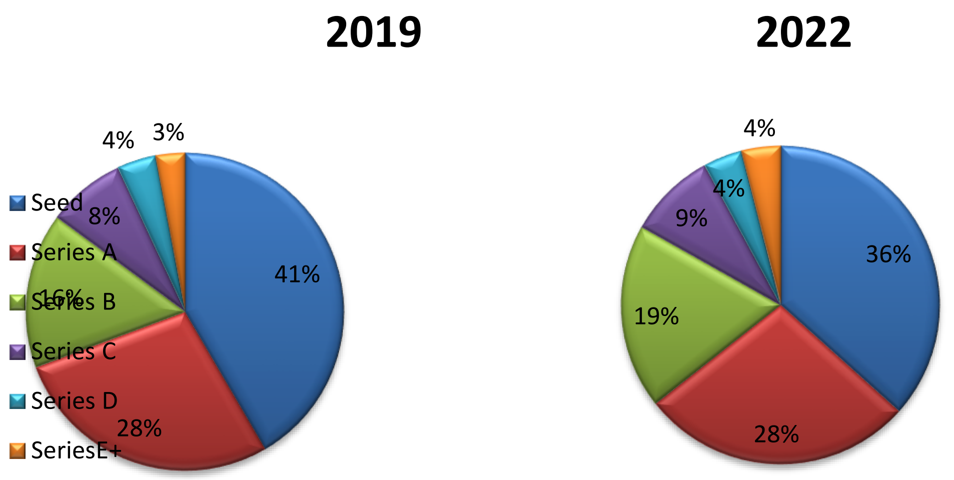

Fig. 3. The structure of deals for fintech companies during 2019-2022

Source: CBInsights (2021). The State Of Fintech Report: Investment & Sector Trends To Watch. Available at https://www.cbinsights.com/research/report/fintech-trends-q4-2020/. Retrieved 25 May 2023; CBInsights (2023). State of Fintech 2022 Report. Available at https://www.cbinsights.com/research/report/fintech-trends-2022/. Retrieved 28 May 2023.

Despite economic instability, influence of the pandemic, banks as major representatives of financial ecosystem continue investing in fintech. One of the key trends in the fintech sector over the past years is a growing focus on core banking systems as banks recognized how legacy infrastructure is holding them back from truly moving forward (KPMG, 2021). The largest US banks continue to make strategic investments in fintech companies operating in various niches (fig. 4).

As it is demonstrated on fig. 4, fintech companies operating on the capital market are the leaders among investment objects. In the 2nd and 3rd places are companies working in the area of asset management and companies serving SMEs (46 and 37 deals, respectively).

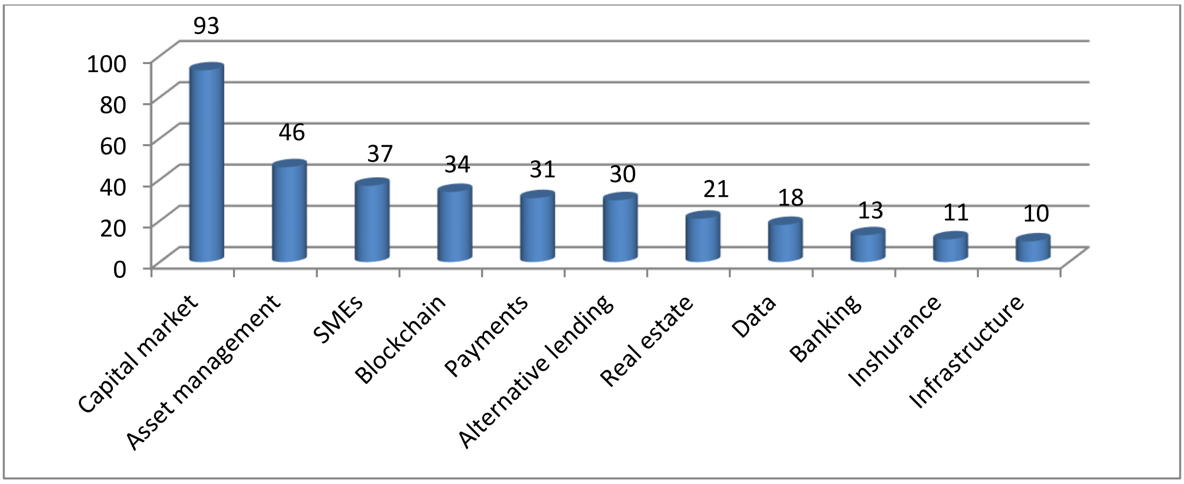

Fig. 4. Number of fintech start-up financing agreements by US banks during 2010-2020 by investment area

Source: CBInsights (2020). Here's Where Goldman Sachs, Morgan Stanley, And Other Top Banks Are Investing In Fintech – And Why. Available at https://www.cbinsights.com/research/top-us-banks-fintech-investments-graphics/. Retrieved 25 May 2023.

The pandemic has made digitization a top priority for any businesses, including financial ones. Period of pandemic is characterized by the following trends in the field of financial services:

- Growing demand for contactless banking services and e-payment solutions;
- Changing consumer behaviour towards increased use of e-commerce platforms, e-wallets and digital service channels;
- Strengthening the attention of regulators to the fintech by supporting and stimulating the development of fintech ecosystems;
- Growth of total volume of investments in fintech;
- Strengthening of partnerships between fintech companies and non-financial corporations;
- Mature fintech companies prefer mergers and acquisitions in order to expand their geographic presence in the market and increase the consumer value of their services.

The global community has entered the era of digital banking, which challenges traditional banks to maintain their competitive positions. Digital banks are representatives of fintech that attract investors. In 2020, digital banks have seen a significant number of mega venture capital funding rounds. The Swedish digital bank Klarna attracted $650 million, Revolut – $580 million, and the US digital bank Chime – $533.8 million (KPMG, 2021). In the conditions of global digital transformation, an increasing share of the population prefers online services and raise a demand for innovative products and services, which stimulates banks to transform their business models with an emphasis on innovation and remote services. Most large banks have the necessary tools and advantages to push the boundaries of their business models. The main driver of transformation is the need to strengthen their positions and competitiveness in terms of uncertainty to ensure sustainable functioning. There are 6 key digital growth strategies for banks that will contribute to their further development (McKinsey, 2018):

1. Going beyond core banking activities into relevant ecosystems.
2. Creation of a financial supermarket.
3. Extend value across the customer journey.

4. Monetize data.

5. Become a product- or infrastructure-sourcing factory.

6. Transformation into a digital attacker.

Results. In order to create sustainable financial ecosystem in the country some changes of the financial services and key players of the ecosystem are required. First of all the banking business has to be transformed, expand the boundaries and reorient itself from the traditional banking services, which form the core of the banking business, to the introduction of digital banking services, the development of cooperation with fintech companies. So, according to the conducted research and analysis sustainable financial ecosystems should be created on the basis of such principles:

- Client orientation;
- Digital transformation of financial market players business models;
- Development of strategic partnership of financial institutions, especially banks, with fintech companies;
- Introduction of "supportive regulation" aimed at the development of fintech ecosystem as a part of sustainable financial ecosystem.

Ukraine follows global trends formed in the financial sphere. The National Bank of Ukraine positions itself as the architect of the financial ecosystem (NBU, 2021). According to the Strategy of Ukrainian Financial Sector Development until 2025, adopted by the National Bank of Ukraine (NBU, 2021), the Ukrainian financial ecosystem includes the following groups of participants:

• Expertise – market participants and state institutions, which create the basis for the professional development of ecosystem participants;

• Regulation and control – state institutions that create rules for the interaction of ecosystem participants and control compliance with these rules;

• Financial service providers – companies, state institutions that directly provide financial products and services to consumers.

• Infrastructure and technology – companies and government institutions that provide products, services and solutions for financial service providers and other participants of the financial sector.

Sustainable financial ecosystem aims to satisfy customers` needs by implementing innovative approaches and technological solutions. In order to achieve SDGs and foster progress of the particular country towards the sustainable development financial ecosystem should be up-to-date, innovative and produce new mechanisms of financing prioritised projects not only economic but also ecological and social ones. Thus it is required to create a sustainable financial ecosystem based on ESG approach that will take into account present and future needs of the all its actors. It has to be consumer-oriented as people welfare including welfare of next generations, the quality of life is a priority for sustainable development. During the previous decades financial system of Ukraine was banks-oriented, banking sector performed a vital role in it. In modern conditions of digitalisation banks have to change their business models and they are shifted from the central position. It is worth noting that in order to build a sustainable financial ecosystem in Ukraine, it is necessary to pay attention to the development of fintech companies as an important component that meets the dynamic consumer demand in modern conditions of digitalisation. On the basis of the conducted analysis it is important to conclude that fintech companies have the growing importance in the transformation of financial ecosystem into the sustainable one. So fintech companies should be considered as a separate part of the sustainable financial ecosystem (fig. 5).

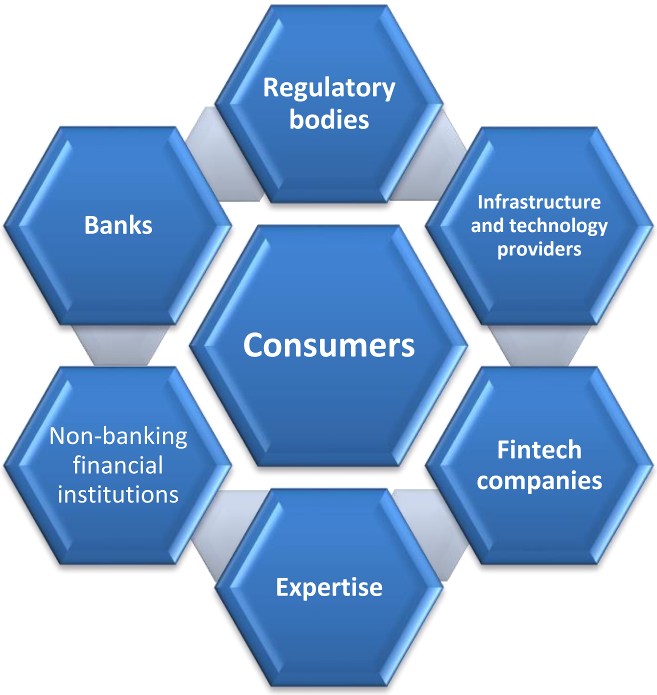

Fig. 5. Model of a Sustainable Financial Ecosystem in Ukraine

Source: Created by the author on the basis of Halonen M. at al. (2022) Recommendations for how Finland Can Develop Sustainable Finance at the National Level. Developing Finland's Sustainable Finance Ecosystems Reform/Sc2020/054 – Sustainable Finance Roadmap for Finland. May 2022. 43 P. Available at https://tem.fi/en/developing-finlands-sustainable-finance-ecosystems. Retrieved 05 October 2023; NBU (2021). Strategy of Ukrainian Financial Sector Development Until 2025. National Bank of Ukraine. Available at https://bank.gov.ua/admin_uploads/article/Strategy_FS_2025_eng.pdf?v=4. Retrieved 28 May 2023; Frolov, S.,Orlov, V., Lozynska, O. and Shukairi, F. (2021). Strategic and tactical benchmarks for restructuring the financial system of Ukraine. Economics of Development, 20(1), 11-22. doi:10.21511/ed.20(1).2021.02 .

An important role in the financial ecosystem is played by the expert environment, which includes educational institutions, researchers, experts, the international professional community, industry associations, business associations, which form the basis for the sustainable functioning of the ecosystem. It is necessary to pay governmental attention to the development of education, to the growth of state expenditures on R&D, which will contribute to the growth of the number of qualified personnel and, accordingly, to strengthen the financial ecosystem in Ukraine. It should be noted that a key role in the development of a sustainable financial ecosystem is played by the availability of financial products and services for users, an extensive network of banks and other financial intermediaries. The leading place is occupied by the development of the corresponding infrastructure, as well as access to the Internet. The creation of a stable, client-oriented financial ecosystem will contribute to the formation of inclusive economic growth of Ukraine and its sustainable development. In order to increase the efficiency of the national financial ecosystem functioning, it is necessary to continue working towards further integration into the global financial ecosystem, to strengthen harmonization of the legislative framework.

The level of financial inclusion plays an important role in building a sustainable financial ecosystem. An inclusive financial sector contributes to the economic growth of the state and the achievement of sustainable development. The issue of financial inclusion is on the agenda in many countries of the world, including Ukraine. The basis for achieving financial inclusion is financial literacy, free access of economic entities to a wide range of financial products and services, as well as the development of innovations, in particular in the banking sector. The index of financial literacy for Ukrainians is 12.3 points out of a possible 21 (USAID, 2021). The study was conducted for the second time in Ukraine according to the OECD methodology, which made it possible to compare indicators with other countries. Ukraine's result is slightly lower than the average (12.7). This indicates the need for further work on the formation of financial literacy of the population at the national level. National financial literacy strategies are already being implemented in more than 50 countries around the world. There is no doubt about the effectiveness of the national approach: among the countries that were the first to organize their measures on the basis of the strategy, there are the most leading countries in terms of financial literacy. To achieve a large-scale effect, it is necessary to ensure the coordinated actions of financial market participants under the guidance of the regulator. Improvement of the level of financial literacy of the population at the macro level will contribute to the expansion of the range of consumers of banking and financial services.

An important step on the way to strengthening financial inclusion is not only educational work among different segments of the population, but also measures designed to ensure the growth of public trust in banking institutions and the banking system as a whole.

Conclusions. It should be mentioned that a necessary condition for financial inclusion and the creation of a sustainable financial ecosystem in Ukraine is the stimulation of the development of financial and banking innovations, which involves the introduction of new products and technologies, the development of remote customer services, which contribute to the formation of loyalty to the provider of financial services, as well as the growth of demand in the relevant market. It is worth noting that the implementation of innovations depends precisely on the providers of financial services, their initiative, creativity and readiness not only to satisfy the dynamic needs of consumers, but also to anticipate them. Ukraine has already made some progress on the way to creating a sustainable financial ecosystem. An important role in this is played by the National Bank of Ukraine, which adheres to global regulatory trends. At the same time, in the conditions of global digital transformation, the domestic banking system faces new challenges that require further work from both the regulator and financial service providers, including banks, to transform their business models in accordance with the needs of a digital society.

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VECTORS OF FOREIGN TRADE COOPERATION OF UKRAINE WITH COUNTRIES OF ASIAN REGION

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Abstract*. At the current stage of development, one of the most promising foreign trade partners for Ukraine are the countries of Asian region, especially China, Japan and India. These countries attract interest due to their unprecedentedly high growth rates and unconventional development path. Development of a long-term program of cooperation between Ukraine and countries of Asian region with determination of priorities and specific measures will contribute to balancing foreign trade cooperation of countries and significantly increasing volume of trade in industrial goods.*

The following conclusions were drawn: due to existing structure of industrial production, military operations taking place on the territory of our country, and other economic factors, Ukraine will continue to export to China raw materials with low added value in near future, while imports will be dominated by goods with high added value. Development of foreign economic cooperation between Ukraine and India in medium term will not have significant changes, which indicates the preservation of existing foreign trade structure. Also, today it is quite difficult for Ukraine to offer Japan products of domestic industry with high added value. At the same time, our country can be integrated into some production chains of Japanese industry thanks to cheap labor, territorial proximity to huge EU sales market, etc. However, in order for this process to be complete and irreversible, a necessary and mandatory condition is primarily the victory of Ukraine in the war with russia, the implementation of relevant reforms, to create comfortable conditions for potential investors in the post-war period.

Introduction. Foreign trade cooperation with other countries is one of the most important components of Ukraine's foreign economic relations, especially in the conditions of "multipolar globalization", which involves searching for new sources of strengthening competitiveness, as well as partners, in cooperation with which it would be possible to accelerate the modernization and development of countries' economies.

Materials and Methods. The theoretical and methodological basis of the research is primarily the scientific works of foreign scientists. The research was carried out using critical and scientific analysis, methods of scientific generalization and systematization, induction and deduction, and the conclusions and recommendations were based on an integrated approach.

Results and Discussion. Many scientific publications are devoted to the issue of foreign trade cooperation of Ukraine with countries of Asian region, in particular Hal'perina L. & Shapoval A. [1], Honcharuk A. [2], Yingying Li, Zakharin S. & Volosiuk M. [3], Kiktenko V. [4], Korablin S. [5], Kurnyshova Yu. [6], Majko V. [7], Medvedkina E. [8], Mernikov H. [9], Sidenko S., Nevhad A. [10], Khomutenko L. & Tereshchenko A. [11], Shevchuk I. [12] etc. At the same time, questions regarding directions of diversification of Ukrainian industrial products in conditions of multipolarity of world trade were left out of the study.

In 2021, the total turnover of Ukraine increased by 46.3% to 135.8 billion US dollars compared to 2017. At the same time, domestic exports in 2021 amounted to 65.9 billion US dollars, which is 1.5 times more than in 2017, and imports during this period increased by 41.5% to 69.9 billion US dollars. During 2017–2021, the trade balance was negative and ranged from USD 10.8 billion in 2019 to USD 4.0 billion in 2021 (fig. 1).

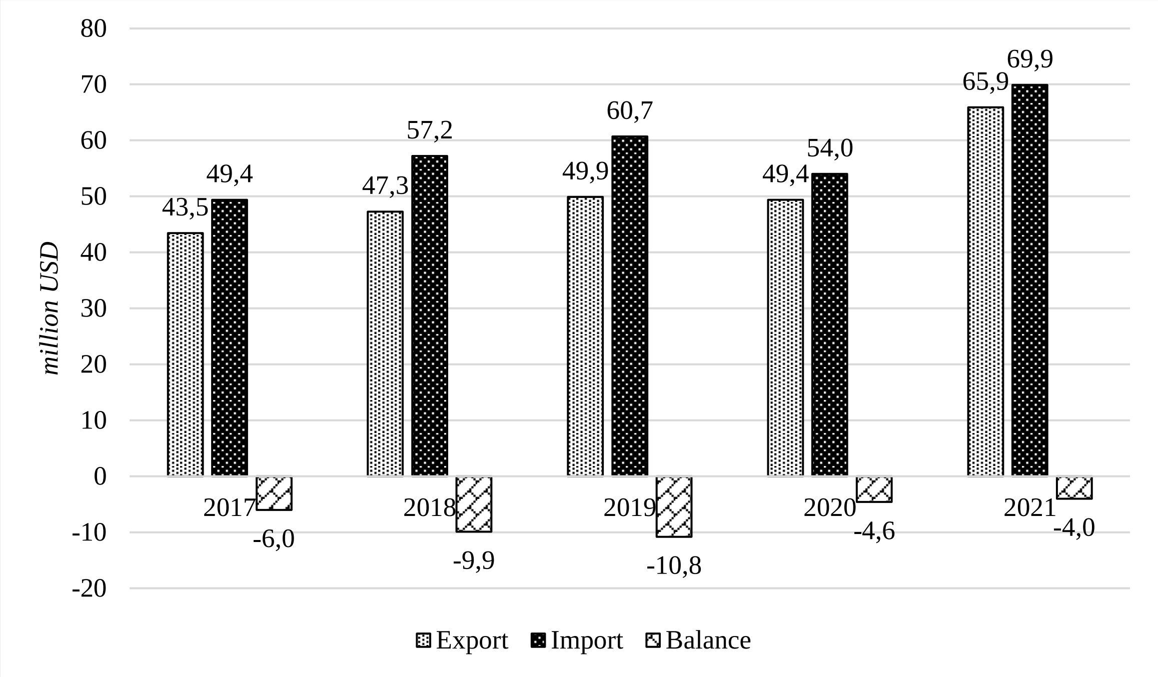

Fig. 1. Dynamics of foreign economic activity of Ukraine in 2017–2021, billion US dollars

Source: [13]

The analysis of the above data shows that Ukraine is sufficiently integrated into world economy and has fairly stable foreign economic relations, which annually ensure positive dynamics of foreign trade turnover [14]. At the same time, such integration leads to an increase in dependence of the national economy on external influences and actualizes issue of creating a geo-economic strategy for development of state as a full-fledged subject of global economic processes with aim of increasing effectiveness of multilateral cooperation and wider participation in international and regional integration projects. At the current stage of development, one of the most promising foreign trade partners for Ukraine are countries of Asian region, especially China, Japan and India. These countries attract interest due to their unprecedentedly high growth rates and unconventional development path. Following the path of economic reforms, countries of this region set themselves the goal of finally establishing themselves as world economic leaders by 2050. Therefore, development of a long-term cooperation program of Ukraine with countries of Asian region, with the determination of priorities and specific measures, will contribute to balancing foreign trade cooperation of countries and significantly increasing the volume of trade in industrial goods.

Among countries of Asian region, the largest volumes of foreign trade operations in recent years were observed with the People's Republic of China (PRC), India and Japan (table 1).

So, today the PRC is developing at a fast pace compared to other Asian countries and shows better prospects for development. Moreover, the rapid growth of the Chinese economy has prompted active discussions around the issue of China's global economic leadership in the near future.

Among the main factors affecting China's economic growth are: cheap labor force; undervalued yuan; "technology in exchange for the market"; sustainability and stability of the political system; gradualist approach to reforms; export-oriented industrial policy [15].

Table 1

Foreign trade operations of Ukraine with the countries of the Asian region in 2020–2021, *million dollars. USA*

Країна	**2020**			**2021**		
	Export	**Import**	**Balance**	**Export**	**Import**	**Balance**
Bangladesh	354,9	97,6	257,3	250,5	123,3	127,2
Vietnam	182,4	462,4	-280,0	278,6	565,2	-286,6
China	**7107,3**	**8357,2**	**-1249,9**	**7992,5**	**10637,8**	**-2645,3**
India	**1971,9**	**721,4**	**1250,5**	**2513,8**	**934,5**	**1579,3**
Indonesia	733,7	278,6	455,1	734,9	414,6	320,3
Japan	**181,7**	**1075,1**	**-893,4**	**341,5**	**1213,5**	**-872,0**
North Korea	351,5	497,1	-145,6	267,3	676,4	-409,1
Malaysia	181,1	230,7	-49,6	136,4	276,4	-140,0
Mongolia	23,1	0,3	22,8	25,1	0,3	24,8
Pakistan	331,0	80,7	250,3	572,6	91,9	480,7
Philippines	169,9	49,1	120,8	107,5	65,3	42,2
Singapore	123,1	45,6	77,5	21,8	46,2	-24,4
Thailand	164,5	193,7	-29,2	262,9	252,1	10,8
Sri Lanka	35,6	36,7	-1,1	23,3	37,6	-14,3
In total	**11911,7**	**12126,2**	**-214,5**	**13528,7**	**15335,1**	**-1806,4**

Source: Made according to the data: [13]

For quite a long period, cheap labor ensured the low cost of Chinese goods. Undervalued exchange rate of the yuan gave Chinese goods additional competitive advantages. In particular, until 1974, the exchange rate of the yuan against foreign currencies was set mainly through the pound sterling, as well as the Hong Kong dollar. Since August 1974, the daily quotation of the yuan against the US dollar and other currencies on the basis of a currency basket was introduced. Since 1994, Beijing has fixed the yuan exchange rate at USD 1 / RMB 8.27. In this regard, leading countries of the world accused China of undervaluing the exchange rate and accumulating foreign exchange reserves, which serve as a tool for stimulating export-oriented growth and provide additional competitive advantages to Chinese goods.

Also, in the early 1990s, Chinese authorities declared a policy of "technology in exchange for the market", which provided for opening of part of the Chinese market to MNCs in exchange for the transfer of foreign technologies to China. Taking advantage of cheap labor, Western MNCs massively moved their production, and later their research centers, to China. Today, China operates 53 high and new technology zones, more than 70 scientific and technical zones for specialists who received education abroad.

The gradualist approach to reforms also had an important impact on the economic growth of the Chinese economy. So, when starting systemic reforms, China started them not with political, but with market transformations, maintaining an authoritarian political system to minimize political risks. The evolutionary path of development was taken as a basis - the implementation of programs and plans stretched over a long time. Market forms of economic integration were gradually introduced into the economy. The formation of private sector took place from scratch, and not as a result of large-scale privatization.

However, the most important factor in China's prosperity is considered to be the successful implementation of the foreign trade policy, which not only radically affected China's foreign economic position, but also became the driver of its rapid internal economic transformations and reforms in country. In 1978, China began implementation of a reform policy aimed at openness to outside world, construction of a socialist market economy and creation of a “small welfare” society [16, pages 54-55]. The Chinese government has allowed international trade and foreign direct investment. Such initiatives raised the standard of living for majority of the Chinese population and later made it possible to support comprehensive reforms [15].

In general, evolution of China's trade development strategy can be divided into two stages: before joining the WTO and after. At the stage “before joining the WTO” (1980-2001), China's trade development strategy consisted of four periods. The first period (1980–1983) was characterized by import substitution and marginal export stimulation. Stimulation of exports, neutralizing import substitution (1984–1990) was characteristic for the second period of implementation of China's trade development strategy. In the third period (1991–1993), export promotion and foreign trade liberalization were observed. During the fourth period (1994–2001), radical trade liberalization took place.

In “after joining the WTO” stage, China transformed its previous trade development strategy with an emphasis on import substitution into a more balanced one aimed at ensuring sustainable development, domestic and external demand, coordinated import and export trade.

According to developed strategy of economic development, from 2001 until now, China is going through three stages, in particular: “fulfilling WTO obligations and continuing trade liberalization” (2001-2005); “adaptation of trade policy and transformation of the growth model” (2006–2008); “recovery after global financial and economic crisis” (2008 – until now) [16, page 55]. At the same time, the adjustment of trade policy helped China to successfully exit the 2009 crisis and improve indicators of foreign economic activity. With the gradual recovery of the world economy and external demand, China's foreign trade began to grow rapidly. Thanks to a positive trade balance over the past few years, China has become the largest exporter in the world and ranked second among the world's largest importers. Despite the strict policy, the country is quite open to foreign trade, the share of which in 2020 was 34.5% of China's GDP.

Trade and economic cooperation between Ukraine and the **People's Republic of China** (PRC) in recent years has been characterized by steady growth in the volume of bilateral trade (fig. 2).

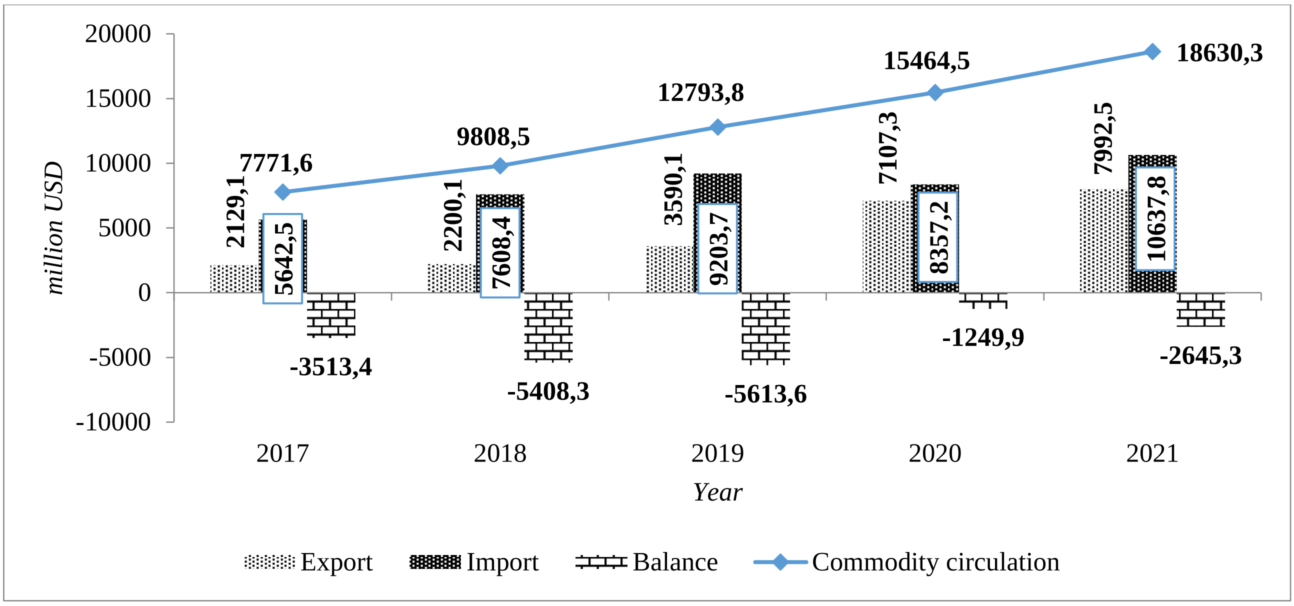

Fig. 2. Dynamics of trade in industrial goods between Ukraine and the People's Republic of China in 2017–2021, *million US dollars*

Source: [17]

In particular, the volume of foreign trade turnover in 2021 amounted to 18,630.3 million US dollars, which is 2.4 times more than in 2017 (7,771.6 million US dollars) and 20.5% more than in 2020 (15,464.5 million USD). The volume of exports in 2021 increased by 3.8 times compared to 2017 and by 12.5% compared to 2020. In 2021, there was also an increase in import volumes by 1.9 times compared to 2017, and by 1.3 times compared to 2020 to 10,637.8 million USD. It is worth noting that during 2017–2021 the balance of the trade balance was negative, despite the fact that in 2021 its volumes decreased by 24.7% compared to 2017.

The main groups of industrial goods exported to the PRC in 2021 were the following (46.0%): 26 Ores, slag and ash (2,960.1 million USD or 37.0%); 72 Ferrous metals (321.6 million USD or 4.0%); 84 Nuclear reactors, boilers, machines, equipment and mechanical devices; their parts (268.5 million USD or 3.4%); 44 Wood and wood products, charcoal (126.3 million USD or 1.6%).

In import structure of industrial goods of the PRC to Ukraine in 2021, the following product groups prevailed: (82.0%): 85 Electric machines, equipment and their parts; equipment for recording or reproducing sound, television equipment for recording and reproducing images and sound, their parts and accessories (2,736.8 million USD or 25.7%); 84 Nuclear reactors, boilers, machines, equipment and mechanical devices; their parts (2057.7 million USD or 19.3%); 87 Vehicles of land transport, except railway or tram rolling stock, their parts and equipment (508.4 million USD or 4.8%); 39 Plastics, polymeric materials and products thereof (425.7 million USD or 4.0%); 38 Various chemical products (342.3 million USD or 3.2%); 64 Shoes, gaiters and similar products; their parts (335.3 million USD or 3.2%); 90 Optical, photographic, cinematographic, control, measuring, precision devices and apparatus; medical or surgical; their parts and accessories (329.8 million USD or 3.1%); 29 Organic chemical compounds (289.4 million USD or 2.7%); 72 Ferrous metals (286.0 million USD or 2.7%); 95 Toys, games and sports equipment; their parts and accessories (281.8 million USD or 2.6%); 94 Furniture, bedding, mattresses, mattress bases, sofa cushions and similar stuffed furniture, lamps and lighting fixtures, not elsewhere specified; light pointers, scoreboards and similar products; prefabricated building structures (270.8 million USD or 2.5%); 40 Rubber, rubber and products thereof (252.4 million USD or 2.4%); 73 Ferrous metal products (241.5 million USD or 2.3%); 30 Pharmaceutical products (240.5 million USD or 2.3%); 76 Aluminum and its products (124.8 million USD or 1.2%).

If we compare the volumes of export and import of industrial goods between Ukraine and the People's Republic of China, it can be seen that in export structure of industrial products (46.0%) in 2021, raw materials prevailed, in particular ores, slag and ash (37.0%), in while in import structure of Chinese industrial goods, we can see goods with a high added value, in particular from electrical machines, boilers and machines, to toys, and even ferrous metals produced in Ukraine.

It should be noted that due to the full-scale invasion of the russia into Ukraine, the volume of foreign trade turnover between Ukraine and the People's Republic of China decreased by 41.3% in 2022 compared to 2021 and amounted to 11.1 billion USD. At the same time, according to the results of 2022, export volumes decreased by 68.9% compared to 2021 – to 2.5 billion USD, and the volume of imports – by 21.2% – up to 8.7 billion USD. Ukraine's losses in foreign trade with the PRC due to the large-scale invasion of the russia by the end of 2022 amounted to 7.8 billion USD.

Unlike our country, the PRC benefited from the russian large-scale invasion of Ukraine. In particular, after the introduction of sanctions by Western countries, China continued to buy oil and natural gas from the russia at preferential prices. It is confirmed by data on the growth of China's trade with the russia from March 2022 to September 2022, provided by the New York Times [18]. In particular, the average monthly import of goods from the russia to the PRC during March-September 2022 increased by 98% compared to the corresponding average monthly imports from the russia to the PRC during 2017-2021. The above shows that in the future the trade policy of Ukraine in terms of concluding free trade agreements or investment agreements should take into account the trade policy of the PRC during the war in Ukraine.

India is one of the countries of Asian region, which is one of the most promising foreign trade partners of Ukraine. Despite the fact that India is a developing country, it is the world's third largest economy in terms of GDP, showing the highest growth rates[7] among the world's largest economies in recent years. The services sector accounts for the largest share in India's GDP (more than 55%). India is a significant exporter of IT and business outsourcing services. The second place in terms of contribution to GDP belongs to agriculture (almost 30%), in which almost half of the country's labor resources are employed, which indicates the low productivity of the industry[8]. Industry provides 16% of country's GDP. The automotive industry is the most promising, thanks to the significant investment in production made by global giants such as Hyundai, Ford, Nissan and Renault. The Indian car market is currently the fifth largest in the world by sales volume and could surpass markets of Japan and Germany [19]. The main drivers of growth in recent years have been private consumption and exports.

The volume of foreign trade turnover between Ukraine and India in 2021 amounted to 3,448.3 million USD, which is 24.6% more than in 2017 and 28.0% more than in 2020 (Table 2).

[7] India's GDP grew at 6-8% during 2013-2018.

[8] According to FAO estimates, at least 40% of vegetables and fruits spoil on the way to consumers.

Table 2

Dynamics of trade in goods between Ukraine and India in 2017–2021, *million USD*

Indicator	Year				
	2017	**2018**	**2019**	**2020**	**2021**
Commodity circulation	2767,3	2792,6	2761,1	2693,3	3448,3
Export	2206,2	2175,9	2019,9	1971,9	2513,8
Imports	561,1	616,7	741,2	721,4	934,5
Balance	1645,1	1559,2	1278,7	1250,5	1579,3

Source: [17]

The volume of exports in 2021 increased by 13.9% compared to 2017 and by 27.5% compared to 2020. Also, an increase in imports was observed during the studied period. In particular, in 2021, import volumes increased by 66.5% compared to 2017, and by 29.5% compared to 2020. During 2017–2021, the balance of the trade balance was positive, ensuring a positive impact on the domestic economy.

The main groups of industrial goods exported to India in 2021 were the following (16.2%): 31 Fertilizers (316.0 million USD or 12.6%); 84 Nuclear reactors, boilers, machines, equipment and mechanical devices; their parts (58.0 million USD or 2.3%); 44 Wood and wood products, charcoal (32.2 million USD or 1.3%).

In the structure of imports of Indian industrial goods to Ukraine in 2021, the following product groups prevailed (73.8%): 30 Pharmaceutical products (241.2 million USD or 25.8%); 27 Mineral fuels; oil and products of its distillation; bituminous substances; mineral waxes (151.3 million USD or 16.2%); 29 Organic chemical compounds (60.5 million USD or 6.5%); 85 Electric machines, equipment and their parts; equipment for recording or reproducing sound, television equipment for recording and reproducing images and sound, their parts and accessories (50.7 million USD or 5.4%); 84 Nuclear reactors, boilers, machines, equipment and mechanical devices; their parts (US$50.2 million or 5.4%); 40 Rubber, rubber and products thereof (33.4 million USD or 3.6%); 38 Various chemical products (29.4 million USD or 3.2%); 87 Means of land transport, except for railway or tram rolling stock, their parts and equipment (25.2 million USD or 2.7%); 72 Ferrous metals (27.7 million USD or 2.6%); 39 Plastics, polymeric materials and products from them (22.8 million USD or 2.4%).

It can be seen from the above that in the export structure of domestic industrial products to India in 2021, raw materials prevailed, and the share of goods with high added value was insignificant. At the same time, the import structure of Indian industrial goods was dominated by goods with high added value.

Due to the full-scale invasion of the russia, according to the results of 2022, the volume of foreign trade turnover between Ukraine and India is characterized by a downward trend. So, in particular, the volume of foreign trade turnover in 2022 decreased compared to 2021 by 25.5% and amounted to 2,574.7 million USD. At the same time, according to the results of 2022, export volumes decreased by 64.2% compared to 2021 – to 892.7 million USD, while import volumes – on the contrary – increased by 75% – to 1,682.0 million USD. Ukraine's losses in foreign trade with India due to the large-scale invasion of the russia in 2022 amounted to 881.0 million USD. However, if we take into account the positive dynamics observed in recent years, the losses from russian aggression may be even greater.

Compared to Ukraine, India, and PRC, also benefited from the large-scale russian invasion of Ukraine. In particular, the average monthly import of goods from the russia to India during March-September 2022 increased by 430% compared to the corresponding average monthly imports from the russia to India during 2017-2021. At the same time, the average monthly export of goods from India to the russia increased by 19% compared to the average monthly exports of India to the russia during 2017-2021. For comparison, since the beginning of the full-scale invasion of the russia in Ukraine, the USA has reduced the corresponding average monthly exports to the russia by 84%, and import – by 20% [20, pp. 97-98]. Accordingly, in the future, Ukraine's trade policy in terms of concluding free trade agreements or investment agreements should take into account India's trade policy during the war in Ukraine.

Japan is one of the largest and most important trading partners for many WTO members. This country ranks fourth in the world in terms of import and exports volume of goods and services, is a leader in the field of production and innovation, and actively participates in global value chains. The volume of foreign trade turnover between Ukraine and Japan in 2021 was 1,555.0 million USD, which is 68.5% more than in 2017 and 23.7% more than in 2020 (fig. 3).

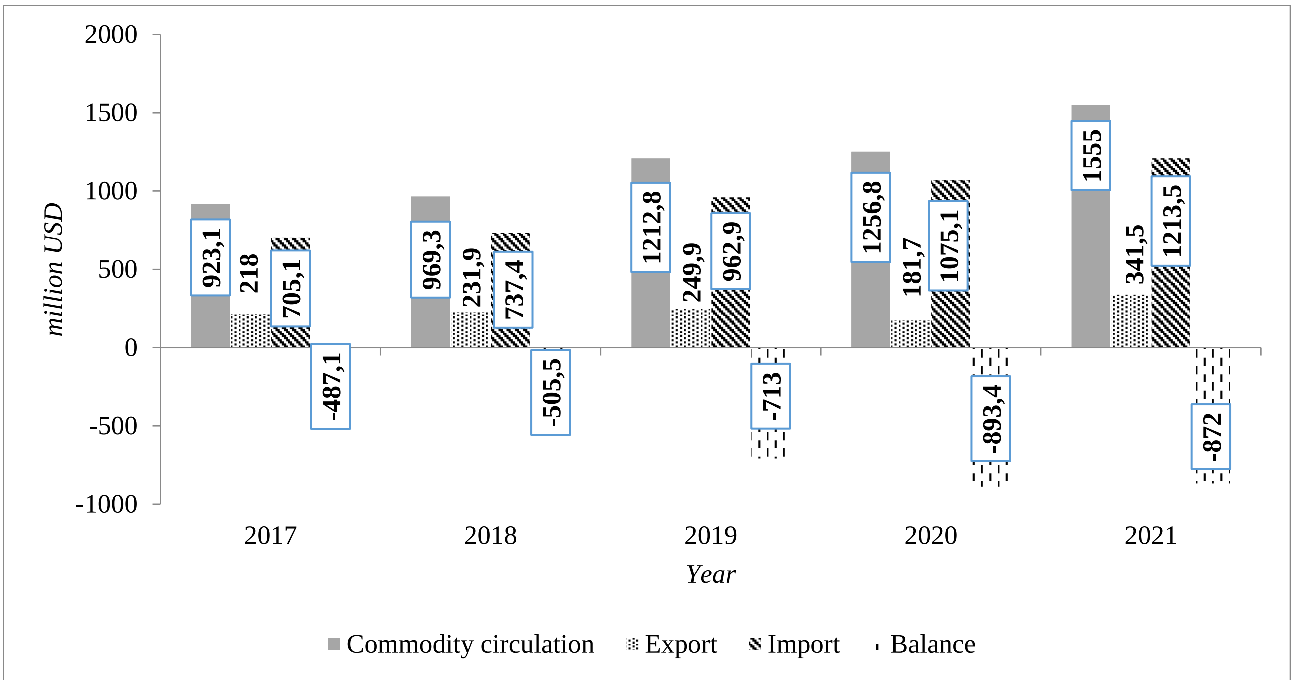

Fig. 3. Dynamics of trade in industrial goods between Ukraine and Japan in 2017–2021, *million USD*

Source: [17]

The volume of exports to Japan in 2021 increased by 56.7% compared to 2017 and by 87.9% compared to 2020. The volume of imports of Japanese goods in 2021 increased by 72.1% compared to 2017, and by 12.9% compared to 2020. During 2017–2021, the balance of the trade balance was negative.

The main groups of industrial goods exported to Japan in 2021 were the following (61.9%): 26 Ore, slag and ash (147.8 million USD or 43.3%); 76 Aluminum and its products (25.5 million

USD or 7.5%); 44 Wood and wood products, charcoal (19.6 million USD or 5.7%); 38 Various chemical products (5.7 million USD or 1.7%); 72 Ferrous metals (4.2 million USD or 1.2%); 81 Other base metals; ceramet; products from them (3.5 million USD or 1.0%); 84 Nuclear reactors, boilers, machines, equipment and mechanical devices; their parts (2.5 million USD or 0.7%); 28 Products of inorganic chemistry; inorganic or organic compounds of precious metals, rare earth metals, radioactive elements and isotopes (2.4 million USD or 0.7%).

In the structure of imports of Japanese industrial goods to Ukraine in 2021. the following product groups prevailed: (92.1%): 87 Means of land transport, except railway or tram rolling stock, their parts and equipment (794.0 million USD or 65.4%); 90 Optical, photographic, cinematographic, control, measuring, precision devices and apparatus; medical or surgical; their parts and accessories (107.4 million USD or 8.8%); 84 Nuclear reactors, boilers, machines, equipment and mechanical devices; their parts (87.0 million USD or 7.2%); 85 Electric machines, equipment and their parts; equipment for recording or reproducing sound, television equipment for recording and reproducing images and sound, their parts and accessories (48.7 million USD or 4.0%); 30 Pharmaceutical products (45.2 million USD or 3.7%); 40 Natural rubber, rubber and products thereof (35.6 million USD or 2.9%).

It can be seen from the above that in the structure of exports of domestic industrial products to Japan in 2021, raw materials prevailed, and the share of goods with high added value was insignificant. At the same time, goods with a high added value prevailed in the structure of imports of Japanese industrial goods.

Due to the full-scale invasion of the russia, according to the results of 2022, the volume of foreign trade turnover between Ukraine and Japan is also characterized by a downward trend. In particular, the volume of foreign trade turnover in 2022 decreased by 52.2% compared to 2021 and amounted to 752.1 million USD. At the same time, according to the results of 2022, export volumes decreased by 69.0% compared to 2021 – to 107.8 million USD, and the volume of imports – by 47.5% – to 644.3 million USD. Ukraine's losses in foreign trade with Japan due to the full-scale invasion of the russia in 2022 amounted to 822.4 million USD.

Conclusions. The article analyzes the main vectors of Ukraine's foreign trade cooperation with the countries of the Asian region and establishes that, in the conditions of the russian-Ukrainian war, these vectors are significantly influenced by political factors and separate bilateral russian-Chinese and russian-Indian foreign trade relations and economic cooperation. It is shown that the main challenges for the domestic trade policy in relations with the PRC and India are a significant increase in the volume of trade of these countries with the russia in 2022 due to the purchase of russian oil and natural gas, which have come under the sanctions of Western countries.

In general, due to the existing structure of industrial production, military operations taking place on the territory of our country, and other economic factors, in the near future, Ukraine will continue to export low-value-added raw materials to **China**, while imports will be dominated by high-value-added goods.

The development of foreign economic cooperation between Ukraine and **India** in the medium term will not have significant changes, which indicates the preservation of the existing foreign trade structure.

Today, it is quite difficult for Ukraine to offer **Japan** products of domestic industry with high added value. At the same time, our country can be integrated into some production chains of Japanese industry thanks to cheap labor, territorial proximity to the huge EU sales market, etc.

However, in order for this process to be complete and irreversible, a necessary and mandatory condition is primarily the victory of Ukraine in the war with russia, the implementation of relevant reforms, to create comfortable conditions for potential investors in the post-war period.

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ENVIRONMENTAL COMPONENT OF SUSTAINABLE DEVELOPMENT

BOTTOM SEDIMENTS OF THE RESERVOIRS IN THE LOWER REACHES OF THE SOUTHERN BUG RIVER AS A DEPOT OF ANTHROPOGENIC RADIONUCLIDES

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Abstract.*The article presents the materials of radioecological studies of the authors on the accumulation capacity of bottom sediments in relation to radioactive substances entering the Southern Bug River during discharges from the South Ukrainian NPP. The aim of the study was to investigate the properties of bottom sediments in the channel reservoirs of the lower reaches of the Southern Bug River (Tashlyk and Oleksandrivske reservoirs) in terms of radionuclides retention.*

The article analyses the content of radionuclides in water and bottom sediments of the Tashlyk and Oleksandrivske reservoirs. The coefficients of accumulation of radionuclides in the bottom sediments of these reservoirs were calculated. Differences between the Tashlyk and Oleksandrivske reservoirs were found in a number of hydrochemical parameters: temperature, hydrogen, alkalinity, dry residue, and dissolved oxygen. It is shown that these differences between the hydrochemical differences of the Tashlyk and Oleksandrivske reservoirs determine significantly lower coefficients of radionuclide accumulation in the bottom sediments of the Tashlyk reservoir. The presence of an inverse linear relationship between water salinity and the values of ^{137}Cs *and* ^{134}Cs *accumulation coefficients in the sediments of the Tashlyk and Oleksandrivske reservoirs was established, and a regression equation was determined that allows estimating the accumulation coefficient of cesium radioisotopes in sediments depending on water salinity.*

Introduction. Monitoring of bottom sediments plays a crucial role in assessing the ecological state of water bodies in general and adjacent areas, as the average composition of bottom sediments can reflect the composition of the humus soil horizon of the water body basin. Therefore, most studies on radioecological monitoring of water bodies are devoted to bottom sediments [2-4]. Water bodies are constantly undergoing metabolic processes that make up a single exchange system, which includes water and bottom sediments. Bottom sediments, which are a direct source of accumulation, play an important role in the formation of a qualitative assessment of water and coastal areas, as well as the content of toxic substances in it. Changes in the physical, chemical and other conditions of the aquatic environment can lead to an imbalance in the sediment-water system, which can cause secondary pollution of the water body, even in the absence of sources of pollutants from the outside [1]. This demonstrates the relevance of conducting monitoring studies of both industrially loaded and conditionally clean water bodies. In this context, a special role should be given to the study of bottom sediments of surface water bodies in the lower reaches of the Pivdennyi Buh River and their ability to accumulate and retain radioactive substances entering the Pivdennyi Buh River during discharges from the South Ukrainian NPP. The aim of the study was to investigate the properties of bottom sediments of the channel reservoirs in the lower Pivdennyi Buh River (Tashlyk and Oleksandrivske reservoirs) in terms of radionuclide retention.

Materials. The study materials were the official materials of the Energoatom Company on radionuclide discharges from SUNPP (1982-2020) [5], the results of radioecological researches by the authors. The Tashlyk and Oleksandrivske reservoirs belong to the South Ukrainian Energy Complex. The Tashlyk Reservoir is intended to serve as a cooler for water coming from the NPP. After the Tashlyk Reservoir, the water enters the Oleksandrivske Reservoir, which in turn is connected to the Southern Bug River.

Results and Discussion. The content of radionuclides in the water of the reservoirs in the period from 1991 to 2017 is shown in Tables 1, 2.

Table 1.

Radionuclide concentrations in water, Bq/l

Reservoir	Radionuclide	2013 year	2014 year	2017 year	2021 year
Tashlyk Reservoir	^{3}H	1,66E+02	1,61E+02	1,66E+02	1,66E+02
	^{90}Sr	4,30E-02	3,54E-02	4,30E-02	4,30E-02
	^{134}Cs	9,05E-03	9,05E-03	9,05E-03	9,05E-03
	^{137}Cs	1,14E-02	1,16E-02	1,14E-02	1,14E-02
Oleksandrivske Reservoir	^{3}H	1,40E+01	1,53E+01	1,40E+01	1,40E+01
	^{90}Sr	2,42E-02	2,59E-02	2,42E-02	2,42E-02
	^{134}Cs	6,90E-03	7,51E-03	6,90E-03	6,90E-03
	^{137}Cs	9,30E-03	9,80E-03	9,30E-03	9,30E-03

Table 2.

Maximum concentrations of radionuclides in water (C^{i}) of water bodies for the period 1991-2020, Bq/l

Reservoir	^{137}Cs	^{134}Cs	^{90}Sr	^{54}Mn	^{108m}Ag	^{110m}Ag	$^{103,106}Ru$	^{57}Co	^{60}Co	^{3}H
Tashlyk Reservoir	0,20	0,10	0,10	0,05	1,12	0,8	0,1	0,09	0,15	270
Oleksandrivske Reservoir	0,09	0,10	0,10	–	–	–	–	–	–	60

The content of radionuclides in the bottom sediments of the reservoirs is shown in Table 3.

Table 3.

Radionuclides content in sediments, Bq/kg

Reservoir	^{90}Sr		^{137}Cs		^{134}Cs		^{60}Co		^{54}Mn	
	2017 year	2021 year	2017 year	2021 year	2017 year	2021 year	2017 year	2021 year	2017 year	2021 year
Tashlyk Reservoir	2,90	3,62	5,39	4,8	0,90	0,29	0,51	0,65	0,39	0,42
Oleksandrivske Reservoir	4,18	4,19	1,07	0,65	0,75	0,62	0,52	0,44	0,37	0,74

The tables show that the content of radionuclides in the sediments has changed. Based on the data from the previous tables, the accumulation coefficients of radionuclides in sediments were calculated and presented in Tables 4 and 5.

Table 4.

Accumulation coefficients of radionuclides by sediments $k^{i}_{bottom}, \frac{Bk/kg}{Bk/l}$

Reservoir	2013 year		2014 year		2017 year		2021 year	
	^{137}Cs	^{134}Cs	^{137}Cs	^{134}Cs	^{137}Cs	^{134}Cs	^{137}Cs	^{134}Cs
Tashlyk Reservoir	38	33	40	32	44	30	50	28
Oleksandrivske Reservoir	94	51	77	56	82	68	82	59

Based on the data of Tables 2 and 3, the accumulation coefficients of radionuclides by sediments were calculated and presented in Table 5.

Table 5.

Accumulation coefficients of radionuclides by sediments k^{i}_{bottom} , $\frac{Bk/kg}{Bk/l}$

Reservoir	^{90}Sr	^{54}Mn	^{108m}Ag, ^{110m}Ag	^{103}Ru, ^{106}Ru	^{57}Co, ^{60}Co
Tashlyk Reservoir	150	250	580	430	420
Oleksandrivske Reservoir	120	320	600	420	400
Average value by reservoirs	135±35	270±50	590±20	425±10	410 ±10

Figure 1 shows a graphical comparison of the chemical composition of the Tashlyk and Oleksandrivske reservoirs. There is a difference between the Tashlyk and Oleksandrivske reservoirs in terms of a number of hydrochemical parameters. As can be seen, the Tashlyk Reservoir, in particular due to its higher water temperature (average value of 12.1 ± 2.2 ^{0}C) compared to the temperature regime of the Oleksandrivske Reservoir (average value of 7.8 ± 1.1 ^{0}C), is characterised by higher pH and alkalinity values throughout the year:

– for the Tashlyk Reservoir, the hydrogen pH varied from 8.4 to 9.2 units, and for the Oleksandrivske Reservoir, the pH varied from 8.3 to 8.4 units, the difference was 10%;

– for the Tashlyk Reservoir, the alkalinity was in the range of 20-25 mg-eq/l, and for the Oleksandrivske Reservoir, the alkalinity was in the range of 5.2-5.7 mg-eq/l, the difference was up to 5 times.

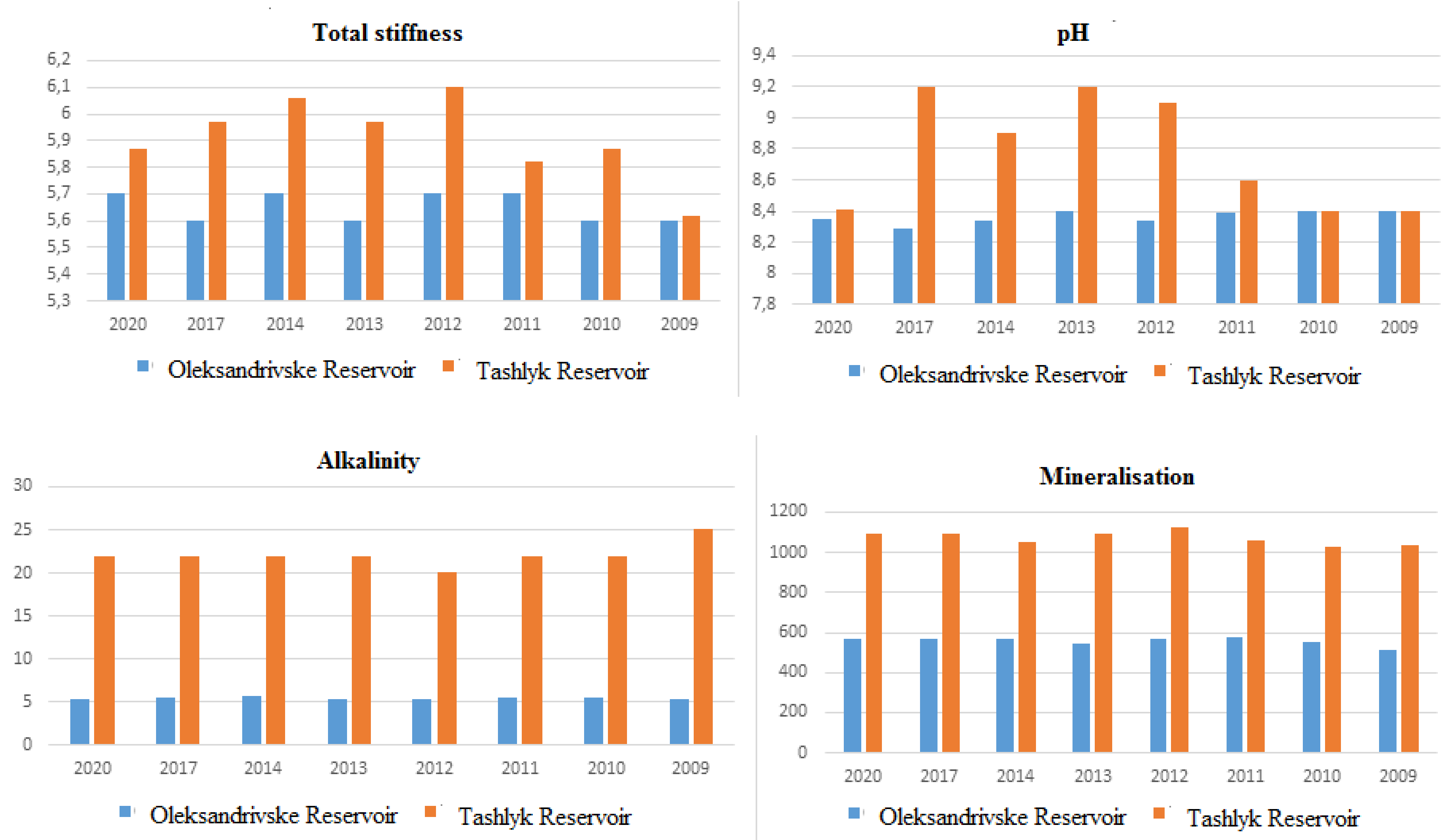

Fig. 1. Comparative analysis of hydrochemical parameters of Tashlyk and Oleksandrivske reservoirs

There is also a significant difference between the values of total hardness and dry residue for these reservoirs. Thus, for the Oleksandrivske reservoir, the dry residue of water samples averaged 572±12 mg/l, while for the Tashlyk reservoir it was 1100±57 mg/l. As you know, dry residual water is an indicator that characterises the amount of dissolved substances, primarily mineral salts, in 1 litre of water. This parameter determines the total amount of mineral inorganic salts of calcium, magnesium, potassium, sodium, heavy metals dissolved in water, as well as a large percentage of organic substances. This parameter is used primarily to determine the overall mineralisation of water. In other words, the waters of the Tashlyk Reservoir are highly mineralised. This usually prevents the accumulation of toxicants, including radioactive ones, by the biota of the reservoir ecosystem, and thus will prevent the deposition of these toxicants by the reservoir sediments.

This explains the lower values of ^{137}Cs and ^{134}Cs accumulation coefficients in the bottom sediments of the Tashlyk Reservoir compared to the corresponding values of the Oleksandrivka Reservoir (see Tables 4, 5).

The relationship between water salinity (dry residue) and the values of ^{137}Cs and ^{134}Cs accumulation coefficients in the bottom sediments of the Tashlyk and Oleksandrivske reservoirs was analyzed (Fig. 2). The results showed a linear relationship (r = 0.98), and the regression equation with a determination coefficient R^2 = 0.92, is as follows:

$$\mathrm{k}_{\mathrm{bottom}}^{\mathrm{Cs}} = -10{,}179C + 101{,}43$$

$\mathrm{k}_{\mathrm{bottom}}^{\mathrm{Cs}}$ – is the coefficient of cesium radioisotopes accumulation by bottom sediments; C is the dry water residue, mg/l.

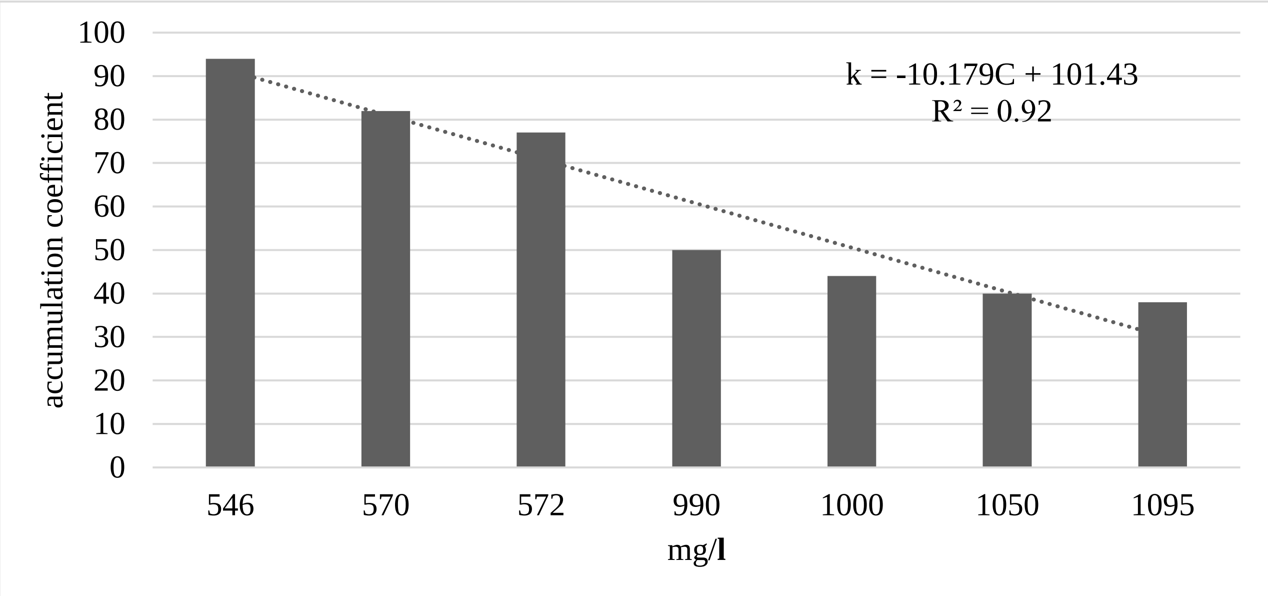

Fig. 2. Relationship between water salinity (dry residual) and ^{137}Cs and ^{134}Cs accumulation coefficients in the bottom sediments of the Tashlyk and Oleksandrivske reservoirs

The presence of dissolved oxygen in water is an important factor that significantly affects the processes of water quality formation and the state of aquatic ecosystems. Determining the oxygen regime of surface waters is an important component of assessing the state of aquatic ecosystems and catchment areas. The concentration of dissolved oxygen in water is one of the main integral indicators that characterize the quality of surface water as one of the most valuable natural resources. The participation of oxygen in the processes of biological, chemical, physical and mechanical self-purification of water bodies indicates that the assessment of dissolved oxygen concentration is of great practical and general scientific importance. Oxygen plays an important role not only in maintaining existing life forms in various water bodies, but also in the transformation of substances that enter surface waters with wastewater from urbanized and industrial areas, as well as with runoff from agricultural and livestock complexes. In recent years, due to increased anthropogenic pressure, the oxygen regime of many rivers, reservoirs, canals and lakes in Ukraine has become increasingly stressed, with the frequency and duration of frost events increasing, and a significant amount of dissolved oxygen being consumed by the decomposition (destruction) of easily oxidized organic substances. The concentration of dissolved oxygen in water is one of the most important hydrochemical parameters that determines the intensity of redox biochemical processes in water bodies. Therefore, the oxygen regime and the oxygen content in water and its dynamics are often taken as an integral indicator of the state of aquatic ecosystems and water quality in them.

For these reservoirs, there is also a difference between the dissolved oxygen in the water of the reservoirs (Fig. 3). In our opinion, this also affects the processes of accumulation and retention of radionuclides by the bottom sediments of the reservoirs, which also justifies lower values of these coefficients for the Tashlyk Reservoir compared to the Oleksandrivske Reservoir.

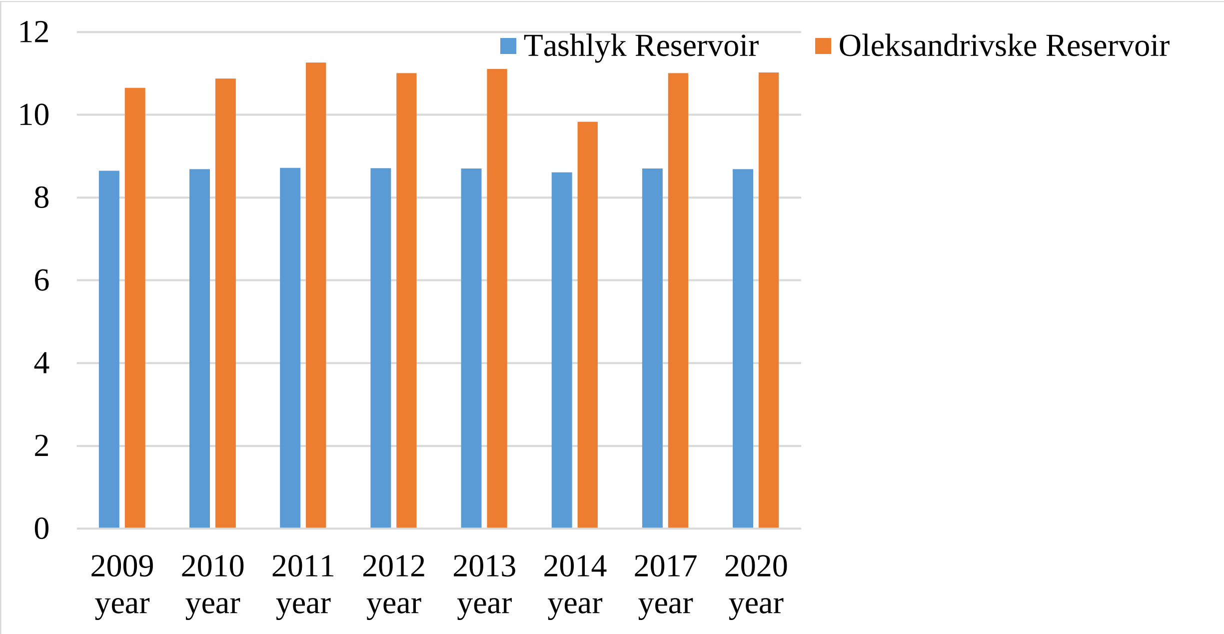

Fig. 3. Difference between the level of dissolved oxygen in the water of Tashlyk and Oleksandrivske reservoirs

Conclusions. The accumulation coefficients of ^{137}Cs (38±5 $\frac{Bk/kg}{Bk/l}$), ^{134}Cs (36±8 $\frac{Bk/kg}{Bk/l}$) are 2.5 times lower than the corresponding accumulation coefficients for the Oleksandrivka Reservoir (78±5 $\frac{Bk/kg}{Bk/l}$, 72±7 $\frac{Bk/kg}{Bk/l}$ for ^{137}Cs and ^{134}Cs, respectively). This may indicate a gradual loss of the accumulation capacity of sediments to retain radiocaesium.

The difference between the Tashlyk and Oleksandrivske reservoirs was established by a number of hydrochemical parameters:

−by temperature: the Tashlyk Reservoir is characterised by a higher average annual water temperature (12.1 ± 2.2 ^{0}C) compared to the temperature regime of the Oleksandrivske Reservoir (7.8 ± 1.1 ^{0}C);

− in terms of hydrogen pH: for the Tashlyk reservoir, the pH level (8.3-8.4 units) is 10% lower than for the Oleksandrivske reservoir (8.4-9.2 units);

−in terms of alkalinity: for the Tashlyk reservoir, the alkalinity is 5 times higher (20-25 mg-eq/l) than for the Oleksandrivske reservoir (5.2-5.7 mg-eq/l),

−on the dry residue (total mineralisation) of water: for the Tashlyk Reservoir, the dry residue (1100±57 mg/l) is 2 times higher than for the Oleksandrivske Reservoir (572±12 mg/l);

−for dissolved oxygen in the water of the reservoirs: in the Tashlyk reservoir, this indicator is 10-20% lower than in the Oleksandrivske reservoir.

These differences between the hydrochemical differences between the Tashlyk and Oleksandrivske reservoirs determine significantly lower coefficients of radionuclide accumulation by the bottom sediments of the Tashlyk reservoir. Thus, in particular, the presence of an inverse linear relationship (r=-0.98) between water salinity (dry residual) and the values of ^{137}Cs and ^{134}Cs accumulation coefficients in the sediments of the Tashlyk and Oleksandrivske reservoirs was established, and a regression equation (R^2=0.92) was determined that allows estimating the coefficient of accumulation of cesium radioisotopes in sediments depending on water salinity.

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IMPLEMENTATION OF THE EU DIRECTIVE 2002/49 IN UKRAINIAN LEGISLATION: EXPERIENCE IN THE CIVIL AVIATION SECTOR

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Abstract. *The prospective of the EU Directive 2002/49 implementation in Ukrainian legislation has been considered. The paper demonstrates the practical aspects of implementing specific provisions of the Directive 2002/49 using the example of civil aviation in Ukraine and analyses the gaps and inconsistencies in current legislative and regulatory acts. The main areas of Directive application and its advantages have been analysed. At this stage of Eurointegration in Ukraine, there is a need to implement a national-level legislative act that aligns with EU Directive 2002/49. Such a legislative act should create the political preconditions for managing major noise sources and harmonizing EU requirements in the field of noise management with those of Ukrainian legislation. The use of a unified methodology and harmonized criteria for noise assessment will allow stakeholders to gain correct information for objective analysis of different noise sources and their impact on human health. This approach facilitates the effective comparison of various modes of transportation and the identification of priority measures to reduce noise and its negative effects on the population. Furthermore, the development of noise action plans enables the implementation of specific measures for noise regulation and the promotion of policies aimed at improving the quality of life for citizens by reducing noise pollution.*

Introduction. The European Environment Agency (EEA) reports (EEA, 2020) that over 100 million European residents suffer from the negative impact of noise, which has harmful consequences for health. It is found that 20% of the EU population resides in areas where noise levels are deemed detrimental to health. This includes over 22 million individuals who fall into the high-annoyance group, 6.5 million people experiencing significant sleep disturbance, more than 48,000 people afflicted with heart disease, and over 12,000 cases of premature mortality. Additionally, it is estimated that there could be more than 12,500 cases of cognitive impairment in children as a potential consequence of noise exposure each year. Thus, noise has become one of Europe's major environmental problems, and in order to improve overall health and protect the environment, EU Directive 2002/49 relating to the assessment and management of environmental noise was introduced to manage noise from the main sources: road traffic noise, railway noise, industrial noise, and aircraft noise (EP&CEU, 2002). The document proposes a unified methodology and harmonized assessment criteria are introduced for these noise sources.

Since Directive 2002/49 includes recommendations for assessing the effectiveness of noise reduction measures every 5 years, many EU countries have already gone through several cycles of implementing the Directive (EP&CEU, 2002). Therefore, at this stage, it is possible to evaluate its achievements and shortcomings, as well as examine how associated EU member countries have adapted to the requirements of this document. In 2021, the Agreement on the Common Aviation Area was ratified in Ukraine, marking the first time among international Eurointegration commitments that the implementation of Directive 2002/49 was included. Indeed, noise management issues should not be limited to the aviation industry alone. However, considering that the aviation sector is often at the forefront of innovation, it is logical to use the implementation of noise reduction measures as a case study for other industries.

Materials and methods. To identify gaps in Ukrainian and European legislation in the field of aviation noise management, an analysis was conducted on key documents from the EU and Ukraine of various levels and subordination, which describe the processes of identification, assessment (modeling, measurement, prediction), and the development of measures to reduce aviation noise. In particular, the main functions of noise management, as defined by EU Directive 49/2002, have been studied. Additionally, Ukrainian legislative and regulatory acts were analyzed, taking into account the context of the current stage of civil aviation development and the influence of current crisis phenomena in society on the perception of aviation noise.

The functions of the EU Directive 2002/49. The EU Directive 2002/49 serves as a framework for the assessment and management of environmental noise in European Union member states. The directive has two main objectives [2]: development of entire approach to prevent the deterioration of the population's health and to provide a basis for the development of measures to reduce noise from major noise sources (EP&CEU, 2002). One of the specific tasks of EU Directive 2002/49 is to collect high-quality data on noise levels from major anthropogenic sources by implementing a unified methodology and harmonized noise assessment criteria. This data is further analyzed to apply best practices for noise reduction, compare different noise sources, their operating conditions, and the effectiveness of implemented measures. The directive covers various sources of noise, including road traffic, railway, industrial, and aviation noise. Other types of noise such as agricultural, military, biogenic, and domestic noise are either considered negligible due to insignificant exposure or included in one of the four specified categories (EP&CEU, 2002). The main sources have been defined as those that 1) affect the largest number of people and 2) generate the highest sound levels.

The implementation results of the Directive should be presented in the following stages (EP&CEU, 2002):

1. Determination of Noise Exposure: This involves conducting noise mapping to assess noise exposure levels. It helps identify areas where noise levels exceed the established thresholds and determine the population affected by noise pollution.
2. Dissemination of Information: The collected information and results of noise mapping should be effectively communicated to the public and stakeholders. This ensures transparency and awareness regarding noise levels and their potential impact on health and the environment.
3. Adoption and Implementation of Action Plans: Based on the findings of noise mapping, action plans should be developed and implemented. These plans should be grounded in the results of noise mapping and aim to reduce the harmful effects of noise on human health and the environment. They may include measures such as noise mitigation strategies, infrastructure modifications, and land-use planning adjustments.

Overall, the Directive aims to establish a framework for developing a comprehensive approach among communities to reduce noise from major sources. It emphasizes the importance of data-driven decision-making, effective communication, and the implementation of action plans to mitigate the adverse effects of noise on human well-being and the surroundings.

Main sources	Noise mapping (requirements of Directive 2002/49)	Basic mapping unit	Results on the portal "The NOISE Observation & Information Service for Europe"
Noise of agglomerations/ industrial noise	-/+	Agglomeration (urbanized territory with a population > 100,000 and high population density)	-/+
Noise from road traffic	+	Main road (>3 million vehicles annually)	+
Railway noise	+	Main railway (>30,000 trains per year)	+
Aviation noise	+	Main airport (> 50,000 operations per year)	+
Main sources	Noise mapping (requirements of Directive 2002/49)	Main sources	Noise mapping (requirements of Directive 2002/49)
Noise from military activities (like training flights)	-	*Biogenic noise*	-
Residential noise	-	*Agricultural noise*	-

Fig. 1. The main sources of environmental noise are coverage EU Directive 2002/49

The key stages for the successful implementation of Directive 2002/42 provisions are as follows (fig. 2) (EP&CEU, 2002):

1. Determining noise exposure boundaries (mapping): This involves identifying and defining the areas affected by noise pollution.
2. Informing and involving the public in the consultation process: This stage aims to engage the community and gather their input and feedback on the noise-related issues.
3. Developing and implementing noise action plans: Based on the findings from the mapping and public consultation, noise action plans are formulated and implemented to address and mitigate the identified noise issues.

An important feature of this algorithm is the ability to review the achieved results every five years (Fig. 2) based on the following criteria: the area covered by noise contours, the number of affected populations, and the cost of implemented measures. The effectiveness of the proposed approach in the European region, combined with the balanced approach of ICAO to aviation noise management, demonstrates the progress that has been achieved, albeit against the backdrop of the COVID-19 pandemic, in reducing aviation noise exposure according to the EASA Report (EASA, 2020). In particular, it is forecasted that the pollution levels of 2019 will not be reached in the next few decades (fig. 3)

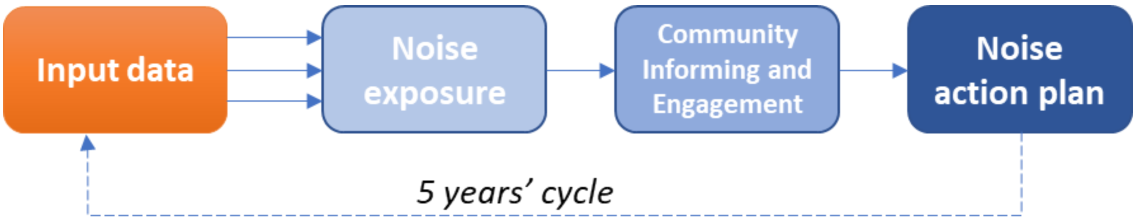

Fig. 2. The Directive 2002/49 cycle and key stages

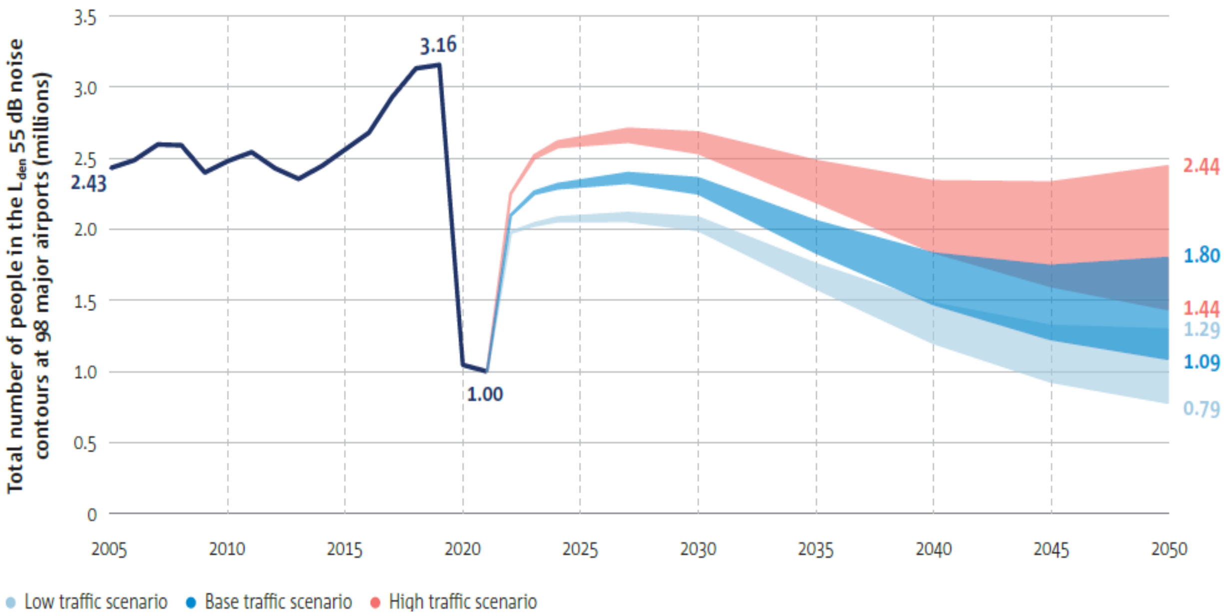

Fig. 3. Aviation noise exposure: forecast after COVID-19 outbreak (EASA, 2020)

On the other hand, the problem of annoyance caused by environmental noise will not decrease proportionally to the reduction in noise exposure due to a number of non-acoustic factors that can significantly influence the level of local population annoyance. Such factors include: characteristics of the sound event, level of engagement of the local population in understanding the issue of acoustic pollution and existing management mechanisms, daily migration processes, and the presence of other environmental stressors, urban planning and design, socio-economic factors, and individual sensitivities to noise. All these factors contribute to the overall annoyance and impact of noise pollution on the local population. In particular, the results of observations on the number of complaints during the pandemic restrictions revealed cases of increased annoyance among the population due to urban noise, including aviation noise, despite a significant reduction in the number of take-off and landing operations. These observations emphasize the need for a comprehensive understanding of noise management strategies that go beyond mere reduction in exposure levels.

For example, during the COVID-19 lockdown in Spring 2020, many cities, including Greater London in the UK, experienced significant changes in daily routines and behaviors due to restrictions on movement and social distancing measures (Tong, H at al., 2021). These changes likely had an impact on noise complaints and patterns (Fig. 4). The results (Tong, H at al., 2021) show that during the COVID-19 lockdown the number of noise complaints increased by 48%, compared with the same period during Spring 2019. In this way, such studies only confirm non-acoustic factors and the necessity to consider not only noise exposure but also the importance of involving the local population in the development of noise action plans.

Implementation of Aviation Rules of Ukraine № 381 and the initial results. In Ukraine, the issue of environmental pollution from airports was not regulated at the state level until 2019. This included the absence of any approved guidelines or aviation rules that would regulate the assessment of the noise impact from airports on the population residing in adjacent areas, as well as practical recommendations regarding the mutual development of airports and local communities. On the other hand, due to significant gaps in national environmental legislation, the information provided to the public about the environmental problems of airports was also at a relatively low level. Airport websites or official aviation authority websites did not contain the results of zoning the areas surrounding airports based on noise impact, emissions, electromagnetic radiation, and third-party risk, which had been carried out by experts from the Airport Environmental Problems Center/ National Aviation University since 2009.

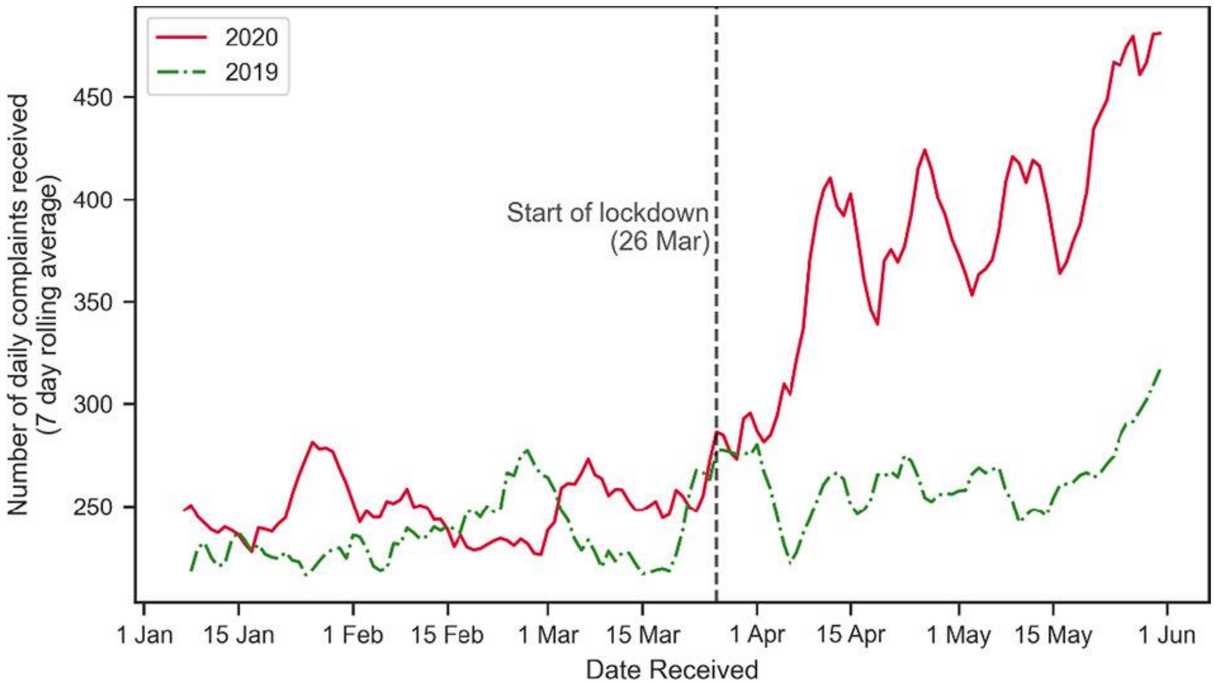

Fig. 4. Results of research in London on changes in noise perception during pandemic restrictions (Tong, H et al., 2021)

Against the backdrop of Eurointegration processes, the State Aviation Service of Ukraine introduced the Aviation Rules of Ukraine № 381 (ARU № 381) in 2019 (ДАСУ, 2019). The implementation of these rules aimed to establish clear requirements for airport operators regarding the conditions and zoning regulations of aerodrome areas based on the impact of aviation noise. It also includes requirements for the quality of input data, the necessity of conducting field measurements, and the publication of data on restricted residential development zones around airports. The publication of ARU No. 381 raised several clarifying questions among airport operators. In order to strengthen and clarify specific provisions, Guidelines for Spatial Zoning of the Area Surrounding the Airport based on the Impact of Aviation Noise (Order of the State Aviation Service of Ukraine № 585, dated April 23, 2020) were developed (ДАСУ, 2020). Therefore, these two documents, despite their different levels, are desirable to be considered together as a comprehensive approach. The new ARU № 381 and MR № 585 establish requirements for creating noise maps in the vicinity of airports. Similar types of regulatory and legislative acts in the field of protecting the population from the harmful effects of noise from other sources (such as road traffic noise, railway noise, industrial noise) are currently absent in Ukraine. However, the existence of restricted development zones (sanitary protection zones) is required by state sanitary and building norms, including State Sanitary Rules № 173.

In 2021, the State Aviation Service of Ukraine (SASU), with the support of the "Consultative Fund to Support the Ukraine-EU Association" and GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit), launched the NOMOS project (Noise Monitoring System, https://nomos.avia.gov.ua/) – Fig.3.

This project essentially serves as an equivalent to the European resource called The NOISE Observation & Information Service for Europe (https://noise.eea.europa.eu). However, a detailed analysis of ARU № 381 and MR № 585 revealed significant fundamental differences from the European approach defined within Directive 2002/49.

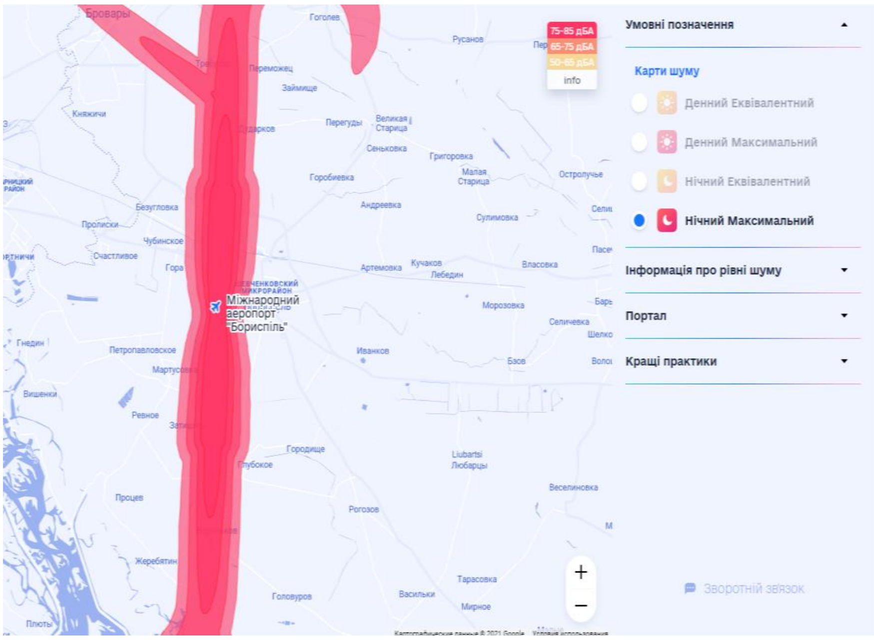

Fig. 5. Example of noise data from NOMOS portal: noise zones and major airport vicinity

Results and Discussion. Although ARU № 381 was developed and approved with the aim of implementing EU Directive 2002/49/EC of the European Parliament and the Council dated June 25, 2002, ARU №. 381 and MR № 585, which complement it, are neither a translation of the Directive nor an improved version of it.

Ukrainian Aviation Regulations №381, implemented by the State Aviation Service of Ukraine in 2019, play a vital role in regulating environmental issues at airports. These regulations aim to ensure flight safety and protect the environment, including mitigating noise pollution. The implementation of ARU № 381 is an important step for Ukraine in aligning with European standards and requirements for environmental protection in the aviation industry. It will contribute to reducing noise impact on the population and improving the ecological situation around airports.

However, alongside these achievements, it is important to note a different logic in the construction of the key stages of aviation noise management compared to the recommendations of Directive 2002/49 (Figure 3). In particular, the analysis of Ukrainian regulatory acts issued by the State Aviation Service has allowed for the development of an algorithm for noise management in airport vicinity, as presented in Fig. 4. As shown, important stages such as community engagement and document development are beyond the requirements of these regulations. There are also no clearly defined obligations to assess the impact of implemented measures once every five years, leaving only the function of a 5-year control that does not conclude with any auditing or verification upon the completion of the 5-year cycle.

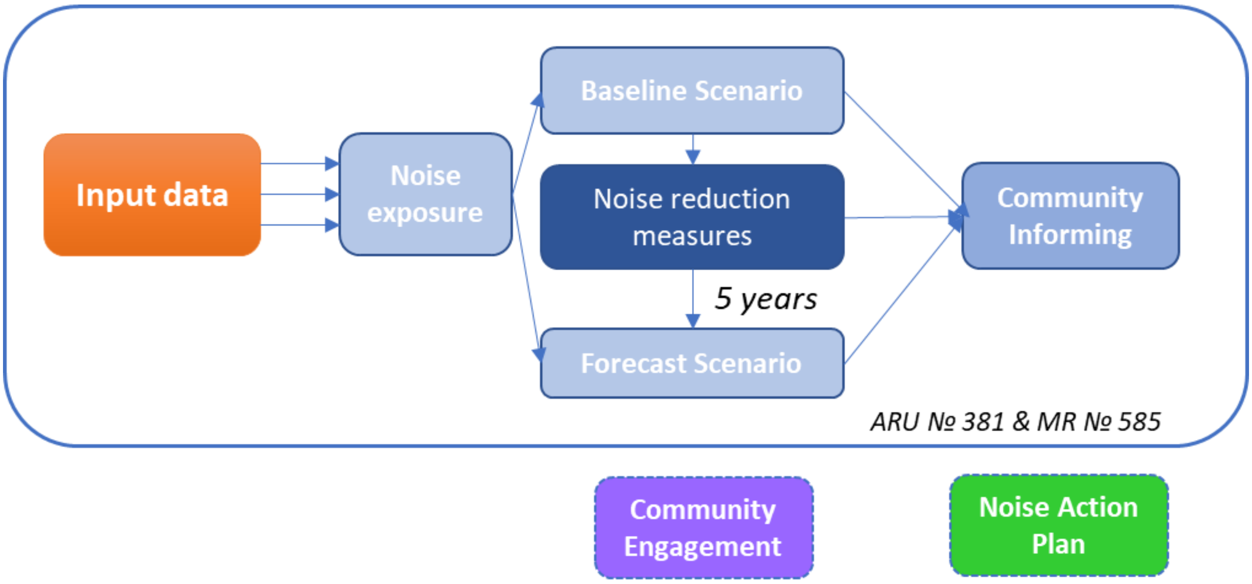

Fig. 4. The ARU № 381 cycle and key stages

A comparative analysis of EU Directive 2002/49/EC and ARU № 381 reveals several differences, with the main one being the level of implementation of these documents (Table 1), although there are also certain conceptual inconsistencies. In particular, ARU № 381 and MR №585 establish zoning requirements for the surrounding areas of all civil aviation airports in Ukraine, regardless of the volume of aviation transport, unlike Directive 2002/49/EC, which focuses on large noise sources - major airports with over 50,000 operations (take-offs and landings) per year (excluding training flights and light aircraft operations). The absence of a minimum number of operations requirement in ARU № 381 makes it challenging to determine noise levels according to the Lden criterion as defined in EU Directive 2002/49/EC.

Additionally, compliance with these regulations will help establish Ukraine's reputation as a responsible participant in the international aviation community and safeguard the health of the population residing near airports. The development and implementation of action plans to reduce aviation noise, as outlined in aviation regulations, are also crucial steps. In EU countries, Directive 2002/49 defines two key indicators, annoyance and sleep disturbance, which, when exceeded, require the formulation of action plans to reduce exposure and protect noise-free areas. ARU contains stricter provisions regarding field acoustic measurements and recommendations for implementing a noise monitoring system.

Table 1

Compliance of ARU No. 381 (including Amendment No. 585) with the requirements of Directive 2002/49

The parameter of compliance	ARU № 381 [3]	MR № 585 [4]	EC Directive 2002/49 [2]
The level of the document.	Industry regulations.	Industry regulations and methodological recommendation	Pan-European
Scale	Any civil aviation airport of Ukraine		The main airport (serving over 50,000 operations per year) City airport
Noise criteria	*LAmax, LAeq, Lden*		*Lden, Lnight*
Time periods	Day: 07:00-23:00 Night: 23:00-07:00	Day: 08:00-22:00 Night: 22:00-08:00	Day: 07:00-19:00 Evening: 19:00 - 23:00 Night: 23:00- 07:00
Normative values of assessment criteria	According to the current National Standards or Building Codes, the values are not specified in the analyzed documents.		The noise levels for zoning are defined in the Appendix to the Directive
The primary method of obtaining data	Modeling and field acoustic measurements		Modeling
The necessity of validating modeling with field acoustic measurements.	+	+	-
Noise monitoring demands	The decision regarding the necessity of installing a noise monitoring system rest with the aerodrome operator		-
The system for informing the population	Noise Monitoring System		The NOISE Observation & Information Service for Europe
Web-site	https://nomos.avia.gov.ua/		https://noise.eea.europa.eu
Development of noise action plan	The development of recommendations regarding the necessity of implementation is required.		The development of an action plan is required.

Conclusions. At this stage in Ukraine, it is necessary to implement a national-level legislative act that would serve as an equivalent to the EU Directive 2002/49. Such a legislative act should create the political groundwork for managing major noise sources and harmonize EU noise management requirements with Ukrainian legislation. Additionally, there is a need to align the requirements of Ukrainian Aviation Regulations № 381 and the corresponding methodological recommendations

(MR № 585) with the current national requirements in the core part of the aviation noise impact assessment methodology. This requires a clear definition of the role of criteria for assessing aviation noise and the duration of research intervals.

Overall, the implementation of the main provisions of the Directive has contributed to raising public awareness about noise pollution issues and the development of strategic action plans. It has also enabled the comparative assessment of different modes of transport based on noise impact criteria, as demonstrated in studies such as the EEA's "Transport and environment report 2020. Train or plane?" (EEA, 2020).

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THE IMPACT OF A FULL-SCALE WAR ON THE BLACK SEA ECOSYSTEMS OF UKRAINE AND THE ENTIRE SEA IN GENERAL

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Abstract. *The Russian full-scale invasion of Ukraine in February 2022 and the ongoing Russian-Ukrainian war have a significant impact on the Black Sea ecosystems, especially on their biotic component. About 87 % volume of the Black Sea are heavily anoxic. The northwestern part of the sea has the best conditions for the development of biota. This water area is well warmed by the sun's rays in the warm period of the year and rivers saturate seawater with dissolved oxygen and nutrients. This part of the sea is of decisive importance for the biota of the entire Black Sea. The impact of war on marine ecosystems is divided into two types: (i) the direct impact of the war – on the biota of the sea; (ii) the indirect impact of the war – on the ecosystems of the Black Sea. As direct impacts in this article are considered the effects of weapons, ammunition explosions (the shock waves, the sound of explosions), the use of powerful sonars – primarily on marine mammals (dolphins and porpoises – probably up to 50 000 cetaceans have already died). The consequences of oil spills due to the flooding and damage of warships and other military equipment, water pollution by toxic components of ammunition (heavy metals, polychlorinated biphenyls etc.), pathogens (as a bacteriological weapon or due to damage to the city sewer or an agricultural complexes), and possible radioactive contamination are considered as indirect impacts. The possibilities of spreading the indirect consequences of the war to non-Black Sea – Mediterranean – ecosystems are highlighted.*

Introduction. The Black Sea is a marginal mediterranean sea of the Atlantic Ocean between Europe and Asia – the water border between Southern Europe and Asia Minor passes along it. It is bounded by Ukraine, Bulgaria, Romania, Turkey, Georgia and Russia. About 16 million people inhabit the coastal area (Black Sea Scene, 2023).

The Black Sea covers 422 000 km^2. Its length (the greatest distance from west to east) is 1 175 *km*, and its width (the greatest distance from north to south) is 580 *km*. The Black Sea has a maximum depth of 2 245 *m*, a volume of 547 000 km^3, a water salinity of 17-18 ‰ (it is the lowest in the northwest – about 13 ‰); the composition of salts is identical to that in the oceans (Black Sea, 2001). It drains into the Mediterranean Sea: the Bosporus Strait – a 31-kilometer belt with a minimum width of 704 *m*, the depth varies from 12,8 to 110,0 *m* (Güngör, 1999) – connects it to the Sea of Marmara which is connected to the Aegean Sea (north-eastern embayment of the Mediterranean Sea) via the Strait of the Dardanelles. The Kerch Strait in the north provides the connection with the Sea of Azov – the shallowest sea on the planet (Troianovski, 2018).

The Black Sea is a unique macroecosystem in the world. It is an almost fully enclosed basin, with only a limited water exchange with the Mediterranean Sea through a counter-current straits system wherein lighter, less saline water flows in a surface current from the Black Sea into the Aegean Sea; while a counter-current of denser, saltier water flows underneath that layer, towards the Black Sea (Ulman et al., 2015).

The marked density difference between the two layers inhibits mixing, leaving only depths shallower than about 150-200 *m* capable of supporting multicellular life. Indeed, the deeper waters – about 87 % volume of the Black Sea – are heavily anoxic, causing the Black Sea to be the largest anoxic body of water in the world with its unique hydrological characteristics (Black Sea Scene, 2023).

In the entire Black Sea at a depth greater than 150-200 *m* there is a permanent *hydrogen sulphide* (H_2S) zone devoid of life. Oxygen is completely absent at this deepwater level. Oxygenated surface waters supporting life in the sea constitute only about 13 % of the sea volume. These features influence the condition of the marine environment and the biodiversity depending on it. They are the key to the character and the problems of the Black Sea's environmental health (Black Sea Scene, 2023).

The northwestern part of the Black Sea is the territorial waters of Ukraine. This part has a very important ecosystem value. The water area between the coast of Odesa region and the Crimea is a shelf. Moreover, a significant part of this shelf has a depth of less than 50 *m*. The largest rivers of the Black Sea basin flow into this water area: Danube, Dnipro, Dniester and Pivdennyi (Southern) Buh.

Thus, the northwestern part of the Black Sea is well warmed by the sun's rays in the warm period of the year. And rivers saturate seawater with dissolved oxygen and nutrients (particularly the phosphorus and nitrogen compounds). Therefore, this water area is of decisive importance for the biota of the entire sea.

Russia is currently waging a naval war against Ukraine in the mentioned water areas. Such a war kills Ukrainians, and also causes irreparable damage to the environment, in particular to all Black Sea ecosystems. The entire biotic pyramid is collapsing: from the base (plankton) to the top (marine mammals). This is real ecocide.

The direct impact of the war on the biota of the Black Sea. Naval mines, surface and underwater explosions, power sonar from Russian warships and submarines have caused an environmental catastrophe for marine wildlife. The submarines and warships have fired at Ukraine – an additional source of acoustic disturbance, along with helicopter motors. Any of hundreds of russian missiles that fell in the sea would have killed fish and cetaceans.

Surface and underwater explosions cause a shock wave that can travel long distances underwater, stunning fish and killing other organisms. This is primarily a result of the anatomical structure of bony fishes, which have a gas-filled swim bladder that bursts readily in the event of large pressure drops. Explosions can also pose a serious threat to Black Sea marine mammals (Sadogurskaya, 2022).

The Black Sea mammal fauna has cetaceans from 3 different species; all of them are endemic subspecies:

– Black Sea bottlenose dolphin (or afalina);

– B. S. short-beaked common dolphin;

– B. S. harbour porpoise (or phocene).

Until the 1960s, populations were in decline. Scientists estimated there were probably between 1 million and 2 million dolphins and porpoises in the Black Sea in 1900. By 1945 had dropped to about 100 000. Hunting was the biggest threat. Cetaceans were caught for the sake of raw materials used for the manufacture of oils, paints, adhesives, varnishes, food, medicines, soaps, cosmetics, leather, and fertilizers. But in 1966 it was banned in Ukraine and Georgia (which were then occupied by the Soviet Union), Bulgaria, Romania and Russia. In 1983 dolphin hunting was banned in Turkey too (Kroeger, 2023).

The most authoritative study of the number of dolphins to date was carried out by *the Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area* (ACCOBAMS) in 2019-2020 – in Ukraine, Bulgaria, Romania and Turkey – and in 2021 (data was collected only in Bulgarian waters). It estimated there were about 250 000 cetaceans in the Black Sea (Gol'din et al., 2021). The total quantity of such marine mammals from 3 different species is shown in Table 1.

The survey covered nearly all of the Black Sea, except for an area around Crimea, which is temporarily occupied by Russia. All 3 species remain on the red list of threatened species maintained by the International Union for the Conservation of Nature (*IUCN*), are listed in the Black Sea Red Data Book, are protected by the Bern Convention on the Conservation of Wild Flora and Fauna and the Natural Convention and the Bonn Convention on the Conservation of Migratory Species of Wild Animals, the *ACCOBAMS* (Polyanska et al., 2020).

Table 1

The total number of cetaceans, were recorded in the Black Sea (in 2019-2021) (Gol'din et al., 2021)

Species		Number of individuals	%
Common name	**Scientific name**		
Black Sea short-beaked common dolphin	*Delphinus delphis ponticus Barabash, 1935*	118 328	46,5
Black Sea bottlenose dolphin	*Tursiops truncatus ponticus Abel, 1905*	42 169	16,5
Black Sea harbour porpoise	*Phocoena phocoena relicta Barabash, 1940*	94 219	37,0
Total		**254 716**	**100,0**

When full-scale war broke out the Black Sea dolphins generally got into terrible conditions. No one knows how many naval mines have been deployed or exploded in the sea since February 24. Large-scale explosions have also been plentiful around ports and strategic outposts. Oil rigs and civilian ships hit with heavy artillery and missiles. And the Ministry of Defence of Ukraine reports 18 (as of May 22, 2023) losses to the russian Navy's Black Sea fleet. These include its flagship, the *Moskva* cruiser (was discovered and sunk on April 13-14, 2022), and a landing craft sunk under heavy bombardment near Zmiinyi (Snake) Island (Fitt, 2022). The bodies of dolphins and harbour porpoises found on the coast were burnt and injured (Hubareva, 2022).

Due to the use of power sonars on Russian warships and submarines, which affect the cetaceans, dolphins have lost their echolocation.

Echolocation is their main unique ability – a biological form of sonar. Cetaceans use echolocation to find their way around, communicate and find food. But many dolphins and porpoises came within the zone covered by ship's navigation devices. The latter disabled their navigation and dealt them powerful acoustic injuries, paralyzing this vital echolocation system. As a result, the animals cannot orient themselves in space, become blind.

Animals have no acoustic control over their surroundings. These dolphins experience stress and panic, are unable to navigate in space, encounter various obstacles, including naval mines and rocks. And most importantly, such blinded animals have trouble finding food and quickly get exhausted. The dolphins, blinded by the sonar impact, become susceptible to viruses and parasites due to weakened immune systems. They become the target of self-infection by pathogens, which constantly live inside them.

Before Russia's full-scale invasion biologists recorded traces of fishing gear on the bodies of dead dolphins with their fins cut off. Now they are found many animals untouched. Powerful underwater explosions trigger dolphins to swim rapidly to the surface of the water causing air embolism, or decompression sickness, that occurs when scuba divers surface too quickly and nitrogen bubbles form in the bloodstream (Datskevych, 2022). As a result, blood clots appear and dolphins or porpoises die.

Ivan Rusev, a doctor of ecology and scientific department head at *Tuzlovsky Limany National Park* (Ukraine), said: before February 24 (2022) he found three to four dead dolphins along the 27 miles of shoreline in the park annually. But when the full-scale war began, the military closed a large portion of shoreline. Between 24 February and the end of August 2022 doctor Rusev and his team discovered 35 dead marine mammals along the 5 *km* of shoreline still accessible (Kroeger, 2023).

Ecologists from Bulgaria, Romania and Turkey have all reported an extraordinary increase in the number of dead dolphins and porpoise washed ashore.

In the Bulgarian city of Burgas alone, about 60 dead dolphins have been found around since the beginning of the year (2022), according to ecological inspection expert Maria Andreeva (Datskevych, 2022).

Bogdan Bulete, regional head ranger at the *Danube Delta Biosphere Reserve* (Romania), received on May 9 2022 what he thought was yet another routine call to check out a possible dolphin stranding near the town of Sulina. But when he reached the beach this time, the sight that met his eyes was "overwhelming," – up to 30 dolphins lay dead on the sand (Fitt, 2022). But Bulete estimated that more than 100 stranded cetaceans went unreported internationally in the Romanian Danube Delta region alone, including the dolphins in Sulina.

Bulete said: "Some of them looked burned, and all of them had marks of nets around their tail or their belly" (Fitt, 2022). Russian landing craft sunk May 7 (2022) under bombardment near Zmiinyi Island – 40 *km* away in Sulina, blowing open Bulete's office doors and windows. He said they felt like earthquakes. The mass mortality occurred two days (May 9) after the offensive that sank the landing craft. B. Bulete explained the dolphins could have swum into fishing nets in panic, while fleeing explosions, or sustained traumas that rendered them unable to detect the nets by echolocation (Fitt, 2022).

Rusev's team spoke to their counterparts in other Black Sea countries (except Russia and Georgia). Some of Ukraine's national parks are now in russian occupied territory. His team couldn't reach any of their colleagues there. When they added up the numbers they learned at least 2 500 dead dolphins had washed up on shore between 24 February, when the war started, and May 2022 (Alund, 2023). But currently this number is much higher, because most dead dolphins simply sink and never to be seen or counted.

Doctor Rusev said that the sea washes up only about 5 % of all dead animals. The remaining 95% go to the bottom and we cannot register them. They are not available for detection and counting from the shore. "Therefore, we estimate that during the war waged by Russian barbarians against Ukraine, probably up to 50 000 cetaceans have already died, which is absolutely terrible for the marine ecosystem", wrote I. Rusev (Barsukova, 2022). 50 thousand dead dolphins, this is a fifth of their total number.

Russian Navy's Black Sea fleet is stepping up security at the Sevastopol base by deploying trained dolphins. Many of the Russian ships anchored there are potentially vulnerable to undersea attacks (Aratani, 2022). The dolphins are kept at the entrance to the harbour to detect and counteract Ukrainian naval drones and military divers. Space satellite images show floating mammal pens in the bay (stretches for 7,5 *km*), which likely contain Black Sea bottlenose dolphins.

Living in a polluted military harbor is very harmful for animals. Russia catches and trains dolphins to perform various missions, including suicide ones. This treatment of animals is very cruel. Many dolphins are injured and die at a very young age. This practice will be stopped immediately after Ukraine's victory in the war.

If the dolphins and other cetaceans, who also act as sanitarians of the sea by eating sick fish, continue to disappear, life in the Black Sea will degrade, the expert fears. *Phocoena phocoena relicta, Tursiops truncatus ponticus* and *Delphinus delphis ponticus*, found only in the Black Sea, are keystone species – they balance the ecosystem by keeping prey populations in check (Fitt, 2022). "Many of the unique fish species we have today will disappear. We will lose a whole ecosystem," said doctor Rusev (Datskevych, 2022).

The initiative launched by the Odesa Regional Prosecutor's Office in July aims to hold Russia accountable for ecocide under Ukrainian law. Ecocide was legally defined as "*unlawful or wanton acts committed with knowledge that there is a substantial likelihood of severe and either widespread or long-term damage to the environment*" in 2021 by an international group of 12 lawyers (Fitt, 2022). But ecocide is not yet criminalized under international law.

The monk seal is believed has disappeared from the sea as a whole, because there is no scientific data on recent sightings for many years. Cetaceans of unique species we have today will also disappear from the Black Sea if the full-scale war continues.

The indirect impact of the war on the ecosystems of the Black Sea. Marine ecosystems are also indirectly affected by hostilities. Remains of sunken warships, submarines, bombs, naval mines and missiles, anchor usage can damage underwater communities on the seabed. The greatest biodiversity is usually concentrated in benthic algal communities, so damage to them may be a determining factor for the entire marine ecosystem.

Warships and submarines of the Russian Baltic, Pacific and Northern Fleets can also accidentally introduce non-native invasive species into the Black Sea where such species were not previously present. This, in particular, can happen through the discharge of ballast water, generally governed in peacetime by laws and regulations and overseen by relevant Ukrainian authorities. Sinking of warships, aircraft, helicopters, naval armed drones and other military equipment can lead to **oil spills** toxic to marine flora and fauna and can poison the marine environment for numerous decades (Sadogurskaya, 2022).

Warships are powered by vast diesel engines. Many Russian ships are powered by bunker fuel, which is diesel of such low quality that it is almost considered waste. Damaged or sunken Russian ships pollute the sea with such diesel fuel.

The *Moskva* cruiser, after it was struck by Ukrainian missiles, is thought to have sunk in the sea 45-50 *m* deep and wrecks can become persistent sources of pollutants. Oil slicks were used to pinpoint the location of the wreck.

On 25 February 2022, a Moldovan chemical tanker *Millennial Spirit* was carrying 600 *tons* of diesel fuel through the Black Sea. The tanker was shelled while underway 22 *km* south of the Ukrainian port of Yuzhne (Odesa region) by Russian warships. About 100 tons of diesel fuel probably spilled into the sea.

For the second time, according to the report of a Ukrainian Ministry of Defence, a *Millennial Spirit* was attacked by Russian aircraft on July 7, 2022. Two *X-31* missiles were fired from a Russian *Su-30* aircraft. One of the missiles hit the tanker which was drifting in the territorial sea of Ukraine without a crew and with more than 500 *tons* of diesel fuel on board. A fire broke out on the ship. The tanker *Millennial Spirit* eventually sank off Odesa after drifting. A lot of diesel fuel got into the sea.

Oil enters the sea due to infrastructure destruction on land by Russian shelling. Oil rigs, which were bombed, still leak a lot of oil products. Ukraine's aerial and marine drone attacks on oil terminals at Sevastopol and Novorossiysk entailed varying risks to the environment.

A lot of fuel oil can get into the sea due to the destruction of hydroelectric power plants. According to Ukrainian military intelligence reports, more than 450 *tons* of fuel oil are stored at the mined Kakhovka HPP alone. Russian terrorists control it and can blow it up. In this case, Dnipro River will carry hundreds of tons of fuel oil into the sea.

The damage from diesel fuel or fuel oil entering water is no less than from crude oil spills. 1 *ton* of oil can cover an area of up to 12 km^2 with a 1 *mm* thick layer (Al Bayaty, 2020). This means that the oil products of only the Kakhovka HPP and the tanker *Millennial Spirit* can be enough to form a stains with an area of up to 12 600 km^2 with a 1 *mm* thick layer. For example, 12 600 km^2 is more than 1/3 of the territory of Belgium or 1/2 of the territory of Slovenia and almost 5 territories of Luxembourg.

Oil prevents sunlight and oxygen from reaching the lower water layers as it spreads through the surface first. As a result, algae don't receive enough light to do photosynthesis to produce oxygen, and fish and millions of fry die, which live and feed almost on the sea's surface. Oxygen-breathing animals die en masse. And eutrophication may begin. Oil spills can also lead to the death of birds, which suffer by falling into oil stains.

Even a small oil spill it is a huge biota loss. It harms tiny organisms – zooplankton and phytoplankton – that float around the surface of the water. Plankton is the basis of the biotic component of the sea. Destruction of this foundation leads to catastrophic consequences for marine ecosystems of the Black Sea.

During the explosions of bombs, missiles, military shells, naval mines and torpedoes, a vast amount of dangerous substances are released into the environment. Some munitions may use very **toxic chemical compounds**. For example, white phosphorus releases poisonous gas and causes burns when ignited, and poisons water if it gets into the environment. Phosphorus is practically insoluble and can be stored for decades in salty seawater under conditions of oxygen deficiency (Black Sea is the largest anoxic body of water in the world). Many compounds developed as chemical warfare agents used by the Russian invaders are highly toxic to humans. Such compounds are also harmful to other vertebrates. They can accumulate and persist for decades in the natural environment and affect aquatic organisms (Hubareva, 2022).

Toxic substances enter the sea due to the destruction of industry and infrastructure on land by Russian shelling. For example, satellite imagery shows huge damage to 13 out of 14 warehouses of the *Olvia QTerminals* in Olvia seaport (Mykolaiv region). The warehouses were enclosed by berms (a raised barriers usually made of compacted soil) – this suggests storage of ammonium nitrate fertiliser, or potentially munitions (The coastal, 2023). Contaminants from toxic compounds are highly likely to have entered the Dnipro–Buh estuary and then to the sea.

There was a major offensive on Mykolaiv between February and May 2022, during which city has endured prolonged artillery and missile attacks. As a result, Mykolaiv and nearby towns have sustained significant physical damage generating large volumes of debris. Such debris contaminated with a broad range of pollutants, including heavy metals, polychlorinated biphenyls (*PCBs*) and asbestos. Some of these hazardous materials have been or will be transported into the Buh estuary and to the sea through surface run-off or via groundwater flow.

One more visible indirect impact was the discharge of sewage between 28 June and 15 July, 2022, from the Halytsynove wastewater treatment plant (plant near the village of Halytsynove treat 83 % of Mykolaiv's wastewater). This was likely associated with an attack on the facility in March. Such releases of untreated wastewater can harm ecosystems through the release of toxic substances (The coastal, 2023).

Croplands turned into battlefields. Therefore, agricultural runoff – pesticides, mineral and organic fertilizers, fuel, battery acids and other liquid components of damaged and destroyed agricultural machinery – enters rivers and then the sea. Most of their components poison water. Mineral and organic fertilizers cause eutrophication.

The Dnieper River is being used as a front line during the war. It is impossible for this source not to be polluted by the toxic chemicals released from the use of ammunition. Almost all of these toxic substances will be carried by the Dnipro River into the Black Sea.

Pathogens are also a factor in the indirect effect of war on the death of marine biota. They can get into the sea as a bacteriological weapon or accidentally due to damage to the city sewer or, say, an agricultural complexes. Scientists discovered this pollution mechanism even before the start of a full-scale war – the Russians deliberately, in a brutal way, polluted their water areas and international waters, dumping sewage from agricultural farms in the Krasnodar Territory into the sea, which caused dolphins to become infected with toxoplasmosis (Hubareva, 2022).

Unfortunately, **radioactive contamination** is not excluded. According to unconfirmed data, there could be missiles with nuclear warheads on the sunken *Moskva*. The warheads could have been damaged when Ukrainian missiles hit the cruiser. This can cause radioactive contamination of biota-rich waters (its wreckage is at a depth of up to 50 *m*).

Russian terrorists also control the Zaporizhzhia nuclear power plant. This is the largest nuclear power plant in Europe. It is located near the shores of the Kakhovka Reservoir. Ukrainian intelligence warns that Russian is probably preparing to commit a terrorist attack at the power plant. The consequence of a terrorist attack can be a terrible radioactive contamination of both the land and the Black Sea.

After the Chernobyl disaster, at least 6 000 *Ci* of *cesium-137* and 5 000 *Ci* of *strontium-90* entered the Dnipro reservoir cascade with aerosol fallout and river runoff. Ecosystems retained about 99 % of ^{137}Cs and 70% of ^{90}Sr. The main part of retained radionuclides – up to 70% – is deposited in the bottom sediments of the Kyiv Reservoir. Russian missiles can destroy the dam of the Kyiv Reservoir. In this case, the concentration of radioactive pollution in the cascade will increase tens and hundreds of times. Now radionuclides are absorbed by mineral and organic components of bottom soils and therefore do not pose a significant danger. Most of the radionuclides deposited at the bottom will enter the water masses and pollute all other reservoirs – and the Black Sea.

Possibilities of the spread of indirect effects of war on non-Black Sea ecosystems. Russia's full-scale war against Ukraine caused great damage to marine ecosystems. But, unfortunately, not only Black Sea ecosystems will suffer.

The Black Sea has positive freshwater balance – it receives more fresh water from the rivers and rainfall than it loses from evaporation. Every year the Black Sea receives about 350 km^3 of river water (more than 283 km^3 (81 %) – from the rivers flowing through Ukraine; Table 2), about 25,5 km^3 of sea water from the Sea of Azov and about 230 km^3 of precipitation (totaling 605,5 km^3) while evaporation takes away approximately 354 km^3 of water.

Table 2

The largest rivers of the Black Sea basin (flowing through Ukraine) (Drainage Basin of The Black Sea, 2020; Dnister River, 2001; River Basin Management Plan for Pivdenny Bug, 2014)

Name	**Annual drainage volume,** km^3	**Drainage basin,** km^2	**Passes through or touches the borders of**
Danube	216,3	801 400	Ukraine, Romania, Moldova, Bulgaria, Serbia, Croatia, Hungary, Slovakia, Austria, Germany
Dnipro	52,7	504 000	Ukraine, Belarus, Russia
Dnister	11,0	72 100	Ukraine, Moldova
Southern Buh	3,4	63 700	Ukraine
Total	**283,4**	**1 441 200**	

Due to its positive balance the level of the Black Sea is higher than that of the Marmara Sea by an average of 0,43 *m*. The surplus of water – about 251,5 km^3 – therefore flows through the Bosporus Strait into the Sea of Marmara and then through the Dardanelles into the Mediterranean Sea. But there is another factor. Two flows through the straits are formed. The upper flow leaves the Black Sea and carries surface water out of it. Meanwhile a bottom flow carries salt water from the Mediterranean to the Black Sea. The volume of the bottom flow is about 300 cubic kilometers (Black Sea Scene, 2023).

Thus, not 251,5 km^3 of surface water flows into the Mediterranean Sea from the Black Sea annually, but about 551,5 km^3. For example, it is almost twice the volume of the Sea of Azov. There are two surface currents in the Black Sea. They caused by the cyclonic pattern of the winds and move counterclockwise parallel to the coastline along closed circuits.

The surface currents form two closed circles. The width of the western circle, opposite the Danube Delta, reaches 100 *km* and decreases towards the south. The velocity of the current is about 0,5 *km* per hour. This current carries polluted waters from the war zone south along the coasts of

Romania and Bulgaria to the Bosporus. The lighter waters of the Black Sea flow as a surface current into the Sea of Marmara at a velocity of 1-2 *m* per second (Black Sea, 2001), or 3,6-7,2 *km* per hour.

Conclusions. The Black Sea is a unique macroecosystem in the world. Oxygenated surface waters supporting life in the sea constitute only about 13 % of the sea volume. Oxygen is completely absent at a depth greater than 150-200 *m*. But the Black Sea biota is well adapted to such natural conditions. 500 years ago Black Sea sturgeon were so numerous that caviar was thought of as a food for the poor among coastal peoples.

The northwestern part of the Black Sea – the territorial waters of Ukraine – has a very important ecosystem value. A significant part of this shelf has a depth of less than 50 *m*. The largest rivers of the Black Sea basin flow into this water area. They saturate seawater with dissolved oxygen and nutrients. Therefore, this region is of decisive importance for the biota of the entire sea. But Russia has been waging war against Ukraine for 9 years.

Active hostilities cause great damage to the territorial waters of Ukraine, and the entire ecosystem of the Black Sea and even the Mediterranean ecosystems. Probably up to 50 000 cetaceans have already died. The oil products of only the Kakhovka HPP and the tanker *Millennial Spirit* sunk by the russians can be enough to form a stains with an area of up to 12 600 km^2 with a 1 *mm* thick layer. During the explosions of bombs, missiles, military shells, naval mines and torpedoes, a vast amount of dangerous substances are released into the environment. Toxic substances (heavy metals, polychlorinated biphenyls, asbestos etc.) enter the sea due to the destruction of industry and infrastructure on land by Russian shelling. Agricultural runoff – pesticides, mineral and organic fertilizers, fuel, battery acids and other liquid components of damaged and destroyed agricultural machinery – enters rivers and then the sea, because croplands are turning into battlefields. On the sunken *Moskva* could be missiles with nuclear warheads. The warheads could have been damaged when Ukrainian missiles hit the cruiser. This can cause radioactive contamination of biota-rich waters. Russians also control the Zaporizhzhia nuclear power plant. The consequence of a terrorist attack can be a terrible radioactive contamination of both the land and the Black Sea.

The destructive war must stop with Ukraine's victory. After that, the Black Sea will become *Εὔξεινος Πόντος* (*"Hospitable Sea"*) again. But if the war continues for a long time, the Black Sea may become dead not by 87 – but by 100 % of its volume.

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BIOTRANSFORMATION OF VEGETABLE WASTE USING MODERN EM-TECHNOLOGIES: EUROPEAN EXPERIENCE AND UKRAINIAN REALITIES

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Abstract. *Accumulation, processing and disposal of organic waste, in particular, vegetable waste, is considered an urgent problem today for Ukraine and the EU countries. Currently, one of the promising ways to solve the problematic issue is the application of modern biotechnologies of organic waste processing with the use of a specific consortium of microorganisms, which allow in the process of bioconversion of beet, carrot and potato waste to obtain digestate and biohydrogen in 6 days of fermentation at a temperature of 37 ^{0}C. The effectiveness of using additional substrates, such as expired bread and probiotic lactulose, to activate the fermentation process of organic waste has been proven. The experiments confirmed the absence of pathogenic cultures in the digestate, which is explained by the high titer of viable cultures of antagonistic microorganisms (lactic acid bacteria, Bacillus subtilis, Paenibacillus polymyxa). The obtained research results show that in all samples (1–7) there is an intensification of the fermentation process on the 2nd, 3rd, and 4th day of fermentation, which is evidenced by changes in the redox potential index, which ranges for samples (1–7) from - 100 to - 200 mV. The release of biohydrogen intensively began on the 2nd day of fermentation and lasted for 6 days of the experiment. In order to intensify the process of transformation of plant waste, the expediency of using additional sources of carbon, namely expired bread in the amount of 10% and lactulose in the amount of 2 and 4% of the mass of waste, was substantiated for the first time.*

Introduction. According to UN data, during the monitoring of the amount of accumulated waste in 152 countries of the world, spoilage of food products during their storage and transportation was recorded, namely, their losses were determined: 47% of root crops, 44% of fruits, 28% of vegetables, 23% of cereals and legumes and 12% dairy products. At the same time, there is a shortage of food products in the world, the depletion of soils due to the use of mineral fertilizers and pesticides is recorded, the amount of energy resources is sharply reduced, which confirms the relevance of the mentioned problem, which needs an immediate solution (Makovetska, 2015). Since Ukraine acquired the status of a candidate member of the EU on June 27, 2022 (European Council conclusions, 2022), the state must fulfill certain obligations regarding the adoption of technical standards and legal norms of the legislative framework regarding waste management and methods of their processing , which will be directed to obtaining renewable sources of energy and biofertilizers through the bioconversion of organic biomass using modern biotechnologies (Directive 2009/28/EC, 2009); European Commission: 2022, 2020a).

For EU member states, these documents highlight targets for a certain period of time that must be met. For example, Latvia has waste recycling targets to be implemented by 2025 (European Commission, 2023b).

The transformation of waste into resources is key to the transition to a cleaner, climate-neutral and circular economy. The reuse and recycling of waste leads to the creation of local jobs, stimulation of innovation, mitigation of negative impact on the environment, as well as reduction of dependence on imported raw materials (European Commission, 2023c).

The document states that the Commission has published an early warning report on the progress of EU Member States in meeting the 2025 waste reuse and recycling targets and the 2035 municipal waste landfill reduction targets. Achieving these goals is essential for the creation of well-functioning markets for secondary raw materials in the EU (European Commission, 2023d).

In the report, the Commission identifies those Member States that are at risk of missing the targets for reuse and recycling of municipal waste and all packaging waste by 2025, as well as the targets for landfilling by 2035. Nine member states are on track to meet the 2025 targets: Austria, Belgium, the Czech Republic, Denmark, Germany, Italy, Luxembourg, the Netherlands and Slovenia (European Commission, 2023e).

The Commission supports Member States in improving the efficiency of waste management with the help of European funds, it provides technical assistance, guidance and other tools (European Commission, 2023f).

According to the analysis, starting from 2015, 120-140 million tons of food waste is generated in the EU every year (Caldeira, De Laurentiis, Corrado, van Holsteijn & Sala, 2019a)

This is 20-25% of the total amount of food. Vegetables, fruits and grains are the food groups that generate the most food waste. The largest amount of food waste is generated during the consumption stage (46%), followed by primary production (25%), and processing and manufacturing (24%) (Caldeira, De Laurentiis & Sala, 2019b; Caldeira, Vlysidis, Fiore, De Laurentiis, Vignali & Sala, 2020).

Incidentally, 44% of the world's largest food companies have begun to count and record food losses and waste in their operations, and 30% of companies measure and report their losses in the absence of their processing into biofertilizer and biogas (Champions 12.3. 2019. SDG target 12.3 on food loss and waste, 2019; Corrado, Ardente, Sala & Saouter, 2017).

Countries that account for only 15% of the world's population are taking massive action to reduce the loss of food that must be processed as waste. But no country has yet announced that it has halved food waste with recycling, as the lack of quantification at the national level prevents tracking of this milestone. Although one-third of the world's 50 largest food companies have implemented programs to reduce food loss and waste. (De Laurentiis, Caldeira &Sala, 2020; Commission Notice (2018/C133/02), 2018b).

To date, the goals of the bioeconomy of the EU member states have been formed, which cover all sectors and systems that depend on biological resources (animals, plants, microorganisms and derived biomass, including organic waste), their functions and principles. They include all primary production sectors that use and produce biological resources (agriculture, forestry, fisheries and aquaculture) and all economic and industrial sectors that use biological resources and processes to produce food, feed, bioproducts, energy and services . To be successful, the European bioeconomy must be based on sustainability and circularity. This will contribute to the renewal of leading industries, modernization of primary production systems, environmental protection and increase in biodiversity (Commission Communication (COM/2018/673), 2019; Commission Delegated Decision (C(2019)3211), 2020).

The Climate Law sets the goal of achieving climate neutrality in the EU by 2050. In the EU, it is planned to reduce greenhouse gas emissions by 55% by 2030 compared to the levels of emissions in 1990. The Farm to Fork Strategy sets out a new approach to ensure that agriculture, fisheries and aquaculture development and the food value chain contribute appropriately to this process. Considering the issue of climate change, the basics of the circular economy and the principles of the bioeconomy, it becomes clear that the vegetable waste generated at the processing stage has a high potential for valorization, since food waste streams are present in large, concentrated and homogeneous quantities. Food waste can be transformed into a number of value-added products through several valorization pathways. It is proposed to use modern biotechnology for their processing. Actions to combat organic waste require an evaluation system that includes SMART goals and key performance indicators for tracking (Commission Communication (COM/2020/381), 2020b; Commission Communication (COM/2020/28), 2020c; Commission Communication (COM/2020/380), 2008).

Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives is a normative act that regulates the procedure for the collection, processing and utilization of waste on the territory of the European Union. It aims at establishing the basic rules of waste management, which will allow to reduce the landfill of waste and ensure the saving of resources due to the reuse and processing of secondary raw materials. This Directive introduces a hierarchy of waste management priorities (Directive 2008/98/EC, 2008; Directive (EU) 2018/851, 2020; FLW Protocol, 2016).

From December 2023, separate collection of organic waste will become mandatory for all EU member states. Separate collection and processing of organic waste contribute to the reduction of greenhouse gas emissions, including methane. Separate waste collection systems differ among the 27 EU member states. The introduction of mandatory separate collection of organic waste followed by bioconversion of food and vegetable waste is based on the principles of circular economy (Manfredi et al., 2015)

Considering the urgency of the problem of processing organic waste and reducing its quantity in accordance with the principles of the circular economy and EU Directives, it becomes clear the need to develop and improve modern biotechnologies for the bioconversion of organic waste into biofertilizer and biogas (Prokaieva, 2021).

The issue of organic waste processing is considered in the paper, which shows the results of evaluating the potential of processing fruit and vegetable waste with sawdust in various combinations and establishes the relationship between microorganisms and physicochemical parameters: C/N in relation to the bioconversion of fruit waste (apple, banana peel , oranges and kiwi) and vegetable waste (cabbage leaves, potato and carrot peels). The total amount of fruit and vegetable waste was approximately 2 kg in each sample, to which different amounts of sawdust (1.23, 0.14 and 0.203 kg) were added to obtain the suggested C/N ratio and limit odor. The results showed that in the first week, the pH is acidic and the conductivity values are high for all three samples, and then the pH values increase during the composting process, while the conductivity values decrease, which is also noted in our presented research results. Taking into account such changes, we recommend adjusting the pH value in order to obtain a biofertilizer with a pH within the neutral range (Ghinea, Leahu, 2020).

The authors proposed a food waste processing technology that is easy to maintain, fast, economical and affordable, and most importantly - ecologically safe and socially acceptable. It is proposed to carry out bioconversion of organic waste based on the principle of biological decomposition with the participation of biodegrading microorganisms, thanks to which it was possible to obtain high-quality biofertilizer, which confirms the relevance of the biotechnological approaches presented in this article (Oktiawan, Hadiwidodo, Priyambada & Purwono, 2019).

Taking into account the problematic issues formed above, which are relevant for the whole world and need to be solved, it is proposed to investigate the process of biotransformation of organic waste according to modern biotechnologies (Prokaieva, 2021). The author discussed the accepted strategies of bioconversion, namely the processing of waste with minimization of the impact on the surrounding natural environment (Reshmy et.al., 2021). The work proved the positive effect of sugars contained in the skins of vegetable waste on the intensity of waste fermentation and on the concentration of organic acids and alcohols in the culture liquid (Kandari et.al., 2012). Also, the optimal fermentation time of vegetable waste was investigated, which is 5-6 days at a temperature of 37 ºC (Kudri, 2020). During the bioconversion of vegetable waste, one of the main techniques is the process of homogenization and mixing of waste (Wang et.al., 2012).

Experiments have proven that the hydrolysis stage has a high impact on the subsequent stages of gas biosynthesis. Namely, the successful passage of the hydrolysis process will help increase the yield of biohydrogen by 1.5-3.0 times (Mishra et.al., 2021). However, accelerating the stage of hydrolysis can lead to an excessive increase in the concentration of acids in the culture liquid, which will inhibit the development of hydrogen-synthesizing microorganisms, so it is necessary to regularly adjust the pH of the medium using buffer solutions (Geletuha and Zhelyezna, 2014). The works studied the role of lactic acid bacteria (LAC) and lactulose prebiotics on the process of hydrolysis and gas biosynthesis. Lactulose is selectively metabolized by microbiota, forming SCFAs, gas (hydrogen, carbon dioxide, and methane), which leads to an increase in bacterial biomass. *Bacteroides oralis*, *Bacteroides vulgatus*, *Bifidobacterium bifidum*, *Clostridium perfingens*, *Lactobacillus casei* strains showed high efficiency in lactulose metabolism (> 20%). Also, it was established that during the first day of fermentation, the pH can decrease by 2.0-2.5 units (Karakan et.al., 2021).

The author investigated the effectiveness of using the solid fraction of digestate for agricultural purposes in order to fertilize agricultural soils (Ratushniak, Koshcheiev, 2011).

Taking into account the above aspects, the objective of the study consists in researching the efficiency of bioconversion of vegetable waste (beetroot, carrot and potato) into digestate and biohydrogen using modern EM technologies.

To achieve the objective, the following tasks were formed:

1) determine the optimal fermentation time of vegetable waste with the addition of EM preparations "Baikal-EM-1" and "Organic-balance";
2) establish the feasibility of using expired bread in the amount of 10% and lactulose prebiotic in the amount of 2 and 4% as additional substrates in the process of biotransformation of vegetable waste;
3) evaluate the quality of the obtained digestate according to the main physicochemical and microbiological indicators (pH, redox potential, content of biogenic elements, titer of viable cells of indicator microorganisms).

Materials and Methods. The method of the experiment consisted in the implementation of bioconversion processes of vegetable waste - beet, carrot and potato, which were fermented both separately and in the form of a mixture with the addition of EM preparations "Baikal EM 1", "Organic-Balance" and additional substrates (expired bread - 10 %, prebiotic lactulose in the amount of 2 and 4% relative to the total mass of waste). Vegetable waste before bioconversion was not subject to heat treatment and disinfection, it contained the remains of the soil, which contains accompanying microflora. Before the start of the fermentation process, the vegetable waste was crushed to a particle size of 0.3-0.5 cm in order to intensify the fermentation process. Unprocessed, crushed vegetable waste was subjected to fermentation in a laboratory setup (Fig. 1), which consists of 2 flasks and a gas outlet tube. Biotransformation of waste took place in thermostatic conditions at a temperature of 37 ^{o}C for 6 days. As a result of the acidification of the fermentation medium by lactic acid bacteria contained in the EM preparation, the pH value of the culture liquid was adjusted daily within optimal limits (pH 6.0-6.5) due to the introduction of a buffer solution (sodium hydroxide). Biopreparation "Baikal - EM 1" consists of a consortium of effective microorganisms that are in symbiosis with each other. Effective microorganisms include lactic acid, photosynthesizing, nitrogen-fixing bacteria and yeast (*Lactococcus lactis*, *Lactobacillus casei*, *Rhodopseudomonas palustris*, *Saccharomyces cerevisiae*). This preparation, according to the instructions, is recommended to be used as a biofertilizer, to protect plants from various diseases, to deodorize and disinfect cesspools. The preparation "Organic-Balance" contains organic substances - stabilizers, biologically active substances, vitamins, enzymes for decomposition of residues, as well as a concentrate of viable microorganisms: antagonistic cultures - *Bacillus subtilis*, *Paenibacillus polymyxa*, and nitrogen fixers *Azotobacter chroococcum*. The titer of cultures in both preparations ranges from $1x10^8$ to $1x10^9$ CFU/cm^3. To prepare a working solution (for effective fermentation of waste) from a mixture of two EM preparations, the following sequence was performed: EM preparations "Baikal EM 1" and "Organic-Balance" were added to a flask with prepared water (distilled and sterile) in concentrations of 10 and 2 ml/l, respectively, sucrose in the amount of 20 g/l. The activation temperature was 37 °C. The prepared working solution was kept in thermostatic conditions for 3.5 hours to activate microorganisms, after which it was used in a ratio of 1:4 relative to the crushed mass of vegetable waste. The following samples were obtained: No. 1 – vegetable mixture, working solution, expired bread (10% relative to the mass of vegetable waste), No. 2 – vegetable mixture, working solution, No. 3 – potato waste, working solution, No. 4 – carrot waste, working solution , No. 5 – beet waste, working solution, No. 6 – vegetable mixture, working solution, 2% lactulose, No. 7 – vegetable waste mixture, working solution, 4% lactulose, No. 8 – vegetable waste mixture, prepared water (without the addition of a biological preparation, control). During the experiment, physico-chemical and microbiological quality control of the digestate was carried out according to the main parameters: redox potential, pH, concentration of biogenic elements (ammonium nitrogen, nitrite nitrogen, nitrate nitrogen, phosphates), titer of viable cells of lactic acid bacteria (*Lactococcus lactis*, *Lactobacillus casei*), yeast (*Saccharomyces cerevisiae*), nitrogen-fixing and hydrogen-synthesizing bacteria on the example of *Paenibacillus polymyxa*, enethorobacteria (*E.Coli*). Indicators were determined daily in order to establish the intensity and depth of the fermentation process, as well as to identify the optimal fermentation time (according to the maximum negative value of the redox potential). The quality indicators of the digestate were evaluated in all experimental samples during the duration of the fermentation process (6 days) and the post-fermentation period (10th, 20th, 30th days) during the recommended storage period of the digestate at a temperature of 4 ^{0}C.

Experimental methods of researching the quality of biofertilizer (digestate) were carried out in accordance with the list of methods for measuring (determining) the composition and properties of samples of environmental objects, emissions, waste and discharges, temporarily allowed for use, approved by the Ministry of Environmental Protection of Ukraine (materials of the electronic system "Zakon", 2007).

a) b) c)

Fig.1. Laboratory installation for the bioconversion of vegetable waste (a) and samples of digestate: b) after separation of the solid fraction at the end of fermentation (after storage); c) without separation of the solid fraction from the liquid at the end of fermentation (after storage)

Indicators of redox potential and concentration of hydrogen ions were measured using a standard certified pH meter (millivoltmeter pH-150 mA), the pH indicator was determined according to ISO 4077-2001. The content of biogenic elements was determined by the photocolorimetric method, using standard research methods. Ammonium nitrogen was measured according to Nesler. The essence of the method is the interaction of the ammonium ion with the Nesler reagent, in which case yellow mercurammonium iodide is formed. Nitrites were determined by the ability of nitrogen nitrites in an acidic medium to form diazo compounds with aromatic amines. During the measurement of ammonium and nitrite nitrogen, the photocalorimeter was set to a green light filter. Nitrate content was determined using salicylic acid using a photoelectrocalorimeter with a blue light filter. Phosphates were determined using a photoelectrocalorimeter with a red light filter. In a dilute solution of phosphates, ammonium molybdate reacts in an acidic environment with the formation of molybdic acid, which is reduced by tin to an intense blue color. During fermentation of the substrate, the volume of gas was measured after determining the composition of the gas phase by the gas chromatographic method. A hermetic gas holder was used to determine the gas volume. After each measurement, the gas holder was completely filled with water in order to avoid errors when calculating the composition of the gas phase. Sampling of gases and culture liquid was carried out with plastic sterile syringes with a volume of 2.5 ml. Samples were taken by piercing the rubber stopper of the bottle with a syringe needle. Before that, the stoppers and needle of the syringes were carefully sterilized by wiping with alcohol and heating in the flame of the burner. The volume of synthesized gas was measured on the scale of the syringe (extrusion of the syringe piston by excess gas pressure). The composition of the gas phase was determined according to the standard method on a LHM-8-MD gas chromatograph. To grow bacteria and fungi in laboratory conditions, a study of their various properties was carried out, and the following generally accepted nutrient media were used: meat-peptone broth, Saburo, Chapek, Endo, MPA, MRS, which correspond to certain standards, creating optimal conditions for the growth, reproduction and vital activity of microorganisms. A nutrient medium with the following composition, mg/l, was used for isolation from the digestate of *R. polymyxa*: molasses -40, corn extract - 20, vermiculite - 0.4, K_2HPO_4 - 0.5, $MgSO_4$ - 0.5, NaCl - 0.5, $CaCO_3$ - 10.5. The technique of tenfold dilutions was used for microbiological studies. Microorganisms isolated from the digestate were cultivated in a thermostat (dry-air thermostat TS-1/80 SPU). The number of viable cells was determined using a DEN-1 densitometer and the direct counting method. Bacterial cell samples were stained according to the Gram staining method, fungi were stained with lactofuxin. Microscopy of test samples was carried out using a microscope (Microscope XS-5520 biological).

The study was carried out with eight samples of prepared organic waste, in 3 repetitions with each. The relative error of experimental studies was defined as the difference between the measured and the true value of the measured value and was within the limits outlined in the above research methods. The relative error did not exceed 5% for all determined indicators. Statistical processing of the obtained research results was carried out using the Microsoft Excel software program.

Results and Discussion. Modern agricultural production in the EU countries is based on the basis of extended reproduction of soil fertility under the conditions of compliance with the safety of the environment and grown products. The rational use of biofertilizers and biostimulants ensures the production of environmentally safe products, the accumulation of soil organic matter, reducing soil fatigue, improving its structure, and as a result, increasing soil fertility. Based on the above, we proposed to carry out bioconversion of vegetable waste with the participation of effective microorganisms of the complex preparation "Baikal EM 1" and "Organic-Balance" in order to obtain high-quality digestate and biohydrogen (the preparation contains cultures of *P.polymyxa* and *Bacillus subtilis*, which belong to hydrogen synthesizing bacteria).

Fermentation of vegetable waste is the metabolism of sugars (substrates), during which energy is obtained as a result of partial oxidation of an organic compound using organic intermediates as electron donors and acceptors. Carbohydrates are the main source of carbon and energy that form the necessary components in the environment. The concentration of sugars affects the growth and functionality of microorganisms, therefore, in order to accelerate the rate of the initial phase of bioconversion, we added additional substrates to the samples - expired bread in the amount of 10% relative to the mass of waste and lactulose - a prebiotic that increases the number of viable LAB that participate in the process hydrolysis of vegetable waste.

During the process of fermentation and storage of digestate, the concentration of hydrogen ions and the redox potential were measured, which indicate changes in the environment, and the stabilization of the redox potential indicator indicates the cessation of fermentation processes in the system, i.e., the possibility of the end of the fermentation process of vegetable waste (Figs. 2, 3).

Analyzing the presented research results (Fig. 2), it is possible to assert the beginning of the stage of acidogenesis at the end of the 1st day of the experiment, especially for samples 1, 6, 7, to which additional substrates were added. Acidification of the fermentation medium was recorded for 1 day of the experiment, which is explained by an increase in the titer of viable cells of the LAB.

The dynamics of fermentation of organic waste was studied according to the following parameters - pH (Fig. 2), Eh (Fig. 3) and intensity of gas formation (volume of isolated biogas). Completion of the fermentation process was determined by visual assessment, i.e. cessation of gas formation, reduction of hydrogen concentration in the gas mixture. The parameters were monitored once a day during fermentation (1-6 days).

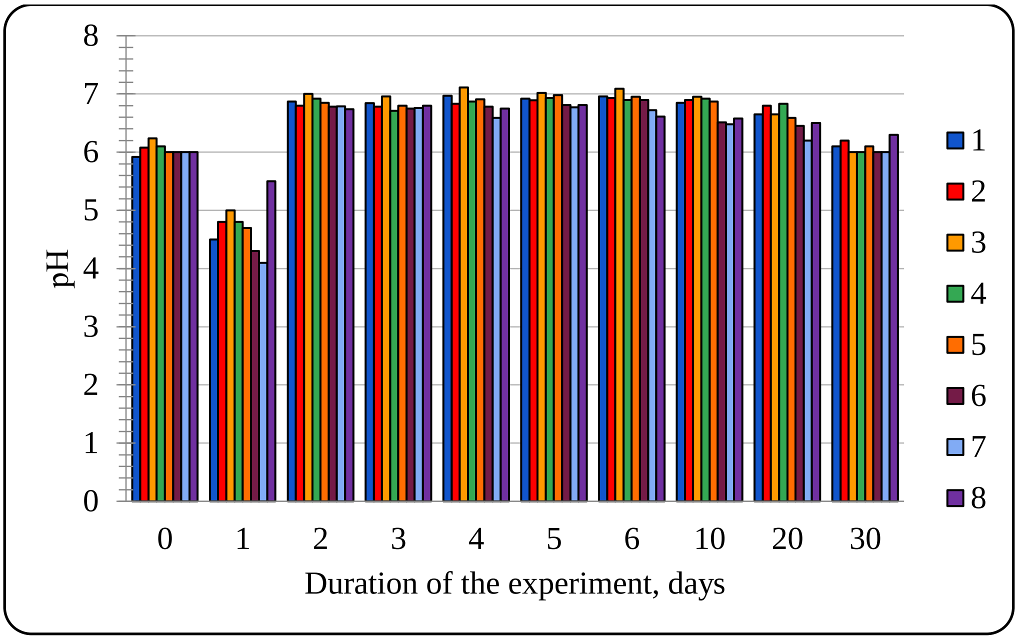


Fig. 2. The dynamics of changes in the concentration of hydrogen ions in the experimental samples during fermentation (1–6 days) and storage (30 days): No. 1 – vegetable mixture, working solution, expired bread (10% relative to the mass of vegetable waste), No. 2 – vegetable mixture, working solution solution, No. 3 – potato waste, working solution, No. 4 – carrot waste, working solution, No. 5 – beet waste, working solution, No. 6 – vegetable mixture, working solution, 2% lactulose, No. 7 – vegetable waste mixture, working solution, 4% lactulose, No. 8 - vegetable mixture of waste, prepared water (without the addition of biological preparations, control)

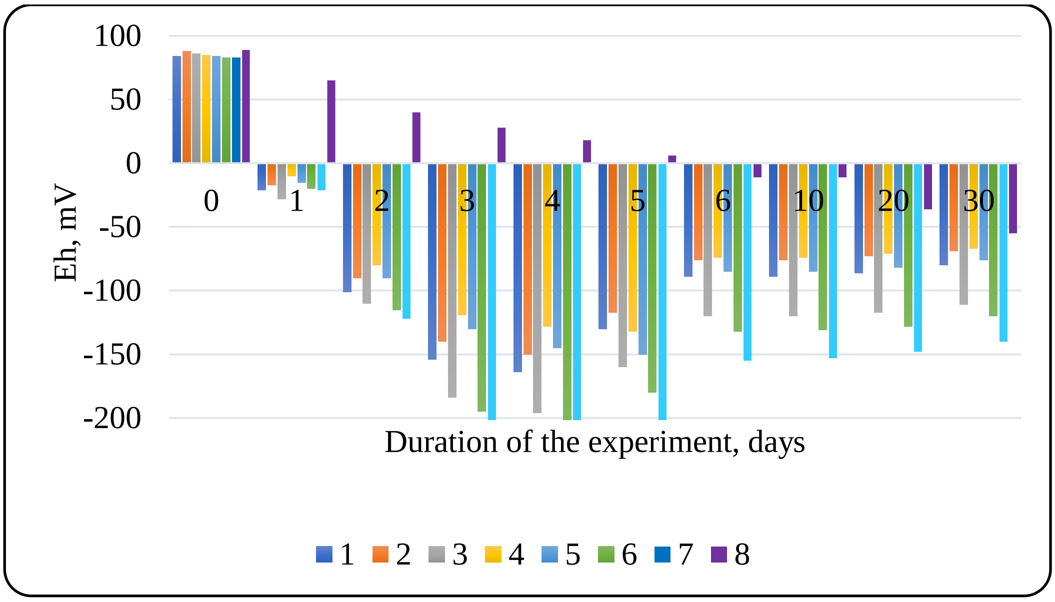


Fig. 3. Dynamics of changes in the redox potential (Eh) in experimental samples during fermentation (1–6 days) and storage (30 days): No. 1 – vegetable mixture, working solution, expired bread (10% relative to the mass of vegetable waste), No. 2 – vegetable mixture, working solution, No. 3 – potato waste, working solution, No. 4 – carrot waste, working solution, No. 5 – beet waste, working solution, No. 6 – vegetable mixture, working solution, 2% lactulose, No. 7 – vegetable mixture waste, working solution, 4% lactulose, No. 8 - vegetable mixture of waste, prepared water (without adding biological preparations, control)

The obtained research results show (Fig. 3) that in all samples (1–7) there is an intensification of the fermentation process on the 2nd, 3rd, and 4th days of fermentation, as evidenced by changes in the redox potential index, which fluctuates within the limits for samples (1 -7) from -100 to -200 mV. The lowest indicator of redox potential was recorded for sample No. 3, which contained only potato waste, as well as for samples No. 6, 7, to which lactulose was added. Therefore, in the biotechnology of directed biosynthesis of hydrogen, it is better to use potato waste, but considering that in small households a mixture of vegetable waste is formed and there is only a need to obtain biofertilizer for own needs, it is better to use a mixture of vegetable waste, which in terms of the content of vitamins and micro- and macroelements will be higher than the digestate obtained from such monowaste as potatoes. Also, if expired bread (experimental sample No. 1) and lactulose (experimental samples No. 6 and 7) are added to the vegetable mixture during fermentation instead of sucrose at the microflora activation stage, the fermentation process can be intensified, as well as the time of the hydrolysis stage and acid accumulation can be shortened. As for samples No. 6 and 7, to which the prebiotic lactulose was added, which contributes only to the increase of the LAB titer, we note the acceleration of the acid accumulation stage, which is confirmed by the results of microbiological studies to determine the LAB titer, which have antagonistic properties in relation to pathogenic bacteria and fungi. Considering the fact that the concentration of fatty acids increases thanks to LAB, at the stage of acetogenesis, they are transformed into hydrogen and then into methane. Experiments proved that in sample No. 8 (control) the waste transformation process is slowed down, which is associated with insufficient reproduction of accompanying microflora, which entered the fermentation medium together with untreated waste, which is confirmed by insignificant changes in pH and redox potential. Therefore, to accelerate the fermentation process and prevent the development of pathogenic wild plants, it is necessary to use EM preparations (Levin, 2014).

The release of biogas (H_2) began intensively on the 2nd day of fermentation, especially for samples No. 3, 6, and 7. This is explained by the fact that potato waste is starch-containing and susceptible to the development of hydrogen-synthesizing microorganisms, especially Bacillus subtilis. In samples No. 6 and 7, to which the substrate lactulose was added, the release of biohydrogen also intensifies, which is explained by the fact that lactulose is a disaccharide consisting of fructose and galactose, it decomposes into lactic acid, acetic acid, and then transforms into hydrogen by with the participation of hydrogen-synthesizing microorganisms.

The hydrogen content for samples No. 3, 6, and 7 at the end of the 2nd day of fermentation was 10.1–11.4 ±2.0%, and on the 4th and 5th day of the experiment it was 32–36, ±2.0%. On the 2nd-3rd day, foam and gas bubbles accumulated on the surface of the fermentation medium, on the 5th-6th day, a gradual destruction of vegetable waste was observed with the deposition of highly dispersed detritus at the bottom of the flask, the amount of fermented substrate (vegetable waste) decreased to approximately 25% in 6 days of cultivation. Therefore, it can be assumed that the full process of waste destruction takes place within 6 days.

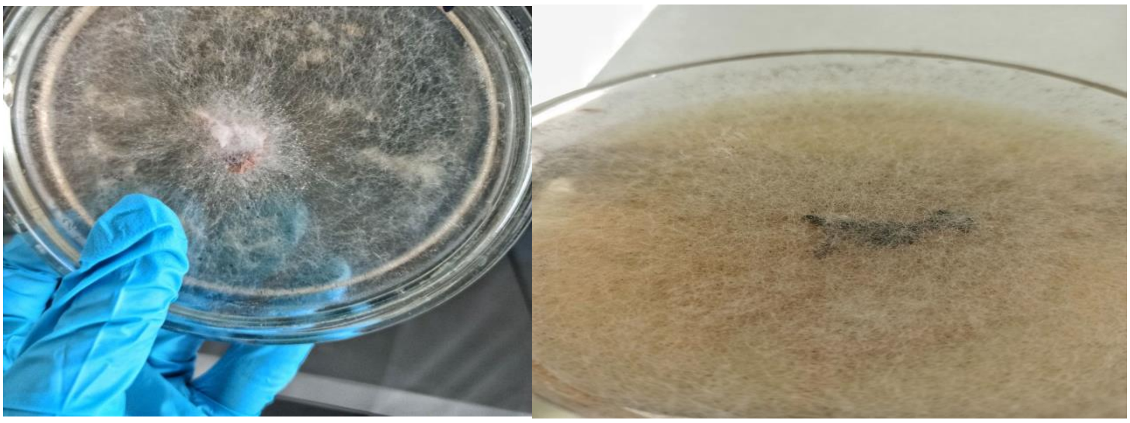
We note that during the experiment there is an active transformation of carbohydrates of vegetable waste by the presented microflora, which was introduced together with the working solutions of two EM preparations. We consider pH=6.3-7.0 and Eh= –100...–200 mV to be the optimal conditions for the biotransformation process. The duration of destruction is 6 days, which also correlates with similar studies (Jarunglumlert, 2018).

According to the generally accepted methods of determining the content of biogenic elements, we determined the quality of the digestate at the end of the 6th day of fermentation, which varies in the range for samples 1–7, mg/l: ammonium nitrogen from 86 to 120, nitrite nitrogen from 10 to 12, nitrate nitrogen from 430 to 480 mg/l, phosphates from 430 to 480, respectively. The obtained results of research indicate the expediency of using digestate as a biofertilizer, since the content of biogenic elements is high enough and needs to be diluted with water in a ratio of 1:2.5.

The next stage is conducting microbiological studies to determine the safety of the digestate from the point of view of the content of *E. coli* and mold fungi, since non-liquid vegetable waste was used, which could not be cleaned, washed and sterilized, and contained soil residues. The use of digestate containing pathogenic cultures is not an acceptable factor in agricultural technologies. In order to identify bacteria of the *Escherichia coli* group, the studied samples were sown on Endo's medium. Due to the use of a working solution with the addition of two EM preparations, which contain a symbiosis of antagonistic bacteria: LAB (*Lactococcus lactis*, *Lactobacillus casei*), *Bacillus subtilis*, *Paenibacillus polymyxa*, no enterobacteria were found in samples 1-7. In sample No. 8 (control, without the addition of EM preparations), the presence of *E. Coli* with a titer of 150 CFU/ml was noted. Unfortunately, the presence of white and green mold was noted in sample No. 8, to which EM preparations were not added (Figs. 4, 5).

a) b)

Fig. 4. Light photo: a) colonies of white mold on carrot waste; b) gray and fusarium fungal disease colonies on beet waste



a) b)

Fig. 5. Light photo: a) aerial mycelium of the causative agent of white fungal disease of carrots on a nutrient medium

b) aerial mycelium of the causative agent of gray and fusarium disease on a nutrient

In the course of the experiment, it was found that white mold got into the vegetable mixture together with illiquid carrots, and gray and fusarium rot - together with beet waste. Potato waste was not affected by pathogens of root crops.

In this study, it was proved that the causative agents of fungal diseases of carrots and beets (*Fusarium Link*, *Sclerotinia sclerotiorum*, *Botrytis cinerea*) are inhibited by the symbiosis of LAB, *Bacillus subtilis*, *Paenibacillus polymyxa*, which are presented in EM preparations, since these representatives have antimicrobial and antifungal effects.

The yeast *Saccharomyces cerevisiae* was detected in Saburo's medium in small quantities (from 2×10^2 to 3×10^3 cells/l), which was isolated from the culture liquid of experimental samples (1-8).

Table 1 shows the number of viable cells of LAB and *Paenibacillus polymyxa*, which were found in the test samples (1-8).

Table 1

The amount of LAB and *Paenibacillus polymyxa* in digestate samples

The number of LAB and *Paenibacillus polymyxa* in samples 1-8	Experiment duration, day					
	2	4	6	10	20	30
	Titer of viable cells, cells/ml					
LAB:						
1	$3,2 \times 10^7$	$1,1 \times 10^7$	$7,1 \times 10^6$	$3,1 \times 10^6$	$8,1 \times 10^5$	$2,9 \times 10^5$
2	$2,4 \times 10^7$	$8,0 \times 10^6$	$4,0 \times 10^6$	$1,8 \times 10^6$	$7,9 \times 10^5$	$1,2 \times 10^5$
3	$1,2 \times 10^7$	$5,6 \times 10^6$	$2,1 \times 10^6$	$7,7 \times 10^5$	$1,7 \times 10^5$	$8,0 \times 10^4$
4	$2,7 \times 10^7$	$7,7 \times 10^6$	$5,2 \times 10^6$	$2,5 \times 10^6$	$6,4 \times 10^5$	$2,1 \times 10^5$
5	$3,0 \times 10^7$	$9,0 \times 10^6$	$6,8 \times 10^6$	$3,3 \times 10^6$	$7,0 \times 10^5$	$3,0 \times 10^5$
6	$5,8 \times 10^7$	$5,5 \times 10^7$	$4,5 \times 10^7$	$1,5 \times 10^7$	$3,5 \times 10^6$	$1,5 \times 10^6$
7	$7,0 \times 10^7$	$6,8 \times 10^7$	$5,9 \times 10^7$	$2,4 \times 10^7$	$5,0 \times 10^6$	$3,0 \times 10^6$
8	$5,0 \times 10^5$	$2,3 \times 10^5$	$2,0 \times 10^5$	$5,0 \times 10^4$	$1,9 \times 10^4$	$7,9 \times 10^3$
Paenibacillus polymyxa:						
1	$7,5 \times 10^5$	$5,5 \times 10^7$	$6,0 \times 10^7$	$3,5 \times 10^6$	$2,0 \times 10^6$	$8,9 \times 10^5$
2	$4,9 \times 10^5$	$4,9 \times 10^7$	$5,8 \times 10^7$	$3,4 \times 10^6$	$1,8 \times 10^6$	$7,5 \times 10^5$
3	$7,8 \times 10^5$	$6,2 \times 10^7$	$6,3 \times 10^7$	$4,0 \times 10^6$	$2,8 \times 10^6$	$8,8 \times 10^5$
4	$5,0 \times 10^5$	$9,3 \times 10^6$	$1,0 \times 10^7$	$6,5 \times 10^6$	$8,5 \times 10^5$	$2,1 \times 10^5$
5	$6,5 \times 10^5$	$1,5 \times 10^7$	$2,3 \times 10^7$	$8,5 \times 10^6$	$1,5 \times 10^6$	$6,9 \times 10^6$
6	$8,3 \times 10^5$	$6,8 \times 10^7$	$7,2 \times 10^7$	$2,5 \times 10^7$	$2,6 \times 10^6$	$9,5 \times 10^5$
7	$9,5 \times 10^5$	$7,7 \times 10^7$	$8,0 \times 10^7$	$4,3 \times 10^7$	$3,1 \times 10^6$	$1,0 \times 10^6$
8	not found	not found	not found	not found	not found	not found

The results presented in Table 1 show that in samples 1, 6, 7, to which additional substrates were added, an increase in the number of studied microorganisms was recorded. On the 2nd day, in samples 1-7, an increase in the titer of LAB, which participates in the hydrolysis process, is noted. After 4 days of fermentation, there is a decrease in the presence of LAB in all samples, which corresponds to the generally accepted provisions on the process of bioconversion of vegetable waste, since the stage of acetogenesis has begun. At the stage of hydrolysis, complex biopolymeric compounds (proteins, carbohydrates, cellulose, etc.) are biotransformed into simpler oligo- and monomers (amino acids, sugars, fatty acids, and water). At this stage, organic substances are fermented by extracellular enzymes of microorganisms (amylase, lipase, protease), as well as the transfer of dry substances from an insoluble state to a soluble state occurs.

In general, hydrolysis occurs very slowly, as it depends on exoenzymes (extracellular enzymes), which, attaching to the cell wall of bacteria, turn complex organic substances into small water-soluble molecules. Therefore, sometimes this process can limit the entire process of biohydrogen formation, since the next stages cannot begin without the end of hydrolysis. The process when the formed monomers are converted by fermenting microorganisms (lactic acid bacteria) into a number of simple compounds: fats, acids, alcohols, lactic acid, methanol, CO_2, H_2, NH_3 and H_2S. At this stage, anaerobic microorganisms utilize the remaining oxygen, creating conditions for the next two stages. At a pH close to neutral, unstable fatty acids (acetic, propionic, butyric, etc.), low-molecular alcohol and gases are synthesized, after which a sharp decrease in pH occurs, i.e., an oxidation process occurs. At the end of the second to sixth day, inclusive, the acetogenic stage of waste bioconversion takes place, namely, the process of converting previously formed products into acetate and a large amount of hydrogen. It is this stage that is key and final in the production of biohydrogen. The formation of a large amount of acetic acid, carbon and CO_2 is recorded. No *Paenibacillus polymyxa* was detected in the control sample No. 8, because we did not add the working solution.

The technology of biotransformation of vegetable waste proceeded according to the following stages: preparation and grinding of waste, the main fermentation process, separation of the liquid fraction from the solid fraction, storage of the liquid fraction of the digestate at a temperature of 4 ^{o}C without access to light. It is recommended to distribute the solid fraction (sediment) immediately to the fields.

Conclusions. An urgent problem today, both in Ukraine and in the EU countries, is the issue of accumulation and processing of organic waste, in particular, vegetable waste. Compressed under tons of garbage and soil, waste without the presence of specific microorganisms does not decompose. That is why, unfortunately, vegetable waste that is not properly prepared does not become compost by itself, therefore the processes of rotting lead to the deterioration of the sanitary condition of the soil and the pollution of groundwater. The process of bioconversion of vegetable waste (beetroot, carrot and potato) by a specific consortium of EM-preparations microorganisms - "Baikal-EM 1" and "Organic-balance" is proposed. The photocalorimetric method confirmed the sufficient content of biogenic elements in the liquid fraction of the digestate, which allows it to be recommended for use for soil fertilization. The novelty of the study consists in the use as additional carbon sources of expired bread in the amount of 10% and lactulose in the amount of 2 and 4% relative to the mass of waste. As a result of biotransformation of vegetable waste, digestate and biohydrogen were obtained in 6 days of fermentation. It has been proven that the quality of the digestate remains at a sufficiently high level in terms of microbiological and physicochemical indicators at a temperature of 4 ^{0}C for 30 days, provided that the solid fraction is separated from the liquid immediately after the fermentation process is finished. Soils usually lack many types of beneficial microorganisms for their recovery. Experiments have proven that the obtained digestate does not contain pathogenic cultures, on the contrary, it contains useful soil microorganisms, which are classified as nitrogen fixers and antagonists in relation to pathogenic cultures, especially molds.

The proposed method of decomposition of organic waste can be used not only in the conditions of small households, but also on large agricultural farms, which are engaged in the cultivation of vegetable crops, their storage throughout the year and conservation. At these agricultural enterprises, great attention is paid to the liquidity of products for further sale. Unfortunately, vegetable losses account for 30-40% of the harvest.. Therefore, the implementation of this method of bioconversion of vegetable waste is also relevant for large volumes of waste. An example of the European experience of using this practice of processing vegetable waste is the agricultural farm of Janis Winter (Latvia). On the farm, up to 75 tons of crushed organic vegetable waste is loaded into the bioreactor in one fermentation cycle. Non-liquid vegetables (carrots, beets, potatoes and other agricultural waste) or vegetables with signs of rotting are used as raw materials on this farm. Waste in the form of expired bakery products is used exclusively to intensify the fermentation process, that is, as an additional substrate. According to Directive 2008/98/EC, this farm implements a full technological waste-free process of growing and processing vegetable crops: growing vegetables in the fields and in greenhouses, their harvesting, preservation and storage throughout the year, processing of generated waste into biogas and biofertilizer and wastewater treatment, which together with the digestate are fed to the fields (Fig. 6).

а ***б*** ***в***

Fig. 6. An example of digestate (biofertilizer) storage in lagoons near agricultural fields: *a* – digestate storage lagoon; *b* – redistribution of digestate through pipelines; *c* – collection of the solid fraction of the digestate

The digestate formed after fermentation is separated into liquid and solid fractions. The liquid fraction contains 3% of the dry mass, it is stored in lagoons (Fig. 6), and thanks to the pipelines, it is distributed among nearby fields (within a radius of 20 km), whereas the solid fraction is sent to fields far from the farm. In the cold season (from November 15 to March 15), the lagoons must be completely emptied. The formed digestate (Fig. 6) is used as a biofertilizer in fields intended for growing vegetables. Today, more than 90% of Latvian biogas cogeneration plants, which enable households and farmer-entrepreneurs to more efficiently use agricultural by-products (manure, straw, vegetable waste and food waste), enable to obtain electrical energy, thanks to support and motivation from the leadership of Latvia and EU countries. As of today, 52 cogeneration stations are operating in Latvia, the capacity of which is about 0.83 MW with the production of electric energy of 6600 MW h/year.

Thanks to cogeneration biogas plants, the obtained biogas can be turned into electricity. According to the information provided by the management of the Janis Winter's "Līgo" farm, it is possible to obtain 1 MW of electricity from 450 m^3 of biogas, which contains 52% biomethane. This farm uses electricity for its own needs (heating greenhouses, lighting, hot water), and the surplus is sold.

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CORRELATION ANALYSIS OF THE WATER QUALITY INDICATORS ON THE SMALL RIVER

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Abstract. *Small rivers form the water resources of medium and large rivers, hydrochemical water quality and creating lands large areas.*

Purpose is determination of interdependencies between hydrochemical indicators of surface water quality on the example of a small river as a limiting factor of formation of aquatic ecosystem of territories.

Correlation analysis of the studied indicators of water quality were conducted on an average value of each indicator (pH, phosphates, nitrates, BOD_5, COD, soluble oxygen) for the period from 2007 to 2021. Found a significant increase in phosphates with time. Positive changes are founded in water object that is related to a decrease in the value of BOD_5. This is due to a decrease in the number of use of oxygen on oxidation of inorganic and organic substances. In general, the use of river runoff of the river above normal, and the overall environmental state of river basin is defined as "extremely poor".

Periods were determined with exceeding the MPC for hydrochemical indicators of water quality; the sources of the input of pollutants into the water object were identified and analyzed. Weak correlations between BOD_5, COD and nitrates, phosphates were determined. These confirm the fact of increasing BOD_5 and COD due to non-oxine-containing forms of phosphorus and nitrogen compounds. A further perspective is to study ways to reduce the supply of phosphates to the water body.

Introduction. Environmental monitoring is one of the country's priorities towards achieving the goals of sustainable development. The one is the goal of the roadmap for the implementation of environmental policy in Ukraine, as a country that has set a course for European integration in terms of implementing programmes aimed at national security and sustainable development of society. Environmental issues outlined in the legislation and regulations of the European Union, namely: Millennium Development Goals (Millennium Development Goals, 2015); Objectives of 2050 of the Seventh Environment Action Programme (7th Environment Action Programme, 2013; Ishchenko et al, 2019), Water Framework Directive 2000/60/EC (Directive 2000/60/EC of the European Parliament and of the Council, 2000; Charis and Galanakis, 2010); Industrial Pollution Directive 2010 /75/EU (Directive 2010/75/EU of the European Parliament and of the Council, 2010); Water Code of Ukraine (Water Code of Ukraine,1995.

The scientific works of scientists have acquired significant scientific significance in the study of environmental problems related to water resources management and anthropogenic impact on the state of water bodies. Staddon C. et al. study the socio-economic issues of water resources management, the structure of water consumption in different countries (Staddon, 2016).

Meyer A.M., Klein C., Fünfrocken E., Kautenburger R., Beck H.P. et al. study the correlations between chemical components, as well as the patterns of distribution of pollutants in the aquatic environment, study the problems of pollution of small rivers (Meyer et al., 2019; Mitryasova and Pohrebennyk, 2017; Mitryasova et al., 2020).

Obolewski K., Glinska -Lewczuk K., Szymanska M., Astel A., Lew S. study the issues of green chemistry of water bodies, search for patterns between the content of chemical components of the aquatic environment and its biological component (Obolewski et al., 2018).

Issues of assessing the impact of industrial enterprises on the water resources state present in the works Kapelewska J. et al. (Kapelewska. et al., 2019). Schickele A. et al. investigate the influence of temperature on the morphological composition of water bodies (Schickele et al., 2020).

The works of Snizhko S. et al. became especially important issue - multifactorial impact on surface water quality (Snizhko, 2004); Grebin V. et al. - regional landscape-hydrological analysis of the modern water regime of the rivers of Ukraine (Grebin and Khilchevskyi, 2016). Thus, the study of Grebin V. and Khilchevsky V., in accordance with the requirements of the Water Framework Directive developed a method of hydrographic zoning of rivers of Ukraine, assessment of aquatic ecosystems.

Vasenko O. et al. develop methods of comprehensive assessment of water bodies taking into account the factors of degradation processes, carry out scientific research to improve the methodology for establishing environmental standards of surface water quality, taking into account landscape and geographical features of aquatic ecosystems, ranking of observation points (Vasenko et al., 2016; Bezsonov et al., 2017; Pohrebennyk et al., 2019; Mitryasova and Pohrebennyk, 2020a).

However, a comprehensive analysis of water resources from the standpoint of assessing the state of small rivers for effective integrated management for sustainable development of the region and achieving proper environmental status of water bodies, in accordance with Ukrainian legislation and the Water Framework Directive, processes of adaptation to EU environmental policy.

Small rivers are an important component of the natural environment. Small rivers form the hydrochemical conditions of water resources and water quality of medium-sized and large rivers, creating landscapes large areas. An important feature of small rivers in the fact that they are the starting point of the river network, and any changes that occur in their mode, marked on the hydrological chain (Tanriverdi et al, 2010; Pohrebennyk et al., 2016; Zeinalzadeh and Rezaei, 2017; Zhang et al. 2018; Alifujiang et al., 2021; Thuy et al., 2021; Mitryasova et al., 2021b; McBean et al., 2022; Tha et al., 2022; Ward, 2021). Water resources of small rivers are part of the shared water resources and are often the main and sometimes the only one source of local water. Small rivers have a number of features that need to be considered when developing environmental management measures (Petrov et al., 2020). The first is the dependence of water content, hydrological regime and water quality of small rivers on the state of the catchment. The second is climatic and weather factors (Mazlum et al., 1999; Mitryasova et al., 2021a; Arndt et al. 2022).

The object of the research is a small river Mertvovod in Mykolaiv region (Ukraine).

The length of the river is 114 km, the area of the drainage basin is 1820 km². The river valley is predominantly trapezoidal, width up to 3 km, depth up to 40 -50 m. The floodplain is 200-300 m wide, up to 1-1,5 km below the ground. The generator is twisted; its average width in the lower reaches is up to 20 m. The slope of the river is 1,8 m/km (Southen Bug River Basin Management in Mykolaiv Region, 2021).

Monitoring studies are conducted by Southern Buh River Basin Management in Mykolaiv region at the point of monitoring near Voznesensk (Mykolaiv region, Ukraine) (fig. 1)

Fig. 1. The sampling point location on the Mertvovod River.

Materials and Methods. The study methods were used: observation; comparisons and analogies; analysis; synthesis; generalization. Also we have used for the research: Google Maps, Microsoft Excel, Origin software. Calculations are made using the correlation formulas 1 and 2 (Buda and Jarynowski, 2010; Kupalova, 2008; Mitryasova et al., 2021):

$$r = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2\sum(y-\bar{y})^2}} \quad (1)$$

r = -1; +1

where x, y are the numeric values of the variables, which set the correlation connection; where $\bar{x}, \bar{y}$ – – average arithmetic value.

$$R = \sqrt{1-(1-r_{yx1}^2)(1-r_{yx2/x1}^2)} \quad (2)$$

r = 0; +1

where r_{yx1} – doubles correlation coefficient;

$r_{yx2/x1}$ – partial correlation coefficient.

To describe the magnitude of the correlation coefficient are the following, which are presented in table 1.

Table 1

Correlation coefficient interpretation

Value	The correlation coefficient interpretation
≤ 0,2	very weak
≤ 0,5	weak
≤ 0,7	average
≤ 0,9	high
≥ 0,9	very high

Correlation analysis was used to find quantitative relationships between natural water quality indicators (pH, phosphates, nitrates, COD (chemical oxygen demand), O_2). Trend analysis using the Shapiro-Wilk test in the Origin program allowed to determine changes in the water body.

To study the relationship between the indicators of surface water quality on the small river example, three integrated indicators were selected, namely soluble oxygen, pH, COD, BOD_5 (biochemical oxygen demand) as well as hydrochemical parameters that fall into the risk zone are: nitrates, phosphates and ammonium for the period from 2007 to 2021.

The value of pH characterizes the active acidity, its value is influenced by the following factors:

- the content of carbon dioxide and oxygen in the water;
- content of humic acids;
- the presence of heavy metal ions;
- temperature regime of the reservoir.

The content of hydrogen ions of natural reservoirs is determined by the quantitative ratio of carboxylic acid and its ions by chemical equation 1:

$$CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^- \leftrightarrow 2H^+ + CO_3^{2-} \qquad (1)$$

The formation of bicarbonates occurs due to the dissociation processes of equations 2 and 3:

$$Ca(HCO_3)_2 \leftrightarrow Ca^{2+} + 2HCO_3^- \qquad (2)$$

$$Mg\ (HCO_3)_2 \leftrightarrow Mg^{2+} + 2HCO_3^-. \qquad (3)$$

Due to the hydrolysis of bicarbonates, the pH increases according to the chemical equation 4:

$$HCO_3^- + H_2O \leftrightarrow CO_2 + OH^- \qquad (4)$$

Surface waters with low carbon dioxide content have a slightly alkaline reaction medium; the pH≤7 with large amounts of CO_2. pH values are closely related to the processes of photosynthesis due to the consumption of carbon dioxide by aquatic vegetation. The source of hydrogen ions is also humic acids, which are contained in soils.

During the hydrolysis of heavy metal salts, strongly acidic waters with pH≤3 are formed (chemical equation 5):

$$FeSO_4 + 2H_2O \leftrightarrow Fe(OH)_2 + 2H^+ + SO_4^{2-} \qquad (5)$$

Such waters are formed when significant amounts of iron, aluminum, copper and many other heavy metals ions enter the water. A similar process of oxidation of heavy metal sulfides occurs during the discharge of mine water by chemical equations 6 and 7:

$$2FeS_2 + 7O_2 \rightarrow 2FeSO_4 + 2H_2SO_4 \qquad (6)$$

$$4FeSO_4 + 2H_2SO_4 + O_2 \rightarrow Fe_2(SO_4)_3 + H_2O \qquad (7\ )$$

The sources of hydrogen ions are humic acids. Acidic, weakly acidic waters (pH = 3 -6.5) are formed during the decomposition of organic compounds, as well as the influx of carbon dioxide and sulfonic acids. Therefore, the pH value of natural waters depends on the content of carbon dioxide, humic and other organic acids, as well as the content of cations of weak bases (ammonium ions, aluminum, iron, organic bases). In these cases, the pH is not below 4.5.

High values of COD and BOD_5 in natural waters are due to a number of indicators, namely the high content of inorganic and organic pollutants, humic substances, hydrogen sulfide, sulfites, sulfides, nitrites, ammonium nitrogen.

Results and Discussions

The correlation nexus between COD, phosphates and nitrates.

Phosphates and nitrates, as the main forms of the most important nutrients of Phosphorus and Nitrogen, often limit the development of water productivity. Therefore, the inflow of excess phosphorus and nitrogen compounds from the catchment (in the form of mineral fertilizers with surface runoff from fields (for example, from a hectare of irrigated land is taken out 0 4-0.6 kg of phosphorus), with runoff from farms (0.01-0.05 kg/day per animal), with untreated or untreated domestic wastewater (0.003-0.006 kg/day per capita), as well as with some industrial waste leads to a sharp uncontrolled increase in plant biomass of the water body (This is especially true for stagnant and low-flowing reservoirs.) There is a so-called change in the trophic status of the reservoir, accompanied by the restructuring of the entire water community and most importantly to the predominance of putrefactive processes.

The presence of nitrates in natural waters is associated with:

- internal processes in the reservoir - nitrification of ammonium ions with the participation of oxygen under the action of nitrifying bacteria;
- atmospheric precipitation, which absorbs oxides of nitrogen formed during atmospheric electric discharges (the concentration of nitrates in precipitation reaches 0.9 - 1 mg;
- industrial and domestic wastewater, especially after biological treatment, when the concentration reaches 50 mg/dm^3;
- runoff from agricultural lands and runoff from irrigated fields where nitrogen fertilizers are applied.

The main processes aimed at reducing the concentration of nitrates are their consumption by denitrifying bacteria and phytoplankton, which in the absence of oxygen use nitrate oxygen to oxidize organic matter.

In surface waters, nitrates are in dissolved form. The concentration of nitrates in surface waters is subject to seasonal fluctuations: minimal in the growing season, it increases in autumn and reaches a maximum in winter, when the minimum consumption of nitrogen is the decomposition of organic matter and the transition of nitrogen from organic to mineral forms. The amplitude of seasonal fluctuations can be one of the indicators of eutrophication of a water body.

The value of COD in all investigated samples exceeded the maximum permissible concentration, minimum value – 15,24 mgO_2/dm^3 and maximum – 68,6 mgO_2/dm^3 (MPC < 15 mgO_2/dm^3).

Exceeding the maximum permissible concentrations by phosphates and nitrates were observed. Exceeding the maximum permissible concentration of COD is associated with oxidation of organic substances which fall into natural water from surface runoff and dumping sewage. There was a weak correlation between indicators (fig. 2). This confirms the fact that high COD values may be due to oxygen-free compounds of nitrogen and phosphorus, such as ammonium phosphide forms. So, with the increase of phosphates COD vice versa decreases, which is typical. The increase of phosphates is caused with deterioration of the river water quality due to the discharge of domestic sewage.

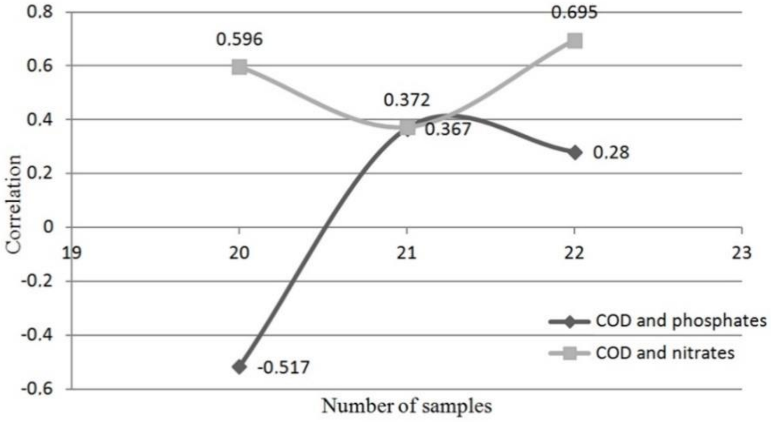

Fig. 2. The nexus between COD and phosphates, and nitrates.

The correlation nexus between soluble oxygen, nitrates and pH.

The values of soluble oxygen in the water were in the norms and were > 4.00 mgO_2/dm^3. The values of nitrates were in the norms and not exceeded MPC. Value of pH were in the rules in not all the samples and was up 8.74 (MPC of pH = 6.5–8.5).

The smallest dependence observed between O_2, nitrates and pH (fig. 3.) Correlation coefficient equals about 0.36, that is, there is a weak dependence between parameters. In the period the soluble oxygen (O_2) decreases, and nitrates on the contrary increase that is typical of data indicators and associated with the maximum increase of COD in the given period that makes up 52.47 mgO_2/dm^3 (MPC < 15 mgO_2/dm^3).

Such excess, allow the claim about water pollution by organic and inorganic substances. Oxidation -reduction process of conversion of nitrogen-containing compounds into nitrates occurs.

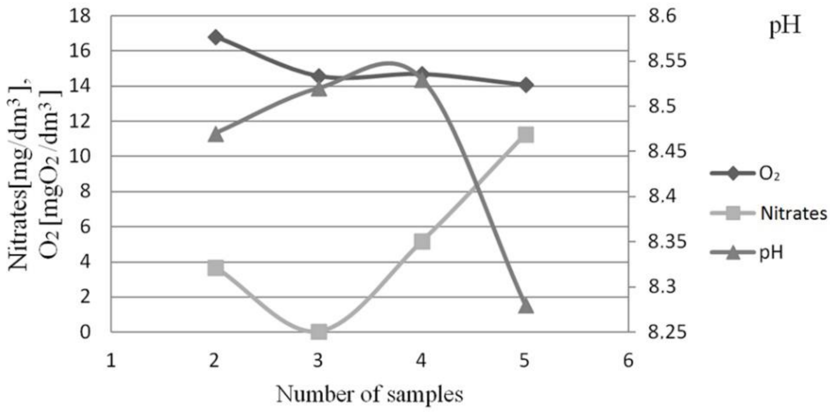

Fig. 3. The nexus between by soluble oxygen, nitrates and pH.

The correlation nexus between BOD_5, phosphates and nitrates.

In the studied period there was observed exceeding of MPC by BOD_5, the maximum value of which was 20.4 mgO_2/dm^3 (MPC < 3 mgO_2 $/dm^3$). The correlation changes in most cases from 0.6 to 1.0 which indicating on close functional connection.

Excess value of BOD_5 confirms receipt of the organic substances of plant and animal origin. With a high content of organic matter in the water, aerobic bacteria multiply rapidly, which require oxygen to function. This can lead to a decrease in the content of dissolved oxygen, create hypoxic conditions and the death of certain species of organisms that live permanently in the aquatic environment. The smallest correlation is observed between BOD_5, phosphates and nitrates (r = 0.31) that is weak link between indicators. Also this confirms the fact that high BOD_5 values may be due to oxygen-free compounds of nitrogen and phosphorus, such as ammonium phosphide forms. So, with the increase of phosphates BOD_5 vice versa decreases, which is typical also.

A sharp increase of nitrates is observed, which is 25.6 mg/dm^3 (with MPC=45 mg/dm^3) (fig. 4). The concentration of nitrates is subject to seasonal variations: the minimum is in the growing season, the maximum is in autumn, when the organic substances decay and nitrogen compounds transition from organic forms in the mineral. Nitrates come mainly from surface runoff, which contains residues of used nitrogen fertilizers. Another source of no-waste is groundwater, which can have fairly high concentrations (up to 100 mg/dm^3) and increase the content of nitrates in the areas of discharge into surface waters. Groundwater is the main source of nitrates in the limited period, when the supply of surface water is mainly due to groundwater runoff. There are also a significant number of other sources of nitrates in surface waters: surface runoff from landfills, urban areas, wastewater from animal complexes, urban waste water. In the research period, the maximum concentration of nitrates was observed in autumn. The amplitude of seasonal fluctuations of the nitrates is an indicator of the eutrophication of the water object.

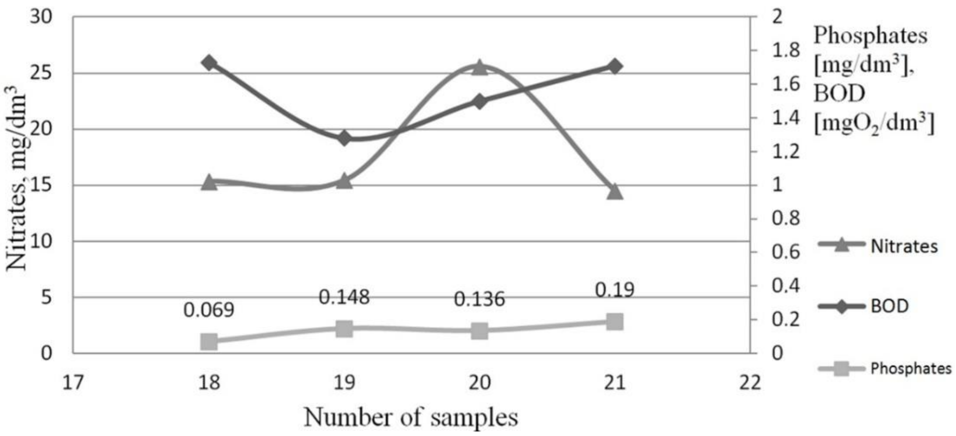

Fig. 4. The nexus between BOD_5, phosphates and nitrates.

The correlation nexus between pH, ammonium and soluble oxygen.

There is excess of MPC on pH that is 8.74 (MPC = 6.5-8.5), exceeding by ammonium, which is 0.84 mg/dm^3 (MPC = 0.39 mg/dm^3), the value of dissolved oxygen is normal and is 4.00 > mgO_2/dm^3. The smallest dependence between parameters observed in the sample №15 and the coefficient of multiple correlation is weak 0.223 (fig. 5).

At the all test period the highest concentration of ammonium is 0.84 mg/dm^3 (MPC = 0.39 mg/dm^3) and meets the sample №17. A sharp increase of ammonium is associated with agricultural ranges, growing downpours the day before sampling.

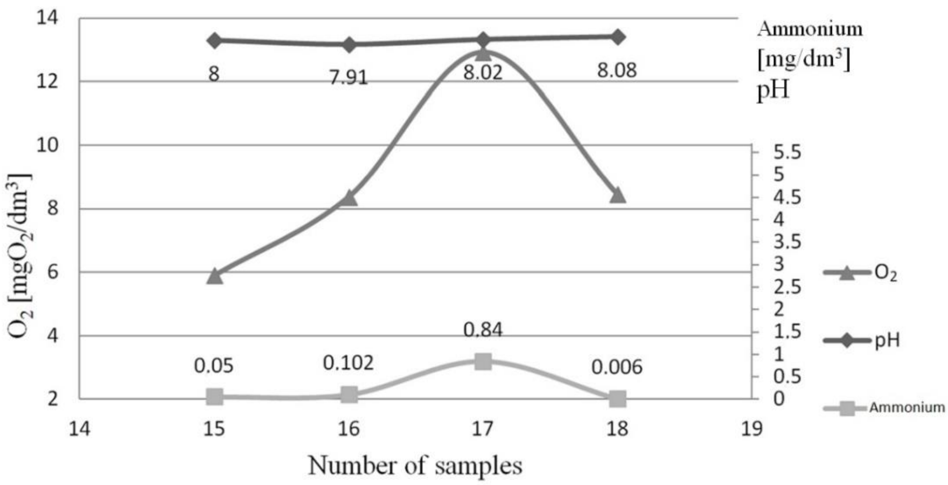

Fig. 5. The nexus between pH, ammonium and soluble oxygen.

Conclusions. The status of the small river is an indicator of the water security of natural surface water. Correlation analysis of dependences between COD, phosphates and nitrates; and also soluble oxygen, nitrates and pH; BOD_5, phosphates and nitrates; pH, ammonium and dissolved oxygen show stable links between chemical components that are caused by chemical interconversions, the influence of external factors (weather conditions, the hydrological regime of the river, the anthropogenic factor).

As a result of the environmental analysis of the river Mertvovod identified periods of excess the MPC by hydrochemical indicators of water quality. The sources of pollutants in the water are discovered and analyzed.

Using of correlation analysis gave a clear idea about weak correlations between BOD_5, COD and nitrates, phosphates. These confirm the fact of increasing BOD_5 and COD due to non-oxine-containing forms of phosphorus and nitrogen compounds. A significant increase by phosphates is detected, which is associated with the collection of cleansers with domestic waters and more with the lack of quality sewer facilities. A significant reduction of COD over the years is detected.

A further perspective is to study ways to reduce the supply of phosphates to the water body. It is also relevant to further study the dependencies between water quality indicators, as well as their interpretation.

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MANAGEMENT OF PACKAGING WASTE IN THE EU AND UKRAINE IN THE CONTEXT OF CIRCULAR ECONOMY PRINCIPLES

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Abstract. *The analysis delves into the specifications outlined in EU regulations concerning packaging and its treatment within the context of waste management. An assessment is made of the recycling rates pertaining to packaging waste across the EU's member states. Concrete instances are furnished to exemplify proficient methods for effectively managing such waste in adherence to the principles of the circular economy. And although the EU has achieved high levels of recycling and waste recovery, the amount of packaging waste continues to grow year after year. As a result, the EU is actively immersed in the process of reevaluating its legislation, particularly within the domain of waste management. Central aspects of the newly introduced EU Proposal for Packaging and Packaging Waste Regulation are outlined including recyclability and reusability issues related to packaging waste treatment. For comparison, the situation with waste management in Ukraine is considered. Statistical data showing that the level of waste recycling and recovery is unsatisfactorily low are given. The main obstacles to achieving high rates of waste recycling are highlighted, as well as possible ways of more effective management of packaging waste in Ukraine are investigated. The need to adapt national legislation to EU legislation regarding the handling of packaging waste is emphasized, especially given Ukraine's aspirations for European integration. The importance of the EU's achievements in the field of waste management, in particular, regarding packaging waste, is emphasized as very relevant and instructive for Ukraine.*

Introduction. Lately, the problem related to the environmental deterioration and the depletion of natural resources has reached unprecedented levels. Across the globe, numerous countries have directed their attention towards combatting the escalating challenge of global warming, attributed to the growing emission of greenhouse gases into the atmosphere. Notably, the European Union (EU) has emerged as a prominent advocate in the battle against climate adversities. With a target set for 2050, the EU aims to attain climate neutrality. This endeavor involves a gradual transition by EU member states from a linear economic model to a circular economy—a paradigm characterized by resource circulation.

On the 11th of March 2020, the European Commission introduced the Circular Economy Action Plan (European Commission, Directorate-General for Communication, 2020a), a pivotal component of the European Green Deal (European Commission, 2019) strategy. This plan is designed to curtail resources consumption rates within the EU, increase the reutilization of resources in the forthcoming decades, and concurrently stimulate economic growth. Comprehensive in scope, the Plan encompasses the complete product lifecycle, from inception and production to consumption, repair, reuse, recycling, and the reintroduction of resources into the economy. Hence, a central facet of building a circular economy involves optimizing resource usage and adopting innovative approaches to waste management, particularly concerning packaging waste. Within the EU, robust emphasis is placed on effective packaging waste management. A slew of organizational and legislative measures has been implemented to curtail packaging waste generation and enhance the efficiency of waste management. Thanks to the established measures, EU member states have been able to achieve some success in managing packaging waste and building effective systems for recycling and recovery of waste. As for Ukraine, it can be noted that the amount of waste generation continues to grow, and the level of its processing, for example, recycling or recovery with obtaining energy, remains at a low level. Given this context, the exploration and application of the EU's experience holds exceptional relevance for Ukraine.

The objective of the research is to analyze the organizational and legal systems of the EU and Ukraine in the field of packaging waste management and consider possible ways to improve the packaging waste management system in Ukraine based on European experience.

Materials and methods. The analysis drew upon regulatory frameworks from both the EU and Ukraine within the realm of waste management. Additionally, analytical reports, scholarly publications addressing challenges and advancements in waste management, specifically in the context of packaging waste, along with statistical data were analyzed.

Presentation of the main results of the study. The general principles concerning waste management are outlined in Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives (Waste Framework Directive) [EU, 2008]. The Directive delineates the hierarchy guiding waste management practices, with foremost emphasis placed on waste prevention, while waste disposal receives the least priority.

It should be noted that the Waste Framework Directive is the most general, which applies to all types of waste. In 2018, this Directive was amended, which is reflected in Directive (EU) 2018/851 (EU, 2018a). Issues related to requirements for packaging and handling of packaging waste are regulated by Directive 94/62/EC (EU, 1994) of the European Parliament and the Council of December 20, 1994 on packaging and packaging waste (PPWD). PPWD has been repeatedly revised. The last revision was adopted in 2018 (EU, 2018b). PPWD encompasses specific objectives for the recovery of packaging waste, as well as contingent upon the nature of the packaging material. In the wake of the most recent update to the PPWD, a mandated objective is established that, by 2025, a minimum of 65% of packaging waste, by weight, must undergo recycling. Furthermore, this target is slated to rise to 70% by the year 2030. The PPWD also outlines tailored goals, delineated by the packaging material, to be achieved both in 2025 and 2030. These specific targets pertain to materials such as plastic, wood, ferrous metals, aluminum, glass, as well as paper and cardboard. Notably, for plastic packaging, the recycling target set for the year 2030 stands at 55%.

The regulation governing the domain of packaging waste generation and management has resulted in notable advancements. Figure 1 illustrates the recycling rates of packaging waste within the EU for the year 2020 (data sourced from Eurostat, 2023). Collectively, an impressive 64% of packaging waste underwent recycling. When evaluating the processing of packaging waste according to the specific packaging materials, the highest recycling rate is recorded for paper and cardboard packaging waste, standing at 81.5%. Metal packaging waste (75.7%) and glass packaging waste (75.9%) have comparable recycling levels. Lower levels of recycling were achieved for plastic and wooden packaging (37.6% and 31.9%, respectively).

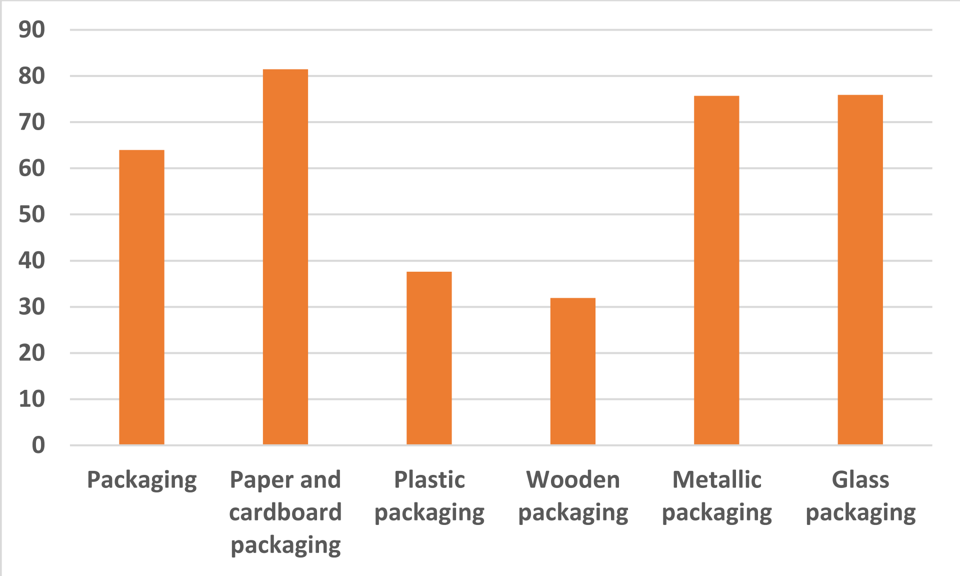

Fig. 1. Recycling rate (%) of packaging waste in the EU in 2020 (Eurostat, 2023a)

Figure 2 displays the accomplishments in packaging waste recycling across individual EU member states. According to Eurostat statistics for the year 2020, Belgium secured the highest recycling rate for packaging waste, reaching an impressive 79.7%. The second and third positions were claimed by the Netherlands and Finland, attaining recycling levels of 76.5% and 73.2%, respectively.

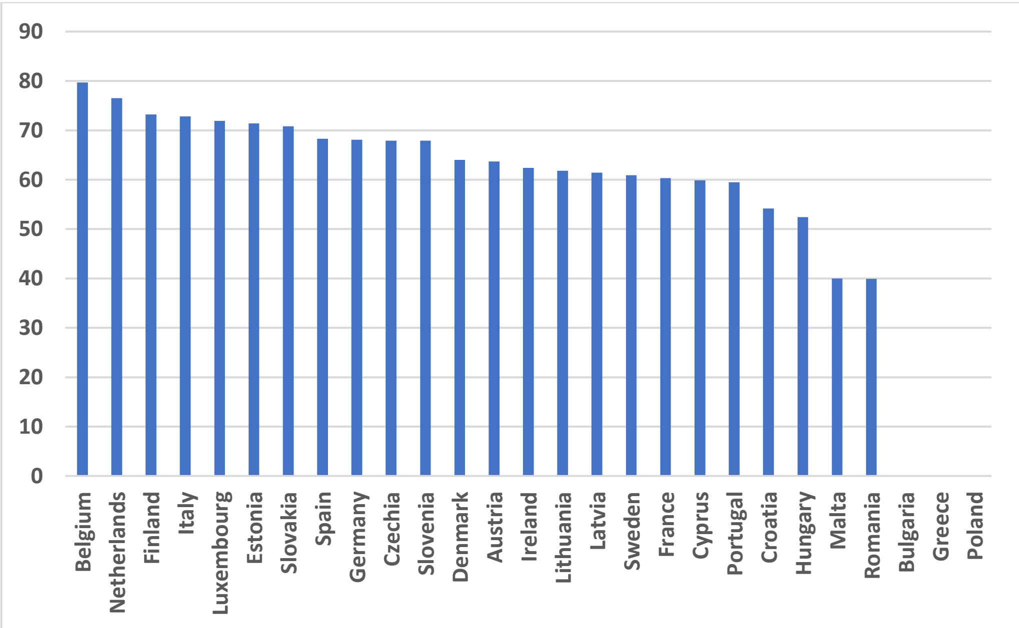

Fig. 2. Recycling rate (%) of packaging waste in the EU in 2020; data for Bulgaria, Greece and Poland are not available (Eurostat, 2023b)

EU member states use different models for packaging waste management systems. For example, an identifying feature of the French approach involves a central coordinating body responsible for establishing the environmental impact fee. This fee is subject to fluctuations through a system of incentives and penalties based on the packaging's recyclability. The extent of this fee adjustment provides advantages to those who align with the preventative program directives. Entities tasked with certifying the packaging's recyclability also extend their support to users engaged in eco-design endeavors (Di Foggia, G., & Beccarello, M., 2022). The Portuguese system stands out with its waste trading platform, acting as a nexus for waste transactions that effectively balances supply and demand, thereby stimulating market growth. This system in Portugal holds promise as a means to foster the expansion of secondary raw material markets (Di Foggia, G., & Beccarello, M., 2022). The European Commission's website offers valuable resources that provide insights into the waste management status of individual EU member states. It presents comprehensive analyses of the challenges and opportunities within this domain, accompanied by pertinent recommendations aimed at enhancing waste management systems within each country. Additionally, the website showcases exemplary practices that can serve as models for emulation (European Commission, Directorate-General for Environment, 2023b). The following can be cited as examples of good practices. For example, in Sweden there is a ban on landfilling certain types of waste, such as organic waste and combustible waste. This, among other measures, made it possible to reach the share of waste disposed of in landfills up to 1% (European Commission, Directorate-General for Environment, 2023c). In Austria, a very interesting practice of taxation in the field of waste management has been implemented. The fee for waste disposal at landfills depends, first of all, on the type of waste. Secondly, the received funds are directed to the protection of old landfills. Austria has announced the remediation of contaminated sites by 2050 (European Commission, Directorate-General for Environment, 2023d). In Ireland, a national campaign has been launched to increase the awareness of the general public in the concept of circular economy. At the same time, organizations of extended producer responsibility take part in this campaign (European Commission, Directorate-General for Environment, 2023e). In Finland, an effective system of returning used packaging with reimbursement of its deposit value is used. The convenience of this scheme has resulted in the country achieving very high levels of container return (e.g. plastic bottles 92%, aluminum cans 96%) (European Commission, Directorate-General for Environment, 2023f; ELY Centres, 2023). And the list of such good practices of EU member states can be continued.

However, in spite of notable progress in the realm of packaging waste recycling and recovery, the production of diverse packaging waste types within the EU persists in its upward trajectory. Eurostat data reveals that the quantity of packaging waste generated in the year 2020 escalated to 177.92 kg per person (as depicted in Figure 3). This trajectory stands in contrast to the waste management hierarchy, which places a premium on preventing waste generation at the outset.

Additionally, it's important to recognize the evolving policy landscape that has unfolded since the initial establishment of fundamental prerequisites for handling packaging waste and its treatment. Particularly noteworthy is the European Commission's dedicated endeavor to foster a circular economy, evident in its EU Circular Economy Action Plan. Most recently, the Commission unveiled a Strategy for Plastics in the Circular Economy (European Committee of the Regions, 2018), outlining a vision for the future where, by 2030, all plastic packaging should be designed for reusability or recyclability. This strategy lays the groundwork for a new era of plastics usage—one that prioritizes design, production, and materials used that align with the principles of reuse, repair, recycling, and the advancement of more sustainable alternatives. Concurrently, the Commission has pledged to cultivate a more comprehensive and equitable Single Market. This commitment involves addressing restrictions within the retail sector, encompassing e-commerce, and undertaking a modernization of the EU standards system, all aimed at fortifying cross-border trade.

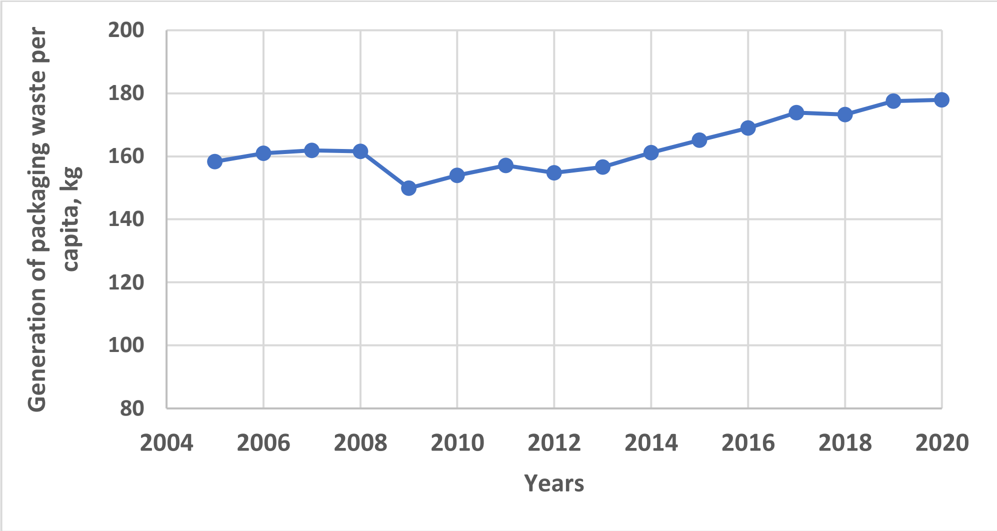

Fig. 3. Packaging waste generation in the EU (Eurostat[c], 2023c)

Taking into account ambitious climate goals of the EU, it was proposed to revise the existing PPWD. The proposed Packaging and Packaging Waste Regulation (European Commission, 2022) distinctly emphasizes the augmentation of packaging's recyclability, reusability, and the integration of recycled elements. The proposed Regulation unequivocally states that the weight and dimensions of each package should be minimized to the greatest extent feasible. Furthermore, the Proposal includes a prohibition on specific types of compact-format packaging. The document is currently undergoing standard legislative scrutiny.

Focusing attention on the situation in Ukraine, the following can be noted. The management of packaging waste stands as an integral facet within the broader framework of solid household waste handling. Presently, this process predominantly involves burying such waste in landfills, many of which are strained beyond capacity and fail to meet stipulated environmental safety standards.

At the national level, there exists a conspicuous shortage of infrastructure for the distinct collection and recovery of packaging waste. This insufficiency culminates in the wasteful loss of a substantial repository of valuable resources, encompassing materials like paper, cardboard, plastic, glass, metals and wood. These materials hold the latent potential for the reintroduction into the economic cycle, subsequently serving as raw materials for the fabrication of novel products.

In 2022, only 9.9% of household waste, which also includes packaging waste, was incinerated or recirculated, namely, 1.66% was incinerated, and 8.24% of household waste went to collection points for secondary raw materials and waste processing lines. The number of overloaded landfills is 163 units (2.8%), while 693 units (12%) do not meet environmental safety standards (Ministry of Community Development, Territory and Infrastructure of Ukraine, 2023).

By signing the Association Agreement between Ukraine, on the one hand, and the European Union, the European Atomic Energy Community and their member states, on the other hand, Ukraine committed to the step-by-step alignment of its waste management regulations with the standards set by the European Union. In the National Report "Sustainable Development Goals: Ukraine" (Ministry of Economy of Ukraine, 2017) (developed on the basis of the global goals of sustainable development), the task of transitioning to the principles of a circular economy was identified as a priority development goal. This report notes the need for the "the introduction of a circular economy model, primarily by focusing on energy saving, sustainable environmentally friendly production and consumption". Another document that sets the task of transitioning to the principles of a circular economy is the National Waste Management Strategy in Ukraine until 2030, approved by Decree of the Cabinet of Ministers of Ukraine dated November 8, 2017, No. 820 (Cabinet of Ministers of Ukraine, 2017). Among the principles on which the strategy is based, the "transition to a closed cycle economy, which assumes that the volume of products, materials and resources is used in the economy as long as possible and the generation of waste is minimized," is also mentioned. The Strategy defines the priorities of state regulation in the field of waste management, taking into account European regulatory documents, in particular Directive 2008/98/EC and Directive 94/62/EC "On packaging and packaging waste".

In 2019, the National Waste Management Plan until 2030 was approved (Cabinet of Ministers of Ukraine, 2019). This Plan provides specific indicators that Ukraine must achieve in the field of waste management, and also notes the need to develop and implement a special law of Ukraine regarding packaging requirements and packaging waste management. As of today, the draft law "On packaging and packaging waste" (Ministry of Environmental Protection and Natural Resources of Ukraine, 2023) is under discussion. The enactment and execution of the "On Packaging and Packaging Waste" law will serve to align national regulations more closely with EU legislation.

The provisions of Directive 2008/98/EC have been implemented into Ukrainian legislation by the Law of Ukraine "On Waste Management" (Verkhovna Rada of Ukraine, 2022). This Law (entered into force on 07/09/2023) provides for the reform of waste management, which will contribute to the transition of Ukraine to models of circular economy and sustainable development, as well as the introduction at the legislative level of the main European approaches and principles, including the five-level hierarchy of waste management and the principle of extended responsibility of the producer.

At the same time, it's crucial to recognize that for building the efficient packaging waste management systems in Ukraine, it is prudent to examine and adopt the exemplary practices observed within EU member states. Acknowledging that waste generation prevention holds prime importance in the EU's waste management hierarchy, it becomes pertinent to elaborate packaging waste management approaches in Ukraine that closely align with the EU's commendable accomplishments in this realm.

Taking into account the achievements of EU member states in the management of packaging waste, we propose the following measures to improve packaging waste management systems at the national, regional and local levels. In our view, the incorporation of mandatory deposit return systems for plastic bottles and aluminum cans in is a vital step, as this practice has proven itself very successfully in some EU member states. Furthermore, in response to conspicuously excessive packaging waste generation, the prohibition of specific packaging types is advisable. For instance, the use of single-use packaging for food and beverages within dining establishments, single-use packaging for fruits and vegetables, and miniature packaging such as hotel shampoo bottles, should either be restricted or altogether banned. In tandem, it's essential to endorse initiatives focused on enhancing the recyclability of packaging. This necessitates the formulation of measures that establish design criteria for packaging, clearly delineating which specific forms of packaging should be compostable, allowing consumers to dispose of them as biowaste. Moreover, the national producers should be compelled to incorporate defined proportions of recycled content within new plastic packaging. This measure aims to elevate the worth of recycled plastic as a valuable raw material.

Lastly, the effective implementation of a "polluter pays" system should be imperative. This system serves to motivate packaging manufacturers to integrate circular economy principles into their production practices.

Conclusions. The present status and regulatory framework governing packaging waste management are examined within the contexts of both the EU and Ukraine. It is shown that various measures undertaken in the EU in the domain of packaging waste management have resulted in notable advancements. At the same time, it is worth noting that the amount of packaging waste continues to grow in the EU, which contradicts the hierarchy of waste management. Therefore, in the near future, the EU plans to update the regulatory document on packaging and packaging waste, one of the goals of which is to reduce the generation of new waste.

In contrast, Ukraine significantly lags behind the majority of EU member states in terms of waste recycling and recovery rates, particularly concerning packaging waste. The predominant practice involves disposing of waste in landfills. To address this, the formulation of waste management legislation, coupled with the enactment of a dedicated law "On Packaging and Packaging Waste," is poised to establish a more efficient organizational and economic framework. This, in turn, will invigorate the integration of packaging waste into a new resource cycle.

Given Ukraine's trajectory towards European integration, the application of superior European practices in packaging waste management, especially in the realms of recycling, reuse, and recovery, holds tremendous significance.

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TOWARDS A SUSTAINABLE FUTURE: EXPLORING THE EUROPEAN DIMENSIONS OF ECOLOGICAL BALANCE AND SOCIAL EQUITY

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Abstract. *Sustainable development is essential for building a prosperous and resilient future for Europe. This article explores the various dimensions of sustainable development in Europe, including environmental, social, and economic sustainability. We used theoretical and empirical research methods in this article. Theoretical methods are analysis, synthesis, generalization and comparison of literary sources. Empirical research methods in this article are observation and measurement. Environmental sustainability in Europe faces challenges such as climate change, biodiversity loss, and pollution. However, there are many successful initiatives being implement, such as the EU Green Deal, to transform the EU economy into a sustainable one. Social sustainability faces issues such as inequality, poverty, and social exclusion, which require policies that promote social cohesion and address these challenges. Economic sustainability involves promoting inclusive and sustainable economic growth, particularly in the face of global challenges such as climate change and technological disruption. To achieve long-term sustainable development in Europe, it is crucial to integrate environmental, social, and economic considerations into decision-making processes. This requires promoting sustainability in all sectors of society, including businesses, governments, and individuals. For the first time, a comparison of three components of sustainable development based on climate change, innovative technologies, and circular economy offered. The principles of sustainable development of ecological, economic and social components improved. Environmental knowledge and competence regarding the implementation of sustainable development in economic and entrepreneurial activities developed. The article concludes by calling for continued efforts towards sustainable development in Europe, highlighting the importance of addressing environmental degradation, reducing social inequalities, and promoting inclusive and sustainable economic growth.*

Introduction. Sustainable development refers to the idea of meeting the needs of the present generation without compromising the ability of future generations to meet their own needs. It encompasses three dimensions: environmental, social, and economic sustainability. Sustainable development is of great importance in Europe, where a balance between economic growth and environmental and social concerns is critical for the well-being of current and future generations. The purpose of this article is to explore the various dimensions of sustainable development in Europe, highlighting the challenges and opportunities that exist, as well as successful initiatives that have been implement to promote sustainability.

In this article, we will examine the current state of environmental, social, and economic sustainability in Europe, and identify the key challenges and opportunities for improving sustainability in each of these areas. We will also discuss the importance of integrating the three dimensions of sustainability for long-term success and highlight successful examples of integrated sustainable development initiatives in Europe.

The scientific novelty of this article. For the first time, a comparison of three components of sustainable development based on climate change, innovative technologies, and circular economy offered. The principles of sustainable development of ecological, economic and social components improved. Environmental knowledge and competence regarding the implementation of sustainable development in economic and entrepreneurial activities developed.

Environmental Sustainability in Europe. Let's consider the issue of Environmental Sustainability in Europe. Environmental sustainability is critical for ensuring a healthy planet and the well-being of all living beings. In Europe, the current state of environmental sustainability varies across different countries and regions. While some areas have made significant progress in reducing greenhouse gas emissions and promoting renewable energy, others continue to struggle with issues such as air and water pollution, deforestation, and loss of biodiversity.

One of the key challenges for improving environmental sustainability in Europe is the need to transition towards a low-carbon economy while simultaneously addressing social and economic concerns. This requires developing innovative technologies, investing in renewable energy, and promoting sustainable land use practices.

Research scientists who research environmental technologies include Tsapko et al [1], Ghofur et al [2], Mislyuk et al [3], Gurgenidze [4], Yatskov et al [5], and Kurbatska et al [6] and other.

In the study [1], the effect of high temperature on the properties of a cable with flame retardant coating investigated. It found that the coating swells and forms a layer of solid particles on the surface of the sample upon heating. This leads to the formation of a barrier to heat penetration, as evidenced by the temperature measurements on the surface and inner side of the sample. Based on the experimental data and established dependencies, the coefficients of thermal conductivity and heat conductivity of wood were calculated, which are equal to $214.4 \cdot 10^{-6} m^2/s$ and $0.62 W/(m \cdot K)$, respectively. This indicates that the swelling of the coating leads to the formation of a heat-insulating layer. The maximum possible temperature penetration through the thickness of the coating also assessed. It found that at a temperature on the surface of the sample, which significantly exceeds the ignition temperature of the polymer sheath of the cable; the temperature on the non-heated surface does not exceed 160°C. In conclusion, the results of the study suggest the possibility of targeted adjustment of the fire protection processes of electrical cables by using coatings capable of forming a protective layer on the surface of the material that slows down the rate of heat transfer.

The study showed, in [2], that peat soil-activated carbon is a promising adsorbent for reducing air pollution from motorized vehicles. It is abundant, easy to make, and effective at reducing CO and HC emissions.

Total, despite these challenges, many successful environmental sustainability initiatives have been implement in Europe. For example, the European Union's circular economy strategy aims to reduce waste and promote resource efficiency, while the EU Biodiversity Strategy seeks to protect and restore Europe's biodiversity. Other initiatives include the Green City Accord, which aims to make cities more sustainable and livable, and the Zero Pollution Action Plan, which aims to reduce pollution across various sectors.

Overall, while there is still much work to be do to improve environmental sustainability in Europe, there are many positive steps be taking towards a more sustainable future.

Social Sustainability in Europe. Let us consider the issue of Social Sustainability in Europe. Ensuring that every member of society has access to basic needs such as healthcare, education, and housing, and can participate in decision-making processes that affect their lives, is crucial for achieving social sustainability. However, the current state of social sustainability in Europe varies across different countries and regions. Some areas have made progress in reducing poverty and promoting social inclusion, while others are still grappling with issues like income inequality, discrimination, and exclusion.

To improve social sustainability in Europe, addressing demographic changes like an aging population and migration is a key challenge. This calls for policies that promote social integration and cohesion, and investments in education, healthcare, and social protection. Despite these challenges, there have been many successful social sustainability initiatives implemented in Europe, such as the European Pillar of Social Rights, which aims to ensure fair working conditions, social protection, and equal opportunities for all Europeans.

Other initiatives include the EU Youth Strategy, which seeks to empower young people and promote their participation in society, and the EU Disability Strategy, which aims to promote the rights and inclusion of people with disabilities. Although significant challenges still need addressed, there are many positive steps implemented towards improving social sustainability in Europe.

The scientists who research society are Dunayev et al [7], Artomova et al [8], Skydan et al [9], Kiran et al [10], and Kunytska-Iliash [11] and other.

For example, authors [7] describe that the object of this study is the factors of implementation of the concept of government as a platform. The study solved the problem of identifying factors and choosing a model for analyzing the conditions for building a socio-technological model of interaction between society and the state. The concept of government as a platform presented in the form of interrelated entities, components of technological infrastructure and digital assets. A feature of the described structure is the consideration of social value, which explained by the principles of the concept under study. The factors of implementation of the concept include professional and personal characteristics of civil servants; organizational structure of the government; legal regulation; financial mechanisms; use of digital technologies of Industry 4.0; digital opportunities of the population and businesses; digital engagement. The identified factors take into account the need to take into account the needs and requirements of citizens, technological readiness, and competence of the government. It established that during 2022 there was a global trend towards an increase in the level of development of e-government. The results of the analysis of user experience on interaction with electronic public services confirm the need to focus on consumers. A theoretical model for adopting the state digital platform developed. The model consists of six independent variables, three intermediate variables, and one dependent variable. In the model, independent variables include tangible ease of use, uncertainty in technology, social pressure, efficiency of work with computer equipment, technical capabilities. Intermediate variables include attitude to use, tangible utility, user satisfaction, and intent to use. The dependent variable is the actual use of technology.

Economic Sustainability in Europe. Let's consider the issue of Economic Sustainability in Europe. In Europe, achieving long-term economic growth while also promoting social and environmental well-being known as economic sustainability. However, the current state of economic sustainability across different countries and regions in Europe varies. While some areas have strong economies with high levels of innovation and competitiveness, others face challenges like high unemployment and low productivity. Promoting inclusive and sustainable growth is one of the key challenges for improving economic sustainability in Europe, particularly in the face of global challenges such as climate change and technological disruption. This requires investing in education and training, research and innovation, and promoting entrepreneurship and small businesses.

Several research scientists study economic processes, including Barseghyan et al [12], Miller et al [13], Biliavska et al [14], John et al [15], and Ratmono et al [16] and other.

For example, authors [12] describe that the relevance of the subject conditioned upon the fact that large park plantations have a great positive impact on the climate of Mediterranean cities, which increases the comfort of living in them. Such weather conditions as abnormal heat are increasingly manifesting in Mediterranean cities due to global warming and other causes. In addition, there is air pollution in cities with solid particles and other impurities harmful to human health. The analysis of scientific literature has demonstrated that in the cities of the Mediterranean, these problems solved through urban park plantings and other types of landscaping. The purpose of this study is to assess the effectiveness of the costs of maintaining large urban park spaces in Barcelona. The leading method to explore this problem is the empirical method, namely, the study of urban landscaping programs and budget expenditures. The research examines the sources of financing the costs of maintaining urban park spaces and considers urban programs for the development of landscaping, and their financing. In addition, the influence of green spaces on the comfort of living in the city of Barcelona explored. Because of the study, it found that landscaping in the city of Barcelona financed for the most part from the city budget, while spending increases annually. It has been identified that the city of Barcelona receives a significant positive effect from investments in green spaces, namely, air pollution decreases, its temperature decreases, people get places for hiking, sports, and other types of activity, the psychological and physiological health of the population improves, the urban environment becomes more comfortable to live in. It is the large park plantings. This park is allow reducing the air temperature, which improves the quality of life in the city.

Regardless of these hindrances, there have been successful economic sustainability initiatives implementing in Europe. For instance, the European Green Deal aims to transform the EU economy into a sustainable one, while the EU Digital Agenda promotes the digital transformation of European businesses and public services. Additionally, the European Investment Plan aims to mobilize public and private investment to support sustainable growth and job creation. In summary, although there is still much work to be done to improve economic sustainability in Europe, many positive steps are being taken towards a more sustainable and inclusive economic future.

Integrating the Three Dimensions of Sustainable Development in Europe. Environmental, social, and economic sustainability are all interconnected and interdependent. Therefore, integrating these three dimensions is crucial for achieving long-term sustainable development in Europe. In this section, we will explore the importance of integrating sustainability and highlight some successful examples of integrated sustainable development initiatives in Europe.

Integrating sustainability means that environmental, social, and economic considerations are taking into account when making decisions and developing policies. For example, promoting renewable energy not only helps to reduce greenhouse gas emissions and protect the environment but also creates jobs and stimulates economic growth.

There are many successful examples of integrated sustainable development initiatives in Europe. For instance, the Nordic countries have implemented various policies and practices that promote sustainable development, such as the Nordic Swan Ecolabel, which promotes environmentally friendly products, and the Nordic Council of Ministers, which promotes cross-border cooperation on environmental and social issues. Another successful example is the EU's Horizon 2020 program [17], which promotes research and innovation that addresses societal challenges such as climate change, energy, and health. The program includes a range of sustainability-focused initiatives such as promoting clean energy, sustainable mobility, and resource-efficient cities.

Looking forward, there is a need for continued efforts towards sustainable development in Europe. This includes promoting sustainability in all sectors of society, including businesses, governments, and individuals. It also requires addressing issues such as inequality, poverty, and environmental degradation. Overall, by integrating environmental, social, and economic sustainability, Europe can build a more resilient and sustainable future. Consider comparative tables 1-3.

Table 1

Comparison of three components according to the «Climate change» feature

Comparison sign	Ecological component	Social component	Economic component	In summary
Climate change	• Melting glaciers • Rising sea levels • Severe weather events • Loss of biodiversity and destruction of habitats • Impact on natural resources • Impact on economic sustainability	• Increasing social inequality • Uncomfortable working conditions • Poor health of employees	• Affects the productivity of agriculture • Increases production costs • Creates new business risks • The tourism industry is suffering	Climate change has wide-ranging impacts on ecological, social, and economic sustainability. Addressing it requires integrated approaches across all components. Neglecting climate change poses threats to sustainability and future generations' well-being

Table 2

Comparison of three components according to the "New technologies" feature

Comparison sign	Ecological component	Social component	Economic component	In summary
New technologies	• Reducing carbon emissions • Improving resource efficiency • Clean energy sources • Smart grids • Production and disposal of electronic devices generate toxic waste	• Information and services to create new jobs • Growing inequality and social isolation • New competencies for their effective use	• Job creation • Productivity • Innovation • New industries • Business models • Increase efficiency and reduce costs, particularly in manufacturing and services	New technologies can lead to job displacement, particularly in manual labor sectors, negatively impacting certain regions and social groups. Therefore, it's crucial to ensure equitable sharing of benefits

Table 3

Comparison of three components according to the "Circular Economy" feature

Comparison sign	Ecological component	Social component	Economic component	In summary
Circular economy	• Waste sorting • Efficient use of resources • Minimization of waste and greenhouse gas emissions • Recycling and secondary use of materials reduce environmental pollution • Protection of natural resources	• Enterprises that process waste can create jobs • New jobs • Promoting social inclusion for social sustainability	• Improve the company's profits • Stimulate economic growth • Waste repurposing • Development of new business models based on cyclical principles	The circular economy can benefit all three components of sustainability by reducing waste and promoting resource efficiency for ecological sustainability, creating jobs and promoting social inclusion for social sustainability, and creating economic value and promoting innovation for economic sustainability

In conclusion, after analyzing tables 1-3, it is easy to see that sustainable development requires a comprehensive and integrated approach that addresses the ecological, social, and economic dimensions of sustainability. Neglecting any of these components can have negative impacts on the others, leading to environmental degradation, social inequality, and economic instability. To achieve sustainable development, we need to balance these components and ensure that the benefits shared equitably across society.

Consider Figure 1 to analyze the relationships between the three components of sustainable development.

As can be seen from Figure 1, the three components of sustainable development - ecological, social, and economic – are interconnect and dependent on each other. The signs of sustainable development, such as climate change, new technologies, and circular economy, can impact all three components simultaneously. Climate change can affect the ecological component, while also having social and economic implications. New technologies can bring both positive and negative impacts on the environment and society, as well as on the economy. The circular economy can create economic value, provide social benefits, and contribute to ecological sustainability. In general, the sustainable development components and signs intertwined and considered holistically for achieving long-term sustainability.

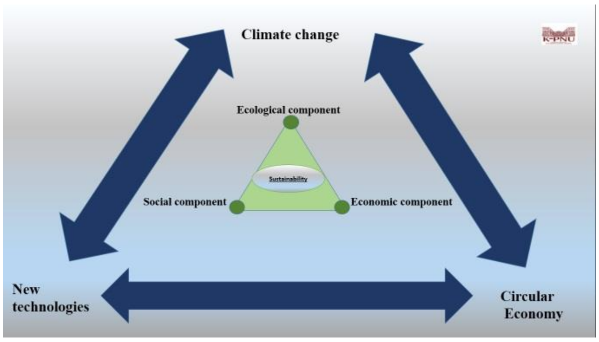

Fig 1. Interrelationship of signs and components of sustainable development

We chose "Climate change", "New technologies", and "Circular economy" as priority areas of sustainable development due to their crucial roles in promoting ecological, social, and economic sustainability. Climate change poses a significant threat to the environment and human well-being, while new technologies offer opportunities for more efficient and sustainable production and consumption patterns. The circular economy promotes resource efficiency and reduces waste, while also creating economic opportunities and promoting social equity. By prioritizing these areas, we can foster a more sustainable and resilient future for both people and the planet.

Conclusion. To recap, we have seen that Europe faces significant challenges in promoting sustainable development, such as addressing environmental degradation, reducing social inequalities, and promoting inclusive and sustainable economic growth. However, there are many positive steps be taken towards sustainable development, such as the EU Green Deal [18], the European Pillar of Social Rights [19], and the Horizon 2020 program [17].

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THE CURRENT STATE OF BIOGAS PLANTS DEVELOPMENT IN UKRAINE AND THE POTENTIAL FOR DEVELOPMENT DURING EUROPEAN INTEGRATION

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Abstract. *This paper examines the role of anaerobic treatment in sustainable development, with a specific focus on biogas production. Anaerobic treatment is a key component of biogas plants, which efficiently convert organic waste into renewable biogas while minimizing environmental impacts. Biogas offers a sustainable solution for waste management by reducing landfill usage and methane emissions. It also provides a renewable energy source that contributes to energy diversification, greenhouse gas reduction, and enhanced energy security.*

The paper analyzes the state of biogas plants in Ukraine, which has made progress with 50 existing plants. However, there is room for further growth. By leveraging Ukraine's agricultural orientation, abundant organic waste resources, and the experiences of European countries, the country can unlock the full potential of its biogas sector. This will contribute to sustainable energy production, waste management, and broader European integration goals.

The paper concludes by emphasizing the importance of sustainable development and maximizing the potential of biogas production. By adopting sustainable practices and promoting biogas utilization, countries can achieve economic growth, environmental protection, and social well-being in line with the EU's objectives and global sustainability targets.

1. Introduction.

1.1 Sustainable development as a key principle of the European Union

Sustainable development has emerged as a critical concept, guiding nations and regions toward a more equitable, resilient, and environmentally responsible future. It emphasizes the interdependence between economic development, social well-being, and environmental conservation. The European Union, with its commitment to sustainable development, has played a pioneering role in setting ambitious targets and implementing comprehensive policies that align economic growth with environmental preservation (European Commission, 2019; European Council, 2010; Kovačič, 2018). Currently, Ukraine is on the way to ensuring European practice related to sustainable development (Shapovalov, et al., 2022; Yakymenko et al., 2022; Yakymenko et al., 2018)

The EU recognizes that sustainable development is essential for ensuring the long-term well-being of its citizens, protecting the planet, and maintaining a competitive advantage in the global economy. By adopting a holistic approach, the EU strives to strike a balance between economic prosperity, social cohesion, and environmental stewardship. This approach aligns with the principles enshrined in the United Nations' Sustainable Development Goals (SDGs) (Sdgs, n.d.) and the Paris Agreement on climate change (EC, n.d.; Kobayashi et al., 2019).

The EU's commitment to sustainable development is evident in its policy frameworks, such as the European Green Deal (Fetting, 2020) and the Circular Economy Action Plan (Bürgin, 2020). The European Green Deal, launched in 2019 (Fetting, 2020), is a comprehensive roadmap that aims to transform the EU into a climate-neutral and sustainable economy by 2050. It sets ambitious targets for reducing greenhouse gas emissions, promoting renewable energy, protecting biodiversity, and ensuring a just transition for all stakeholders.

Moreover, the Circular Economy Action Plan focuses on decoupling economic growth from resource consumption and waste generation. By promoting circular practices, such as recycling, reuse, and product design for longevity, the EU aims to create a more resource-efficient and less wasteful society. These policy frameworks exemplify the EU's commitment to integrating sustainability into all aspects of its decision-making processes.

The EU's special role in promoting sustainable development extends beyond its borders. Through international partnerships, such as the Partnership Agreement with Africa, the EU supports sustainable development efforts in other regions. The EU also contributes significantly to global climate finance, assisting developing countries in their transition towards low-carbon and climate-resilient economies.

Sustainable development stands as a cornerstone of the European Union's agenda, reflecting its dedication to creating a prosperous, inclusive, and environmentally conscious society. Through comprehensive policy frameworks, initiatives, and international cooperation, the EU aims to lead the global community toward a sustainable future. By embracing sustainable practices, the EU sets an example for other nations and reinforces its position as a global leader in sustainability. The subsequent sections of this paper will delve deeper into specific aspects of sustainable development within the EU and examine the transformative initiatives driving this paradigm shift.

1.2 The role of anaerobic treatment in sustainable development

In the pursuit of sustainable development, the management of waste and wastewater plays a crucial role in minimizing environmental impacts and promoting resource efficiency. Anaerobic treatment, a biological process that occurs in the absence of oxygen, has gained recognition as an effective and sustainable method for treating various types of organic waste and wastewater. Sustainable biogas production technologies are that technologies, which can provide biogas production from waste (not from useful products), and characterized by high performance of destruction, with obtaining of high quality of biogas and biofertilizer, being maximally environment-friendly (Shapovalov, Usenko, et al., 2022; S. Zhadan et al., 2023) that means that it could be sustainable approach.

Renewable Energy Production. One of the key benefits of anaerobic treatment is its ability to generate renewable energy in the form of biogas. During the anaerobic digestion process, microorganisms break down organic matter, such as sewage sludge, agricultural waste, and organic residues, producing biogas primarily composed of methane and carbon dioxide. Methane, a potent greenhouse gas, can be captured and utilized as a valuable energy source. Biogas can be combusted to generate heat and electricity, reducing the reliance on fossil fuels and contributing to the transition towards a low-carbon economy. The utilization of biogas not only reduces greenhouse gas emissions but also provides a sustainable energy solution, thereby promoting sustainable development.

Greenhouse Gas Mitigation. Anaerobic treatment plays a significant role in mitigating greenhouse gas emissions, particularly methane, which has a significantly higher global warming potential than carbon dioxide. By capturing methane produced during anaerobic digestion, the process prevents its release into the atmosphere, thus reducing the overall carbon footprint. Moreover, anaerobic treatment facilitates the conversion of methane into carbon dioxide, which has a lower global warming potential, further minimizing the environmental impact. The implementation of anaerobic treatment systems, particularly in sectors such as agriculture, food processing, and wastewater treatment, presents a viable strategy for greenhouse gas mitigation, supporting climate change mitigation goals and sustainable development objectives.

Resource Recovery. Anaerobic treatment also enables the recovery of valuable resources from organic waste and wastewater. The byproduct of anaerobic digestion, known as digestate, is a nutrient-rich material that can be utilized as a biofertilizer. This digestate, when properly treated and processed, can be safely applied to agricultural lands, enhancing soil fertility and reducing the need for synthetic fertilizers. By recovering nutrients from organic waste through anaerobic treatment, the reliance on non-renewable resources, such as phosphorus and nitrogen, can be reduced, contributing to resource conservation and sustainable agricultural practices. The recovery of resources from waste streams not only reduces environmental pollution but also creates economic opportunities and promotes a circular economy.

Anaerobic treatment plays a vital role in ensuring sustainable development through its contributions to renewable energy production, greenhouse gas mitigation, and resource recovery. By harnessing the potential of anaerobic digestion, organic waste and wastewater can be transformed into valuable resources, minimizing environmental impacts, and promoting resource efficiency. The adoption and expansion of anaerobic treatment systems in various sectors hold great promise for achieving sustainability goals, both at the local and global levels. Future research and technological advancements in anaerobic treatment processes will further enhance its effectiveness and contribute to the realization of a more sustainable and circular economy.

Therefore, it is important to provide development of anaerobic treatment technologies to ensure sustainable development. It is important to ensure high efficiency of anaerobic treatment. To provide this, it is important to analyze the characteristics of biogas plants to understand the state and requirements for optimization to ensure sustainability. The optimization of technologies requirement was proven before and specially for complex to treatment substrates (Shapovalov et al., 2020). **This paper aims** analyzing of the current state of anaerobic technologies in Ukraine and define the potential of its development during European integration.

2. Methods

Data set generation. We collected data related to biogas plants from open sources. It was structured in form of Google Sheets by specific criteria related to biogas plants. We analyzed the data on official web pages of companies such as MHP (Ukrainian poultry company) (MHP, n.d.) and analysis's of NGOs (Geletukha et al., 2022; Matveev, 2012; UABIO, n.d.) and government institutions (Derzhenerhoefektyvnosti, 2019) that provided data accumulation and processing. We also accompanied the data with geodata of location of such biogas plants. To ensure the same metric type, we have provided calculations.

Specific criteria. The specific criteria were «Main substrate», «Cosubstrate 1», «Cosubstrate 2», «Cosubstrate 3», «Cosubstrate 4», «Ratio of main substrate to cosubstrate, %», «Moisture, %», «Volume (total, all reactors), m^3», «Number of biogas plants», «Substrate amount, t», «Productivity, m^3 of biogas/ day», «Energy production, MW», «Methane output, m^3/m^3», «Year of implementation», «TYPE of reactors», «Biogas plant manufacturers», «Owner», «Features» and «Location».

Data analysis. We used Google Maps to visualize location of the biogas plants. To provide data analysis and define main trends, we used Pvot tables in Google sheets. We discuss the potential of biogas plants development based on the Eurostat data related to biogas plants and energetic.

3. Results

3.1. Main characteristic of biogas plants

It is important to define essential characteristics used to analyze biogas plants. We used to analyze Plant Capacity that denotes the maximum biogas production capacity, typically measured in megawatts (MW). This characteristic provides insights into the potential energy output of the plant. In addition, Plant Efficiency is important as it assesses the overall efficiency of biogas production and utilization, taking into account energy conversion and resource recovery. It helps evaluate the effectiveness of the plant in achieving sustainable energy production and waste management.

Feedstock description is important to define the type of organic material used as feedstock, which can include agricultural residues, manure, or other organic waste. Understanding the feedstock used helps evaluate the sustainability and resource availability of the biogas plant.

Biogas plants could use different digestion technologies. This category describes the specific anaerobic digestion technology employed in the plant, such as mesophilic or thermophilic digestion, or the practice of co-digestion. This characteristic influences the efficiency and operational parameters of the biogas plant. We described the biogas utilization purpose whether it is for electricity generation, heat production, or upgrading to biomethane for injection into the natural gas grid. Understanding the end use of the biogas aids in assessing its value and potential contribution to the energy mix. Currently there is a huge problem with a digestate Management. This characteristic focuses on how the byproduct of anaerobic digestion, known as digestate, is managed. This can include land application as fertilizer or composting. Effective digestate management is crucial for closing nutrient loops and minimizing environmental impacts.

"Operational Status" indicates the current status of the biogas plant, whether it is in the planning, construction, or operational phase. This characteristic provides insights into the stage of development and potential for future contributions.

Lastly, the analysis related to environmental impact may provide environmental benefits and impacts associated with the biogas plant, including greenhouse gas emissions reduction and waste management. This helps evaluate the plant's contribution to sustainability goals and environmental protection.

The main features of biogas plants are shown int the table. This table provides a comprehensive summary of the characteristics used to analyze the amount and features of biogas plants. By considering these characteristics, stakeholders can assess the performance, efficiency, and environmental impact of biogas plants, facilitating informed decision-making and promoting sustainable energy production and waste management practices. Description of main characteristics of biogas plants is shown in Table 1.

Table 1.

Description of main characteristics of biogas plants

Characteristic	*Description*
Plant Capacity	The maximum biogas production capacity of the plant, typically measured in kilowatts (kW)
Feedstock	The type of organic material used as feedstock, such as agricultural residues or manure
Digestion Technology	The specific anaerobic digestion technology employed in the plant, e.g., mesophilic, thermophilic, or co-digestion
Biogas Utilization	The purpose and utilization of the biogas produced, e.g., electricity generation, heat production, or upgrading to biomethane for injection into the natural gas grid
Digestate Management	The management approach for the digestate byproduct, such as land application or composting
Plant Efficiency	The overall efficiency of biogas production and utilization in terms of energy conversion and resource recovery
Operational Status	The current operational status of the biogas plant, whether it is in planning, construction, or operational phase
Location	The geographical location of the biogas plant, which can provide insights into regional distribution and potential
Funding Sources	The sources of financial support for the biogas plant, including public funding, private investments, or international cooperation
Environmental Impact	The environmental benefits and impacts associated with the biogas plant, such as greenhouse gas emissions reduction and waste management

3.2. Current state of the biogas development in Ukraine

Today, the data in a systematical view related to the amount and characteristics of biogas plants do not exist. Some analysis is provided by the NGO “Bioenergy Association of Ukraine" (UABIO, n.d.), a member of the Board of the European Bioenergy Association. However, it does not cover the importance of technologists’ aspects.

According to our data, as of 2018, more than 50 facilities producing biogas were operating in Ukraine (figure), of which 33 operated on organic waste. Taking to account the method used to collect data that provides the possibility to collect such data, but it does not provide the exact data for all biogas plants as each source provides data in individual structure and fullness. Therefore, the number of values will be additionally noted to provide the possibility to justify the relevance of the data. Generally, there is data related declared 27[9] biogas plants that operate on industrial waste and we will provide additional data on the number of each value that it was able to consider. In data is in line with data of NGO “Bioenergy Association of Ukraine" (UABIO, n.d.) and Government Energy Efficiency Agency where number of biogas plants that processing industrial waste was similar. According to it, 28 stations are designed for the production of biogas from agricultural raw materials and at 9 stations, biogas is produced as a result of anaerobic treatment of industrial wastewater (UABIO, n.d.). According to Government Energy Efficiency Agency (Derzhenerhoefektyvnosti, 2019).

[9] We took additional information about biogas plants form informational sources like https://zaxid.net/vichna_energiya_z_vidhodiv_n1507364 , https://mhp.com.ua/uk/prat-oril-lider, https://uabio.org/wp-content/uploads/2012/11/matveev.pdf, https://ecolog-ua.com/news/na-vinnychchyni-zapustyly-naybilshiy-v-sviti-biogazovyy-kompleks

Substrate. Ukrainian biogas plants utilize diverse feedstocks, including agricultural residues, such as crop residues and manure from livestock farming, as well as organic waste from food processing and municipal sources. The choice of feedstock is influenced by the local agricultural and industrial sectors, as well as regional waste management practices. There is data related to the substrate that biogas plants use.

The analysis of the dataset comprising 27 samples revealed variations in substrate utilization for biogas production. The distribution across biogas plants was as follows: beet pulp (2 occurrences), cattle manure (3 occurrences), chicken manure or litter (5 occurrences), dairy farm effluents (1 occurrence), effluents of yeast production (1 occurrence), manure drains (1 occurrence), pig manure (4 occurrences), and wastewater (1 occurrence). The distribution of substrates across different biogas plants provides insights into their prevalence and suitability for biogas production. Chicken manure or litter emerges as the most frequently utilized substrate, indicating its abundance and favorable biogas production potential. Cattle manure and pig manure also demonstrate notable utilization, reflecting their availability and efficiency in biogas generation. Beet pulp, dairy farm effluents, effluents of yeast production, manure drains, and wastewater are employed to a lesser extent but showcase their potential as alternative substrates for biogas production. The pie diagram of the substrates used in Ukraine to produces biogas is shown in Figure 1.

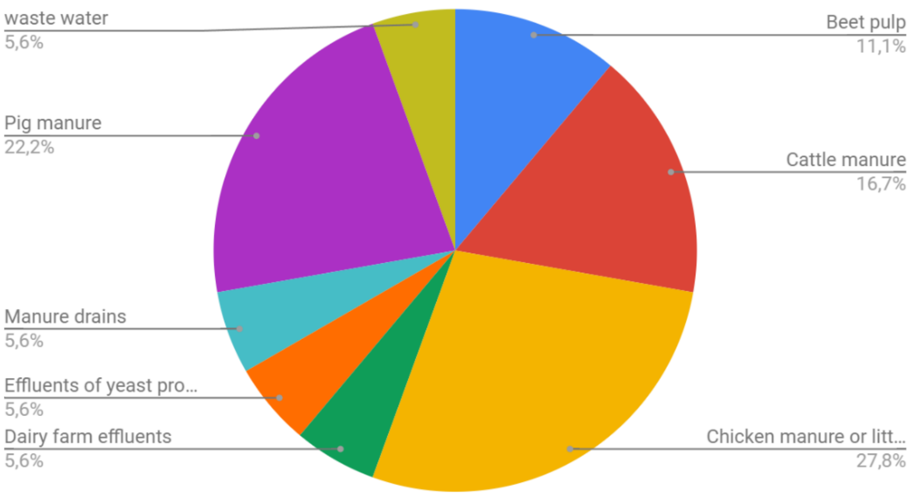

Fig. 1. The pie diagram of the substrates used in Ukraine to produces biogas

Co-substrates usage. Analysis of the dataset consisting of 15 recorded instances of cosubstrate usage revealed that generally, 10 different biogas plants utilized cosubstrates (there was no data for the other 17 biogas plants). Some of these biogas plants employed multiple cosubstrates. The data is given in relation to usage of cosubstrate (not in related to biogas plants). The distribution of cosubstrates across the different biogas plants was as follows: beet pulp (1 occurrence), CIP waste (1 occurrence), corn silage (3 occurrences), fat waste from animal slaughter (1 occurrence), flotation sludge from treatment plants (1 occurrence), green biomass (1 occurrence), pig manure (1 occurrence), silage (3 occurrences), sorghum (1 occurrence), wastewater (1 occurrence), and wastewater from washing poultry houses (1 occurrence). Therefore, the most common cosubstrates are silage (and its different types). The distribution of cosubstrates provides insights into their prevalence and effectiveness in biogas production. Cosubstrates such as corn silage, silage, and sorghum demonstrate their suitability for enhancing biogas production due to their high organic content. Other cosubstrates, including beet pulp, CIP waste, fat waste from animal slaughter, flotation sludge from treatment plants, green biomass, pig manure, wastewater, and waste water from washing poultry houses, show potential for further exploration and optimization in biogas production. The pie diagram of the cosubstrates used in Ukraine to produces biogas is shown in Figure 2.

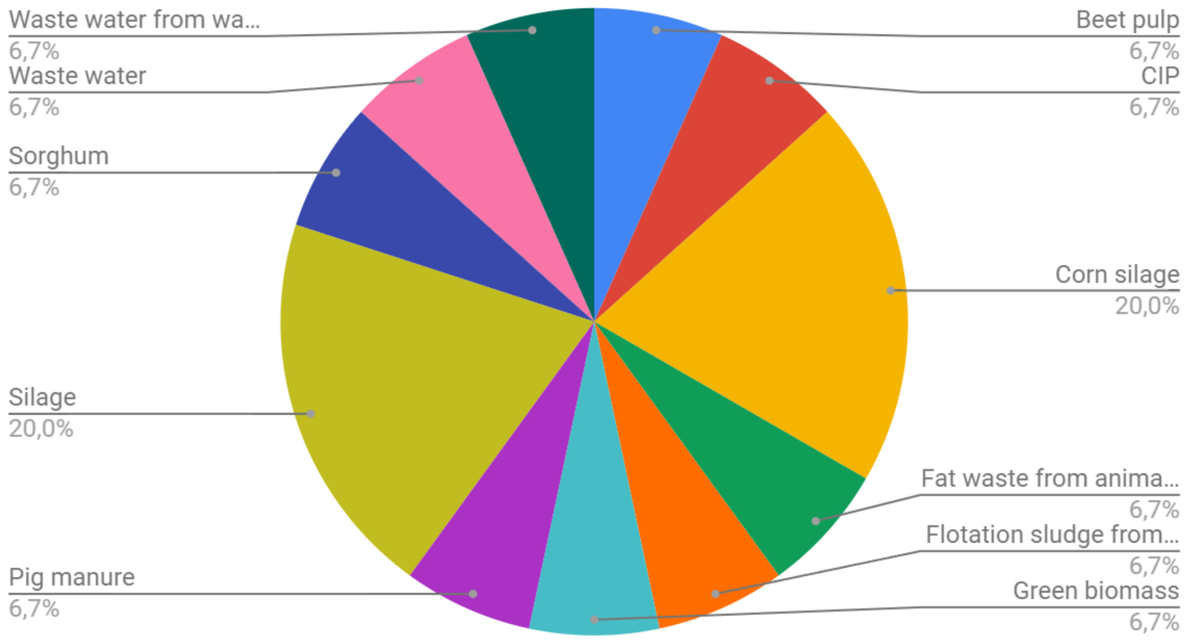

Fig. 2. The pie diagram of the substrates used in Ukraine to produces biogas

Plant Capacity. Biogas plants in Ukraine exhibit a wide range of capacities, varying from small-scale installations with capacities as low as a few kilowatts to large-scale facilities capable of generating several megawatts of biogas. The capacity of these plants is influenced by factors such as the availability of organic waste feedstock, financial resources, and the intended energy utilization.

The table provides valuable insights into the performance and capacities of the analyzed biogas plants. The range of the amount of treated substrate varies widely, from 20 tons per day to 6000 tons per day, indicating significant differences in feedstock availability and processing capabilities among the plants.

Biogas production ranges from 650 to 150,000 m^3/day, with an average of 42,483 m^3/day. This indicates diverse biogas production capacities among the studied plants, influenced by factors such as feedstock composition and plant design.

Methane production, although represented by only two data points, shows a narrow range, indicating relatively consistent methane production levels within these specific plants.

The power generated by the plants varies significantly, with a minimum of 0.13 MWt and a maximum of 32.5 MWt. The average power production is 12,94 MWt, suggesting the substantial energy generation potential of biogas plants. This data is line with data of Government Agency of

Energy Efficiency where general power generated by biogas plants is 70 MWt (Derzhenerhoefektyvnosti, 2019)

Electric power and heat production follow similar patterns, exhibiting a wide range of values. The year of construction data indicates that biogas plants have been constructed over a span of several years, from 2000 to 2016, demonstrating the continuous development and implementation of biogas technology.

It is important to note that the counts of the available data points vary for each parameter. The "Amount of treated substrate," "Biogas production," "Power," and "Year of construction" have a count of 16, 8, 13, and 5 respectively, indicating the number of values that were available in the dataset. The limited count in some parameters reflects the need for comprehensive and standardized data collection practices within the biogas industry.

The results provide valuable insights into the capacities, energy production, and temporal aspects of the studied biogas plants. Further analysis and research on these parameters, along with an increased count of available data points, will contribute to optimizing biogas plant design, operation, and overall efficiency. The main characteristics of productivity of biogas plants in Ukraine is shown in Table 2.

Table 2.

The main characteristics of productivity of biogas plants in Ukraine

Value name	*Amount of treated substrate ,t per day*	*Biogas production, m3/day*	*Methane production, m3/day*	*Power, Mt*	*Electric power, Mt*	*Heat production, Mt*	*Year of construction*
Min	20	650	30	0,13	0,16	0,32	2000
Max	6000	150000	35	32,5	16,00	320,00	2016
Avarage	592	42483	32	12,935	3,51	67,63	2010
Count	16	8	2	14	4	4	5

The analysis of the dataset revealed the following distribution based on the manufacturer: "Ecotank" (1 biogas plant), Bigadan Ltd (Denmark) (1 biogas plant), BTG (Holland) in collaboration with "NTC Biomass" (Ukraine) (1 biogas plant), Byteko Biogas (2 biogas plants), Holland (1 biogas plant), Integro (1 biogas plant), NVT (Holland) in collaboration with "ukrletfarmin" (1 biogas plant), Poldanor S.A (1 biogas plant), Wawatech (Poland) (1 biogas plant), and ZORG (4 biogas plants). Additionally, 16 biogas plants had no specific manufacturer data. The distribution of biogas plants based on the manufacturer provides insights into the industry landscape. While some manufacturers, such as "Ecotank," Bigadan Ltd (Denmark), BTG (Holland) in collaboration with "NTC Biomass" (Ukraine), Byteko Biogas, and ZORG, are associated with multiple biogas plants, others have a single representation. The presence of various manufacturers indicates the diversity in biogas plant manufacturing and suggests that different manufacturers may employ different technologies and approaches in their biogas plant designs. The data also highlight a significant number of biogas plants (16) with no specific manufacturer data, emphasizing the need for improved documentation and reporting practices within the biogas industry. The pie diagram of the manufactures of biogas plants used in Ukraine is shown in Figure 3.

There were no data (24 biogas plants), 2000 (1 biogas plant), 2012 (1 biogas plant), 2013 (2 biogas plants), and 2016 (1 biogas plant) by years of construction. The distribution of biogas plants based on the year of construction provides insights into the temporal landscape of biogas plant development. The majority of the analyzed biogas plants (24) lacked specific data regarding their year of construction, highlighting a significant gap in information. This emphasizes the need for improved data collection and documentation practices within the biogas industry. However, the available data suggests that biogas plant construction has occurred across various time periods, with one plant constructed in 2000, one in 2012, two in 2013, and one in 2016.

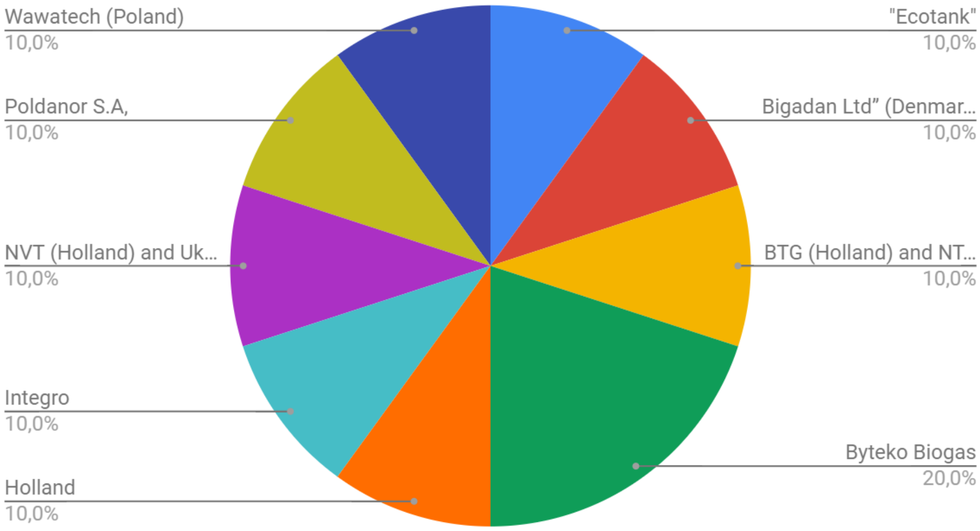

Fig 3. The pie diagram of the manufactures of biogas plants used in Ukraine

The presence of biogas plants constructed in different years indicates a range of development stages within the industry. It suggests that biogas plant construction has been ongoing over the years, with sporadic progress observed in certain time periods. The limited number of recorded biogas plants with known construction years indicates the necessity for comprehensive and standardized data collection methods to track the progress and evolution of biogas plant construction. The diagram of the years of construction of biogas plants in Ukraine is shown in Fig. 4.

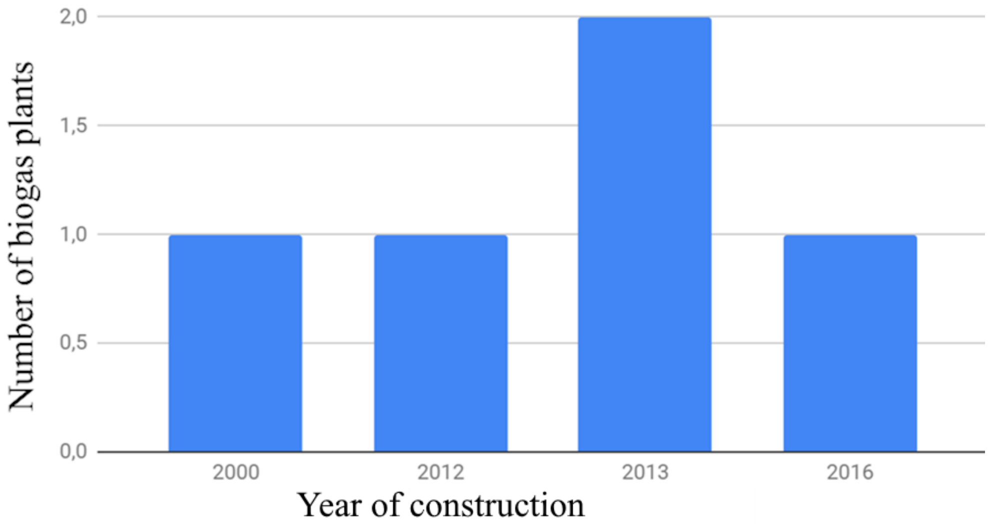

Fig. 4. The diagram of the years of construction of biogas plants in Ukraine

Digestion Technology. Various anaerobic digestion technologies are employed in Ukrainian biogas plants, including both mesophilic and thermophilic digestion processes. Additionally, co-digestion is increasingly being adopted, allowing the co-processing of multiple feedstocks to optimize biogas production. These technologies contribute to efficient biogas production and resource recovery.

Biogas Utilization. Biogas produced in Ukrainian plants is primarily utilized for electricity generation and heat production. Combined Heat and Power (CHP) systems are commonly employed to maximize energy efficiency by utilizing the heat generated during electricity production. Some plants also upgrade biogas to biomethane for injection into the natural gas grid, enabling wider use and distribution.

Digestate Management. Digestate management practices in Ukraine vary, with some biogas plants utilizing the digestate as a valuable biofertilizer through land application. Others may opt for composting or further treatment to produce high-quality organic fertilizers. The choice of digestate management approach depends on the specific requirements of the agricultural sector and environmental regulations.

Plant Efficiency. The efficiency of biogas plants in Ukraine is a key focus to maximize energy output and resource recovery. Technological advancements, including improved digester designs and process optimization, enhance plant efficiency and economic viability. Ongoing research and development efforts aim to improve further the overall efficiency of biogas production in the country.

Operational Status. Ukraine has many operational biogas plants, with many already contributing to the country's renewable energy generation. However, there are also biogas projects in various stages of planning and construction, indicating a positive outlook for future growth and development in the sector.

Location. Biogas plants in Ukraine are distributed across the country, with concentrations in regions where agricultural and industrial activities generate significant organic waste streams. Proximity to feedstock sources and potential energy consumers is crucial in determining plant locations. The distribution of biogas plants in Ukraine is shown in Fig. 5.

Funding Sources. The funding of biogas projects in Ukraine relies on a mix of sources, including public grants, private investments, and international cooperation. Government support programs and incentives, as well as financial institutions and project partnerships, play a vital role in providing the necessary funding for biogas plant development and operation.

Environmental Impact. Biogas plants in Ukraine make significant contributions to environmental sustainability. By utilizing organic waste, they help reduce methane emissions, mitigate greenhouse gas emissions, and promote circular economy principles. Moreover, the use of digestate as a biofertilizer supports sustainable agriculture practices and reduces dependence on synthetic fertilizers.

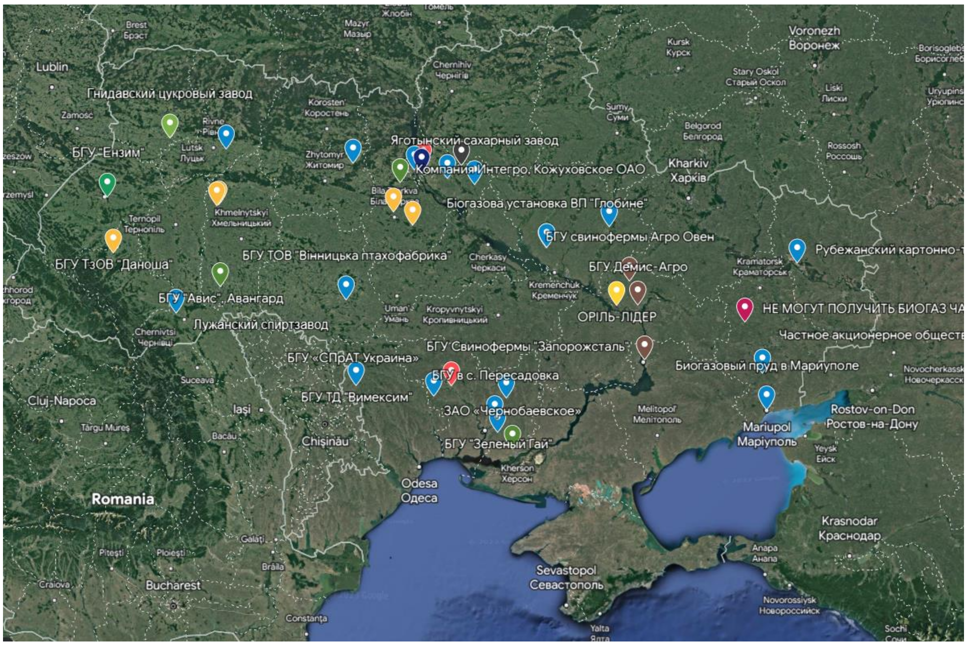

Fig. 5. The distribution of biogas plants in Ukraine

In summary, the current state of biogas plants in Ukraine reflects a diverse landscape with varying capacities, feedstocks, digestion technologies, and utilization methods. The sector shows promising growth potential, with operational plants significantly contributing to renewable energy generation and waste management. Continued efforts in improving plant efficiency, expanding operational capacities, and advancing sustainable practices will further strengthen the biogas sector in Ukraine.

3.3. The Potential Development of Biogas Plants in Ukraine during European Integration

As Ukraine pursues European integration, the development of biogas plants holds significant potential for contributing to sustainable energy production and waste management. With 50 existing biogas plants, including 33 located on factories that treat their waste, Ukraine has already taken steps towards harnessing the benefits of biogas. In this context, the country's vast territory, agricultural orientation, and the tendencies observed in European countries provide a solid foundation for the future growth and expansion of biogas production.

Agricultural Orientation and Organic Waste Resources. Ukraine's agricultural sector, with its vast arable land and diverse livestock farming, provides ample organic waste resources suitable for biogas production. The abundance of agricultural residues, such as crop residues and livestock manure, can be effectively utilized as feedstock for biogas plants. This agricultural orientation aligns with the core requirements for successful biogas development, as organic waste is readily available and can be efficiently converted into renewable energy.

European Integration and Transfer of Best Practices. The process of European integration offers an opportunity for Ukraine to adopt best practices from European countries with well-established biogas sectors. Countries like Germany, Denmark, and Austria have made significant strides in biogas development, demonstrating successful models of policy frameworks, technological advancements, and business models. By leveraging these experiences and knowledge-sharing, Ukraine can accelerate the development of its biogas sector, benefiting from the lessons learned in European countries.

Supportive Policy Framework. The integration process provides an impetus for Ukraine to align its policies and regulations with European standards and directives. The European Union (EU) has set ambitious renewable energy targets and implemented support mechanisms, such as feed-in tariffs and renewable energy subsidies, to encourage the growth of biogas and other renewable energy sources. Ukraine can draw inspiration from these policies to establish its own supportive framework, including incentives for biogas plant construction, feed-in tariffs, and favorable regulations to attract investments.

Regional Collaboration and Funding Opportunities. European integration also facilitates regional collaboration and access to funding opportunities. Ukraine can tap into EU-funded programs, such as the European Structural and Investment Funds, to support the development of biogas projects. Additionally, partnerships with European institutions, research organizations, and industry associations can promote knowledge exchange, technology transfer, and capacity building in the biogas sector.

Environmental and Energy Security Benefits. The development of biogas plants aligns with Ukraine's goals for environmental sustainability and energy security. Biogas production from organic waste helps reduce greenhouse gas emissions, mitigates climate change, and contributes to a circular economy by turning waste into a valuable resource. Furthermore, biogas can provide a stable and decentralized energy source, reducing dependence on imported fossil fuels and enhancing energy security within the country.

The integration process and the presence of 50 biogas plants in Ukraine, particularly those treating waste from factories, demonstrate the existing potential for biogas development. Ukraine's agricultural orientation, abundant organic waste resources, and the tendencies observed in European countries provide a favorable environment for the expansion of biogas production. By adopting supportive policies, leveraging European best practices, and fostering regional collaboration, Ukraine can unlock the full potential of its biogas sector, contributing to sustainable energy production, waste management, and the country's broader European integration goals.

It worth note that we European integration will positively effect on the providing innovation as it promotes the policy of using science results and best available practice. As, it was noted before, anaerobic treatment could be not suitable depending on technology and it is required to be optimized (Shapovalov et al., 2021; Shapovalov, Usenko, et al., 2022). Therefore, innovations like production of ammonia from animal waste (S. O. Zhadan et al., 2021).

3.4. The Impact of European Integration on Electricity Prices and the Potential Increase in Biogas Plants in Ukraine

The process of European integration has the potential to bring about significant changes in various sectors, including the energy market. This section focuses on the potential impact of European integration on electricity prices in Ukraine and explores the subsequent increase in the number of biogas plants. The analysis aims to shed light on the factors contributing to the price disparity between the European Union (EU) and Ukraine in terms of electricity and energy sources. Furthermore, it seeks to understand how this disparity may drive the expansion of biogas plants in Ukraine.

European Integration and Electricity Prices. The European Union has been working towards creating a unified and integrated electricity market across member states. This integration aims to promote competition, enhance energy security, and achieve a more sustainable energy system. As a result of this process, the EU has implemented various policies and regulations to harmonize electricity markets and facilitate cross-border energy trade. However, the integration process has also led to higher costs in the EU compared to Ukraine in terms of electricity and energy sources.

Price Disparity in Electricity Costs. The difference in electricity costs between the EU and Ukraine can be attributed to several factors. Firstly, the EU has made significant investments in renewable energy sources, such as wind and solar power, which has driven up electricity prices. These investments have been supported by various subsidies and incentives aimed at promoting green energy production. In contrast, Ukraine relies heavily on conventional energy sources, which tend to have lower production costs. Secondly, the EU's stringent environmental regulations and emission reduction targets have necessitated costly upgrades and improvements in energy infrastructure. These additional expenses are ultimately passed on to consumers in the form of higher electricity prices. In contrast, Ukraine's energy infrastructure may not be subject to the same level of regulatory requirements, resulting in relatively lower production costs.

Potential Effects of European Integration on Ukrainian Electricity Prices. The process of European integration is likely to have a direct impact on electricity prices in Ukraine. As Ukraine seeks closer economic and energy ties with the EU, it may be compelled to align its energy policies and standards with those of the Union. This alignment could result in the adoption of stricter environmental regulations and increased investments in renewable energy sources. Consequently, Ukrainian electricity prices may experience an upward trend to match the EU's higher costs.

Increase in Biogas Plants as a Response to Higher Electricity Prices. The anticipated increase in electricity prices due to European integration may create incentives for Ukraine to explore alternative energy sources. One such potential source is biogas, which is produced through the anaerobic digestion of organic materials. Biogas plants can utilize various feedstocks, including agricultural waste, organic waste from municipalities, and dedicated energy crops. These plants can contribute to a more sustainable energy mix and reduce reliance on conventional energy sources.

Given the higher electricity prices in the EU, Ukrainian entrepreneurs and investors may find it economically viable to establish biogas plants to capitalize on the price disparity. The production of biogas not only provides an alternative energy source but also offers opportunities for waste management and agricultural sector development. Therefore, an increase in biogas plants in Ukraine could be a potential response to the rising electricity prices resulting from European integration.

Conclusion. The analysis highlights the importance of sustainable development and its special role in the European Union (EU). The EU has recognized the significance of sustainable development in achieving long-term social, economic, and environmental goals. By integrating sustainable development principles into its policies and practices, the EU aims to create a harmonious balance between economic growth, social well-being, and environmental protection.

The discussion then delves into the role of anaerobic treatment in ensuring sustainable development, particularly in the context of biogas production. Anaerobic treatment, a key component of biogas plants, enables the efficient conversion of organic waste into renewable biogas while minimizing environmental impacts. It provides a sustainable solution for waste management, reducing landfill usage and methane emissions. Moreover, biogas generated from anaerobic treatment offers a renewable energy source that can contribute to energy diversification, reduce greenhouse gas emissions, and enhance energy security.

Furthermore, the text emphasizes the need to consider the characteristics used to analyze the amount and features of biogas plants. These characteristics encompass plant capacity, feedstock type, digestion technology, biogas utilization, digestate management, plant efficiency, operational status, location, funding sources, and environmental impact. By understanding and evaluating these characteristics, stakeholders can make informed decisions regarding biogas plant development, operation, and their overall contribution to sustainable development goals.

Regarding the current state of biogas plants in Ukraine, the provided criteria shed light on the diversity and potential of the sector. With 50 existing biogas plants, including those located on factories treating their waste, Ukraine demonstrates progress in harnessing biogas benefits. However, there is room for further growth and development. Ukraine's agricultural orientation, abundant organic waste resources, and the tendencies observed in European countries provide a solid foundation for expanding biogas production. By aligning policies with European standards, collaborating with regional partners, accessing funding opportunities, and learning from European best practices, Ukraine can unlock the full potential of its biogas sector, contributing to sustainable energy production, waste management, and its broader European integration goals.

Overall, sustainable development and the development of biogas plants are integral components of a greener and more sustainable future. By embracing sustainable practices and maximizing the potential of biogas production, countries can foster economic growth, environmental protection, and social well-being in line with the objectives of the EU and global sustainability goals

The potential impact of European integration on electricity prices in Ukraine necessitates a comprehensive analysis of the factors driving price disparities and the subsequent response regarding alternative energy sources. Exploring biogas plants as a potential solution highlights the importance of promoting sustainable energy development and reducing dependence on conventional energy sources. By understanding the implications of European integration on electricity prices, policymakers and stakeholders can make informed decisions to shape the energy landscape in Ukraine.

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ASSESSMENT OF THE QUALITY OF SURFACE WATERS IN KHMELNYTSKYI REGION BASED ON SANITARY, HYDROLOGICAL, AND TOXICOLOGICAL INDICATORS

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Abstract. *The article provides an analysis of enterprises located in the Khmelnytskyi region, their characteristics are described, and an analysis of their impact on water ecosystems is conducted. Their sanitary protection zone and hazard class have been determined. It has been determined that the largest water user is the municipal water supply and sanitation enterprise in the city of Krasyliv, the communal enterprise "Miskvodokanal", the communal enterprise "Izyaslavvodokanal", Theofipol Housing and Utilities Management Production Department, and Aslan-Textile LLC. These companies are the largest water consumers in terms of volume and also discharge significant amounts of wastewater into surface waters.*

According to the monitoring studies presented in the article, concentrations of pollutants in the control sections of water bodies in Khmelnytskyi region were within the permissible limits in surface waters. However, it was noted that all samples of the collected water exceeded the norm for BOD (Biochemical Oxygen Demand) and COD (Chemical Oxygen Demand), except for the water in the Sluch River, Korzhivka village section..

The article presents the results of the ecological assessment of water resources in Khmelnytskyi region based on sanitary and hygienic indicators. The impact of environmentally hazardous objects on the state of surface waters was determined, and concentrations of pollutants in water ecosystems were identified. As a result of the conducted research, it was found that the surface waters of Khmelnytskyi region, in terms of sanitary and toxicological condition, correspond to an acceptable and moderate level of pollution. The indicator of the limiting criterion of harmfulness ranged from 0.4 to 1.0 units of measurement.

Introduction. The use of water is increasing at such a rate that questions arise regarding the control of surface waters and obtaining ecologically safe water for consumption. According to literary sources, it has been established that in Ukraine, there is no water body that has not been altered by human anthropogenic activities or their consequences [1].

According to literary sources, it has been proven that there is also a deterioration in the quality of water resources in European Union countries due to excessive anthropogenic influence. For instance, in the Czech Republic and Slovakia, two-thirds of rivers are polluted by industrial and agricultural waste. In Poland, some rivers fall into the moderately polluted category, and three-quarters of Hungary's rivers contain chemical pollutants. [2; 3].

In most cases, anthropogenic interventions lead to water bloom, which is known as anthropogenic eutrophication, resulting in a high influx of biogenic compounds into water bodies [4; 5]. The process of eutrophication is characterized by a sharp increase in biomass of algae, higher aquatic vegetation, and phytoplankton due to the input of nutrient-rich biogenic substances, resulting in oxygen depletion and subsequent occurrences of hypoxia. Decomposition of plant organisms occurs, leading to the release of toxic substances into the water, posing a significant threat to the survival of aquatic organisms and being hazardous to both animals and humans [5].

As a result of scientific research, it has been determined that chemical, food, and petroleum processing industries initially impact the quality of surface waters, leading to the alteration of organoleptic, microbiological, and physicochemical properties of aquatic ecosystems due to the presence of pollutants. These processes further enhance the accumulation, migration, and translocation of these pollutants within natural water ecosystems. Therefore, the study of pollutant accumulation and migration in surface waters, as well as the development of methods for water ecosystem purification, is being undertaken by researchers such as L.V. Levandovsky, O.I. Semenova, I.V. Shumigay, and N.O. Bublienko [6; 7].

Materials and methods. The analysis of sanitary-toxicological assessment of surface waters in the Khmelnytskyi region was conducted based on the pollutant content data obtained from observations conducted by the Khmelnytskyi Regional Hydrometeorology Center during the period of 2020-2021.

The determination of sanitary-hygienic indicators was carried out in the control sections of rivers in the Khmelnytskyi region. Water samples were collected from the main stream at a depth of 0.2-0.5 meters below the water surface. In the case of deep rivers, samples were taken from multiple layers to reflect the average composition of the water. Water samples for analysis of organic and chemical substances were collected in chemically clean or carefully prepared bottles with tightly sealed stoppers made of durable glass or polyethylene [8].

The determination of ammonium nitrogen, nitrate nitrogen, nitrite nitrogen, phosphates, sulfates, chlorides, total iron, and heavy metals content was carried out according to generally accepted methods [8-12].

The research objects were environmentally hazardous objects that influence the processes of forming the indicators of water resource quality and surface water in the Khmelnytskyi region. The subject of the study was the level of pollution of rivers in the regions of the Khmelnytskyi region.

The analytical and methodological parts of the work were carried out during the years 2020-2021. The program of analytical research included the performance of an ecological assessment of the state of water ecosystems based on sanitary and hygienic indicators.

A comprehensive ecological assessment based on sanitary-toxicological indicators of surface waters was calculated separately for each pollutant that contributes to the harmfulness criteria.

$$W = 1 + \frac{\sum_{i=1}^{n}(g_i - 1)}{n} \quad (1)$$

Where:

W - comprehensive assessment of water pollution level based on the limiting criterion of harmfulness;

n - number of indicators used in calculations;

g_i - multiplicity of exceeding the actual concentration of the i-th ingredient in the water (Ci) over the normative value of a single indicator.

$$g_i = \frac{C_i}{N_i} \quad (2)$$

Where:

N_i - normative value of a single indicator (usually equal to MAC - Maximum Allowable Concentration).

The degree of water pollution, depending on the magnitude of the comprehensive assessments W calculated based on the limiting criterion of harmfulness, is determined by the classification of W value ranges (sanitary-toxicological indicators): acceptable pollution level corresponds to 1.0 W units, moderate pollution level ranges from 1.0 to 3.0 W units, high pollution level ranges from 3.0 to 10.0 W units, and extremely high pollution level exceeds 10.0 W units.

Research results and their discussion. The study included a monitoring assessment of the quality of surface water. Table 1 presents the volumes of wastewater discharge and pollutant levels in the surface water of the Khmelnytskyi region for the years 2020-2021.

In the territory of Khmelnytskyi region, there are numerous enterprises that have a negative impact on the environment, particularly on the water ecosystem. Regular inspections of these enterprises have been carried out annually. However, the list of hazardous facilities at the national level is presented in Table 2. From this table, it is evident that the largest water users are the water supply and sewage utilities of Krasyliv city, the municipal enterprise "Miskvodokanal," "Izyaslavvodokanal," Theofipol Production Management of Housing and Communal Services, and Aslan-Textile Private Enterprise. Since these enterprises are the largest water users, they also discharge significant volumes of wastewater into the surface water.

The total discharge of wastewater amounted to 1661.8 thousand cubic meters, and the volumes of wastewater discharge increased. In 2021, it reached 3312.4 thousand cubic meters, while in 2020, it was 2790.5 thousand cubic meters. One such enterprise, "Starokostiantynivsky Specialized Quarry" CJSC, is involved in the extraction of decorative and building stone, limestone, gypsum, chalk, and clayey shale, as well as the production of concrete products for construction, production of concrete mixtures ready for use. Therefore, this facility falls into the second hazard class, and the sanitary protection zone should be at least 500 meters. The main hazard of this enterprise in the production of building materials is the formation of quarry water, which becomes contaminated with mechanical particles and chemical compounds through the erosion of excavation waste rocks and useful minerals, as well as mineral oils, alkalis, phenols, and other substances used in drilling, excavation, extraction, and transportation machinery.

The company "Protein Invest" LLC is engaged in the production of oils and animal fats. Its technological process is high-powered, placing it in the fourth hazard class, and the sanitary protection zone should be at least 300 meters. The wastewater generated during the production of oil products includes neutral fats, phospholipids, organic acids, and other organic substances. These pollutants are insoluble in water and contribute to the formation of stable emulsions in the form of suspended matter.

"Vinkivtsi Cheese Factory" LLC is engaged in milk processing and the production of butter and cheese, resulting in the formation of whey and buttermilk, which are subsequently used as secondary raw materials. The wastewater generated during the production of butter and cheese falls into the category of highly concentrated water, characterized by the presence of suspended solids and marked with highly acidic properties. The COD level is approximately 4000-4500 mg/O2, and the BOD level ranges from 3000-3375 mg/O2. Therefore, this company belongs to the fourth hazard class, and the sanitary protection zone should be at least 300 meters.

Table 1.

Enterprises that discharge wastewater and pollutants into surface waters

Object name	Water supply source	Discharge volume of wastewater, thousand cubic meters	Quantity of pollutants discharged with wastewater, t (tons).
1. Water supply and sewerage enterprise, Krasyliv city.	Sub-basin of the Pripyat River	562,5	375
2. Municipal Enterprise "Iziaslavvodokanal", Iziaslav city, Shepetivka district.	Sub-basin of the Pripyat River	281,3	157,7
3. Private Enterprise "Aslan - Textile", Basalia village, Khmelnytskyi district.	Sub-basin of the Pripyat River	103,6	122,3
4. Public Joint-Stock Company "Starokostiantyniv Specialized Quarry", Krasnosilka village, Khmelnytskyi district, (quarry waters)	Sub-basin of the Pripyat River	27,5	12,3
5. Municipal Enterprise "Bilogirya Spectransbud", Bilohirya village	Sub-basin of the Pripyat River	27,5	6,0
6. Theophilpol Production Management of Housing and Communal Services, Theophilpol town	Sub-basin of the Pripyat River	90,5	73,0
7. Municipal Enterprise "Lozove Communal Service", Lozove town, Khmelnytskyi district.	Southern Bug River basin	20,4	15,5
8. Municipal Enterprise "Zlagoda", Letychiv town.	Southern Bug River basin	40,4	32,0
9. Limited Liability Company "Podol-Expo", Khmelnytskyi district.	Southern Bug River basin	19,0	5,0
10. Municipal Enterprise "Starokostiantyniv Central Water Supply and Sewerage System No. 1", Stara Syniava village, Khmelnytskyi district.	Southern Bug River basin	17,4	1,0

11. Municipal Enterprise "City Water Utility", Dunayivtsi city.	Dniester River basin	280,9	227,0
12. Non-Governmental Organization "Victoria", Yarmolyntsi town.	Dniester River basin	33,9	35,0
13. Municipal Enterprise "Vinkovetsky Communal Service", Vinkivtsi town.	Dniester River basin	48,8	38,5
14. Municipal Enterprise "Satanevskye", Satanev town, Horodotsky district.	Dniester River basin	15,7	16,0
15. Water Utility State Enterprise, Nova Ushytsia town.	Dniester River basin	39,0	30,0
16. LLC "Diada D," Nova Ushytsia town.	Dniester River basin	47,6	34,5
17. LLC "Protein Invest," Dunayivtsi town, Dunayevetsky district.	Dniester River basin	10,5	8,0
18. LLC "Vinkivtsi Cheese Plant," Vinkivtsi town.	Dniester River basin	12,0	22,0
19. Municipal Enterprise "Komunservis," Chemerivtsi village, Khmelnytskyi district.	Dniester River basin	56,4	41,4
20. LLC "Vesna 21" Agricultural Enterprise, village of Humentsi, Kamianets-Podilskyi district.	Dniester River basin	2,0	0,0

Accordingly, a monitoring quality control of surface waters was conducted. Table 2 presents the concentrations of pollutants in the monitoring points of water bodies in the regions of the Khmelnytskyi Oblast (Table 2).

Based on sanitary and hygienic indicators, the results of the water analysis from the monitoring points comply with the safe level standards. However, in almost all water samples taken, there is an exceedance of the norm for BOD and COD, except for the water in the monitoring points of the Sluch River in Korzhivka village.

Possible reasons for exceeding the permissible norms of BOD and COD in the monitoring points of rivers could be the discharge of wastewater from industrial enterprises. This can be explained by the low efficiency of pollutant removal in the treatment facilities, indicating an intensified anthropogenic impact on natural water bodies.

Furthermore, the water quality was assessed using aquatic plants (macrophyte index) and macrozoobenthos (Maier and Woodiwiss indices). Based on the available bioindicators, the Southern Bug River in the vicinity of Khmelnytskyi and Kopystyn villages can be classified as a eutrophic water body with polluted water. The pollution level based on the macrophyte index was 6, Maier index was 12, and Woodiwiss index was 7. This can be attributed to the fact that the investigated sections of the river are located directly near industrial pollution sources and domestic wastewater discharge points.

An increase in the total iron content was also observed in all monitoring points of the rivers, exceeding the standard limit (0.3 mg/dm3). The elevated iron content can be attributed to the relatively high corrosive activity of the water.

Regarding the limiting criterion of harmful substances (phosphates, ammonium nitrogen, nitrite nitrogen, heavy metals) for objects of domestic and cultural use, they are characterized as toxic.

The water samples collected from the river monitoring points, as presented in Table 4, showed variations within the maximum permissible concentrations for heavy metals, phosphates, sulfates, and chlorides.

The nitrate nitrogen content in the river monitoring points ranged from 0.023 to 0.077 mg/dm3, while the concentration of nitrite nitrogen ranged from 0.439 to 2.172 mg/dm3.

Elevated levels of ammonium nitrogen were observed in the monitoring points of the Pivdennyi Bug River, specifically in the vicinity of Kopystyntsi village, where its concentration reached 10.62 mg/dm3. Such an increase indicated water pollution by organic substances and fertilizers from agricultural and industrial enterprises located in Kopystyntsi village.

Table 2

Sanitary-toxicological indicators of water in river reservoirs based on data from wastewater dischargers into surface waters (mg/dm^3).

Indicator	Maximum Permissible Concentration (MPC)	Measured value				
		River Buzhok, town Medzhybizh	River Southern Bug, city Khmelnytskyi	River Southern Bug, village Kopystyntsi	River Styr, village Krasnosilka	River Sluch, village Korzhivka
Chlorides	300	20,25	43,95	73,05	47,67	42,85
Sulfates	100	12,3	13,14	18,04	18,75	19,62
BOD (Biochemical Oxygen Demand) mgO_2/dm^3	30	35,51	32,86	55,32	37,26	31,97
COD (Chemical Oxygen Demand) mgO_2/dm^3	6	6,10	6,01	6,67	6,27	4,763
Ammonium nitrogen	2,0	0,95	0,78	10,22	3,44	2,19
Nitrite nitrogen	0,1	0,03	0,02	0,05	0,07	0,04
Nitrate nitrogen	10	0,45	0,39	2,17	0,71	0,43
Phosphates	3,5	0,05	0,20	0,66	0,32	0,19
Total iron	0,3	0,5	0,7	0,54	0,4	0,3
Copper	0,005	0,002	0,003	0,004	0,003	0,026
Zinc	1,0	0,44	0,21	0,77	0,39	0,29
Nickel	0,1	0.05	0,05	0,05	0,05	0,05

Table 3.

Comprehensive ecological assessment of surface waters.

River name	Comprehensive assessment, W.	Level of pollution
River Buzhok, town of Medzhybizh	0,5	Permissible
Southern Bug River, city of Khmelnytskyi	0,6	Permissible
Southern Bug River, village of Kopystyń	1,0	Moderate
Sluch River, village of Krasnosilka	0,4	Permissible
Sluch River, village of Korzhivka	0,5	Permissible

Based on monitoring studies, it has been proven that the ecological state of surface waters in the regions of Khmelnytskyi Oblast, according to sanitary-toxicological indicators, corresponded to an acceptable and moderate level. This can be explained by the fact that discharges from agricultural and industrial enterprises, in inadequately treated condition, enter surface water bodies, resulting in the concentration of pollutants that are present in wastewater contributing to their contamination. According to the limiting criteria of harmfulness, the rivers' pollution level corresponded to an acceptable level, ranging from 0.4 to 0.6 TU (Toxic Units).

However, it should be noted that in the Pivdennyy Bug River, which flows through Kopystyntsi village, the pollution level reached 1.0 TU and approached a moderate level of contamination. From Table 3, it can be seen that the Pivdennyy Bug River in Kopystyntsi village exhibited an increased concentration of ammonium nitrogen, with a content of 10.22 mg/dm3. Such an increase indicates contamination of water with organic substances and fertilizers, which subsequently led to a decrease in dissolved oxygen content in the water and the occurrence of hypoxic conditions in the water body.

Conclusions. Based on the conducted research, it has been established that the waters of all reservoirs in the Khmelnytskyi region meet the acceptable and moderate levels of pollution according to sanitary-toxicological indicators. The indicator of the limiting criterion of harmfulness varied within the range of 0.4 to 1.0 TU.

It should be noted that the water sample from the reservoir of the Southern Bug River in the village of Kopystyn has a value of 1.0 TU, which is close to the moderate level of pollution. This can be attributed to the negative anthropogenic impact on surface waters caused by the presence of agricultural-industrial enterprises (LLC "Karmaliuk YuA", private farm "MAISS," and others) in the village. It is possible that the insufficient efficiency of the existing wastewater treatment facilities contributes to the pollution of the water body.

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SOCIAL COMPONENT OF SUSTAINABLE DEVELOPMENT AND PUBLIC HEALTH SUSTAINABLE

RESPONSIBLE CONSUMPTION IN THE FOOD SECTOR: GLOBAL TRENDS AND UKRAINIAN REALITIES

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Abstract. *The article is devoted to the study of current problems in the food sector and food waste management in Ukraine at the level of individual consumers; establishing the degree of involvement of Ukrainians in world trends of responsible consumption. Based on the analysis of literary sources, it is shown that the nature of food consumption is one of the main factors influencing the state of the natural environment, which is manifested in an unreasonably high level of resource use and is one of the causes of the formation of greenhouse gases. It has been proven that Ukrainian consumers are only at the initial stage of the movement towards responsible consumption in the food sector, which is due to a number of both subjective and objective reasons. It was established that a large part of consumers is not familiar with the principles of responsible consumption and handling of food waste, does not have information about the real volumes of their formation and does not suspect the possible consequences of irresponsible handling of them. It was determined that one of the most effective ways to reduce the amount of food waste is the formation of a culture of food consumption, increasing the level of awareness and consciousness by consumers of the consequences of their eating behaviour and the impact of food waste on the environment. It was revealed that a significant problem on the way to responsible consumption in the food sector is the lack of the necessary infrastructure. It is shown that the low effectiveness of initiatives initiated by the state, business, and public organizations is explained mainly by the imperfection of communication systems with the target audience: many consumers simply do not have information about the relevant initiatives and, accordingly, do not have the opportunity to use them.*

Introduction. The final document of the United Nations Sustainable Development Summit 2015 (September, 2015) “Transforming our world: the 2030 Agenda for Sustainable Development” is a kind of plan for dignity, peace and prosperity for people and the planet at the current stage and in the future. The 17 Sustainable Development Goals and 169 tasks announced by the Summit are aimed at developing the gains achieved within the framework of the Millennium Development Goals and at completing the implementation of tasks that could not be fulfilled (United Nations Development Programme, 2023). One of the critical tasks for the coming years is to ensure sustainable consumption and production patterns (Goal 12). Governments and all citizens have to work together to improve resource efficiency, reduce waste and pollution, and create a circular economy. One of the objectives under Goal 12 is to halve the amount of global food waste per capita by 2030, both in terms of retail trade and for consumers; reduce food losses in production and supply chains, including post-harvest losses (United Nations Development Programme, 2023; United Nations Ukraine, 2023).

Furthermore, the nature of food consumption is essential among the factors influencing the state of the natural environment (Haas, 2021). The environmental consequences of such impacts include climate change, soil degradation, pollution and water scarcity, loss of habitats and biodiversity. Food waste causes an unreasonably high level of use of such resources as water, arable land, fertilizers, fossil fuels, and is also one of the causes of greenhouse gas formation (Kummu et al., 2012). Thus, household food consumption leads to more than 60% of global greenhouse gas emissions and 50 to 80% of total resource use (Ivanova et al., 2016).

The issue of preventing the formation of food waste is included in the EU's circular economy action plan (EIT Food, 2023). Directive 2008/98/EC also aims at reducing and monitoring food waste. The directive obliges member states to implement food waste prevention programs, encourage food donations and other redistribution; create incentives to apply the waste hierarchy, for example, promoting charitable food donation (The European Parliament and the Council of the European Union, 2008; 20018).

For Ukraine, as a candidate country for joining the European Union, reducing the amount of waste, including food waste, should be one of the priorities of the state environmental and social policy. Reducing the amount of food waste per capita at the level of retail trade, hospitality establishments and consumers themselves is crucial for creating food security and transitioning to a resource-efficient economy (Teodorovych & Kyianytsia, 2022). One of the effective ways to reduce the amount of food waste is the formation of a culture of food consumption, increasing the level of awareness and consciousness by consumers of the consequences of their eating behaviour and the impact of food waste on the environment.

In high-income countries, the transformation of food consumption is considered essential for achieving the global goals of sustainable development (UN, 2016). Increasing the ecological sustainability of food models is gaining more and more importance (Springmann et al., 2016; Hartmann and Siegrist, 2017; Magrini et al., 2018; Hedin et al., 2019).

The article aims to identify current problems in handling food products and food waste in Ukraine at the level of individual consumers, as well as to establish the degree of involvement of Ukrainians in global trends of responsible consumption.

Materials and Methods. The article uses the analysis of scientific literature sources, systematization, synthesis, generalization, methods of quantitative research and data processing. The main tool of the research was a questionnaire, which included 17 questions with multiple choices, closed and open type. The questionnaire focused on the following main areas: demographic data of respondents (age, gender, field of activity, region of residence); familiarization with the basics of responsible consumption; nature of behaviour with food waste (causes and frequency of formation, method of disposal); use by consumers ways to reduce food waste (buying goods at discounts, using food banks, etc.); the main factors affecting consumer choice when buying food products.

The current state of responsible consumption culture among domestic consumers was assessed through an anonymous survey in May 2023. The study covered 150 people of different age groups, fields of activity and regions of residence. The survey was conducted online by using Google Forms.

Results and Discussion. Every year in the world about 1.3 billion tons (17%) of food products with a total value of almost 1 trillion dollars end up in landfills, forming food waste. This amount of food is enough to feed 2 billion people (Dehtiarenko, 2021). About 30% of the world's food production, including fruits, vegetables, oilseeds, meat, dairy products, and fish, is lost or wasted. This even though about half of them are suitable for consumption. Approximately 30-50% of all waste is organic waste: clippings of vegetables, fruits and greens, leftovers, spoiled products, bones, sometimes withered flowers, leaves. This is the classic wastebasket set in its organic form (Food Waste Index Report, 2021). The problem of food waste is relevant throughout the food chain, from the production of agricultural products to storage, processing, transportation, trade and consumption (Paužuolienė, Šimanskienė & Fiore, 2022).

The Food Waste Index 2021 report released by the United Nations Environment Program (UNEP) states that in 2019 global food waste was 931 million tonnes (about 121 kg per capita), with about 690 million people going hungry. It is noted that 61% of food waste occured in households, 26% - on public catering and 13% - on retail trade (Food Waste Index Report 2021). Specifically, on a global scale, 17% of the food produced in the world is wasted (11% - by households, 5% - in the food sector, 2% - in retail trade). Together they lead to 8-10% of global greenhouse gas emissions. (Food Waste Index Report 2021).

The generation of waste is an equally urgent problem in all countries, regardless of their level of socio-economic development: in low-income countries a large part of it falls on production, in developed countries - on the consumption stage (Kundieieva & Kulish, 2020).

Ukraine is one of the leaders among European countries in terms of the number of landfills: each resident of Ukraine sends an average of 250-300 kg of solid household waste to the landfill per year, 60% of which is organic waste, including food products. According to statistical data, in Ukraine about 7 million tons of food products are simply thrown into the trash every year. The total value of discarded products still suitable for consumption is more than UAH 6 billion (Kundieieva & Kulish, 2020). The lack of effective measures aimed at preventing the formation, processing and utilization of food waste and losses inhibits the development of the national economy, contradicts the principles of sustainable development (All-Ukrainian Environmental League, 2019).

A significant reason for the accumulation of excessive amounts of food waste is a low consumption culture. Food preferences, choices and habits occupy a central role in human cultures, and food consumption goes far beyond its functional role as a means of survival (Vermeir, Weijters & Verbeke, 2020). The conducted research is aimed at studying the habits of Ukrainians regarding food consumption and food waste management in everyday life.

The demographic picture of the survey participants is as follows: 75.4% of women and 24.6% of men participated in the poll. The most active age group among the respondents was youth, aged 17-21 years - 67.5%. The structure of survey participants by other age groups has the following indicators: respondents under 17 years of age – 3.5%; 22-30 years old - 2.6%; 31-40 years old – 8.8%; 41-50 years old – 9.6%; over 50 years - 7.5%.

As for the respondents' field of activity, 53.5% of the respondents are students of educational institutions; 8.8% – employees and civil servants; 3.5% – private entrepreneurs; 1.8% do not study or work anywhere; 21.1% are working students; 8.8% – lecturers and scientists; 2.6% are employed in the household.

Representatives of almost all regions of Ukraine are presented in the survey (Fig. 1). At the same time, the vast majority of respondents live in Kyiv region (47.4%) and the city of Kyiv (8.8%). A large part of the survey participants live in cities - 64%; 23.7% of respondents live in villages, 12.3% live in urban settlements.

Despite the fact that 66.7% of respondents know and understand the essence of the concept of "responsible consumption", a large part of those interviewed have heard such a term, but do not understand its meaning (26.3%) or have not come across such a concept at all (7%).

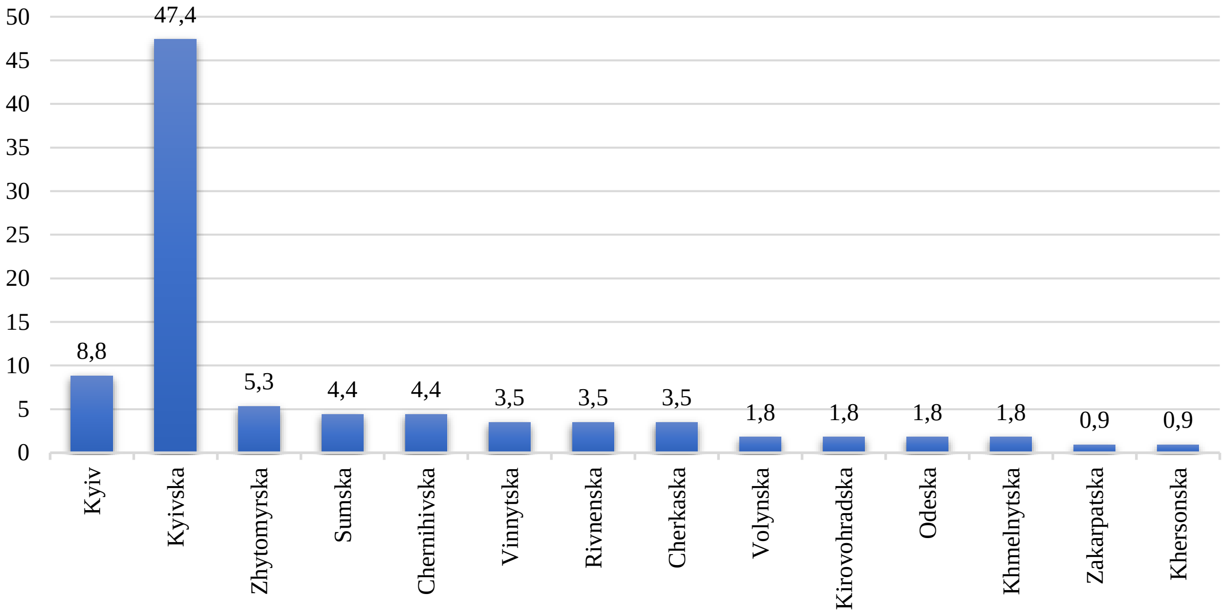

Fig. 1. Distribution of survey participants by region of residence, %

Regarding the behaviour of respondents with food and food waste, the study showed: only 16.7% of respondents never throw food in the trash; they do it occasionally - 68.4%; 14.9% often do it. At the same time, only spoiled products are thrown away by 85.1% of respondents; and 7.9% of survey participants noted that they also throw away products that are still suitable for consumption.

Analysis of the reasons for which food products end up in the trash led to the formulation of the following conclusions. This most often happens during the holidays, when consumers buy more products and prepare meals for the festive table - 48.2%. Quite often there is a situation when the consumer discovered that they purchased a low-quality product, but for various reasons cannot / does not want to return them to the seller - 31.6%. Also, some respondents (29.8%) noted that they often buy products in advance and forget their expiration date (fig. 2).

Most often, ready-made first courses end up in the trash - 46.5%; fruits and vegetables - 46.5%; as well as milk and dairy products - 27.2% (fig. 3). The results of the survey showed that the vast majority of surveyed consumers use spoiled or useless food as animal feed (50.9%) or throw it in the general trash (60.5%) – fig. 4.

In general, it should be noted that life in rural areas, from the point of view of minimizing food waste, is more ecological and socially responsible. Almost all leftover food (organic waste) is used as animal feed or disposed of in a compost pit, turning into a humus. Surplus food is either distributed to neighbours or also fed to animals. Most of the city dwellers throw all their organic waste into the trash.

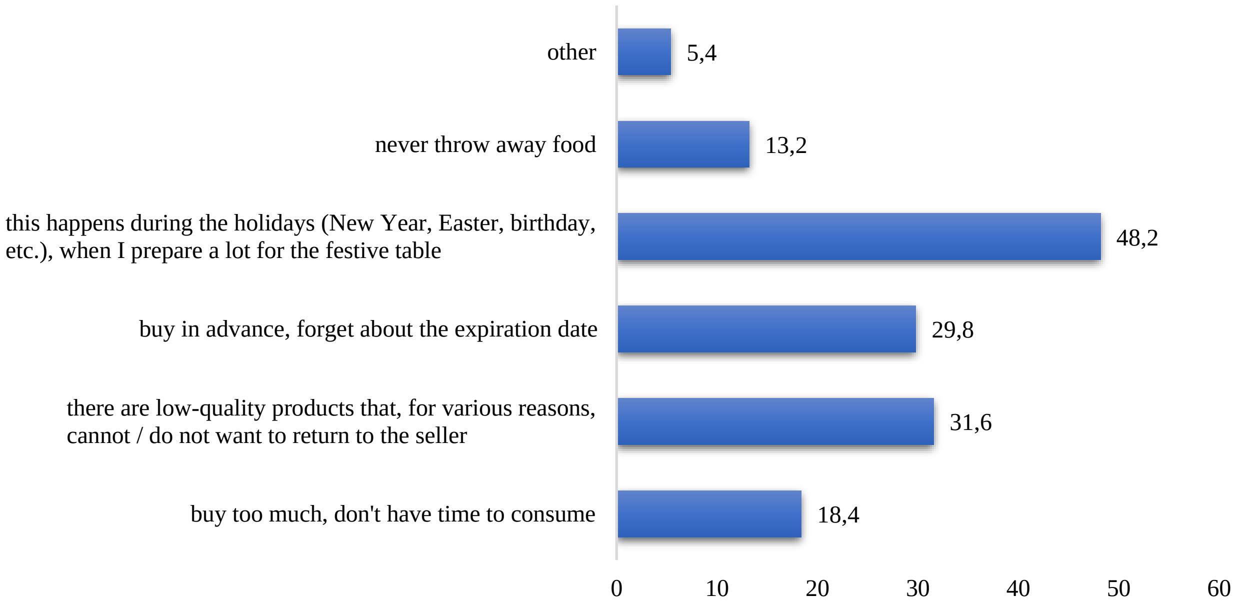

Fig. 2. The main reasons why consumers throw away food products, %

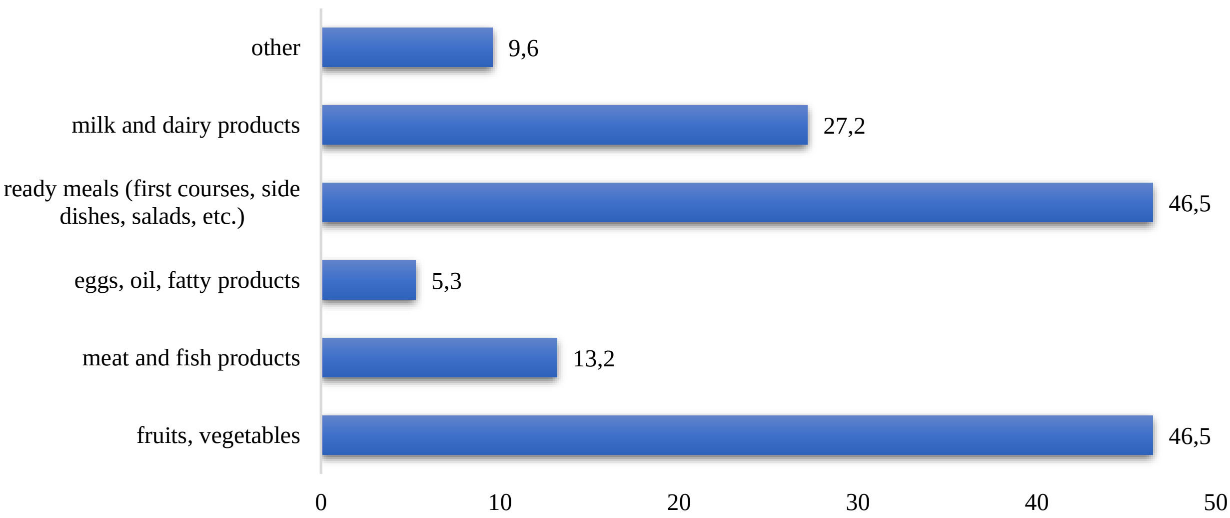

Fig. 3. Groups of food products that most often end up in the trash, %

A number of global initiatives are aimed at preventing an irresponsible attitude to food and avoiding the threat of hunger. One of the directions for reducing the amount of food waste, which has long gained popularity abroad, is the creation of food banks. These organziations are engaged in distributing food products from private individuals or businesses (manufacturers, trade organizations, catering establishments and other suppliers). Food banks operate in more than 40 countries, providing more than 40 million people with products whose shelf life is ending, or the appearance of which does not suit stores. The largest global networks of food banks include (Dehtiarenko, 2021): Global Food Banking Network (GFN), Feeding America, European Food Banks (FEBA). Social trends - food sharing and food saving - are also spreading in the world (Teodorovych & Kyianytsia, 2022).

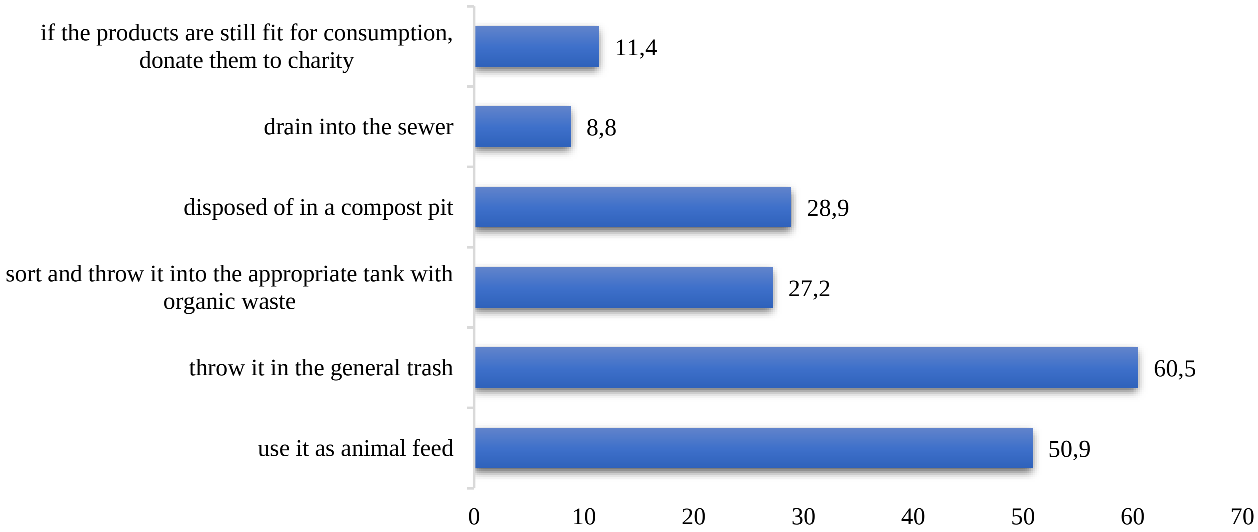

Fig. 4. Main methods of food waste disposal, %

Ukraine is gradually joining the global trends of responsible consumption. In 2011, the Ukrainian food bank "Kyiv City Charitable Fund Foodbank" began its work with the support of the European Food Bank Federation (KCCF "Food Bank", 2012), which unites 240 Foodbank organizations in 21 European countries (European Food Banks federation, 2023). In 2021, the Food and Agricultural Organization of the United Nations (FAO) launched a pilot project aimed at reducing food waste in Kyiv and Lviv. In the same year, the first food bank "Tarilka" started working in Lviv, and in 2022 - in Kherson. The main mission of the projects is to reduce waste, provide food to people experiencing poverty, form a culture of food banks in Ukraine, spread ideas about a rational attitude towards products and help others. However, for various reasons such initiatives have not yet become widespread.

The results of our research showed that consumers in Ukraine practically do not use the services of food banks. Most of the respondents (70%) had not heard about the existence of such organizations and their mission at all (Fig. 5). Only 23% of respondents know about domestic food banks and initiatives such as "Tarilka", food sharing and food saving (Fig. 6). It should be noted that urban residents (79.4%) and young people (76.5%) predominate among respondents who have at least minimal information about the activities of food banks.

Physical, economic, and social access to food products is one of the key priorities in ensuring the country's food security. Under the conditions of military aggression, the problem of overcoming the hunger of the Ukrainian population acquired its urgency. The popularization and further development of the activities of food banks can become an effective tool for ensuring the food needs of the civilian population in wartime conditions.

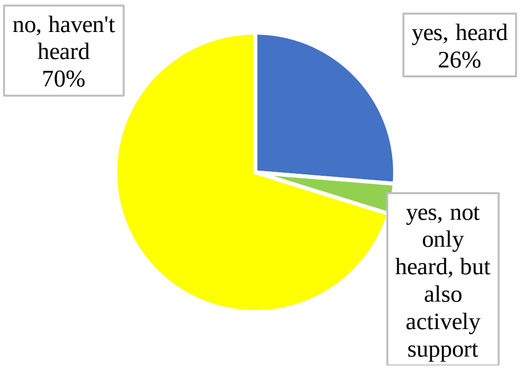

Fig. 5. Consumer awareness of food banks

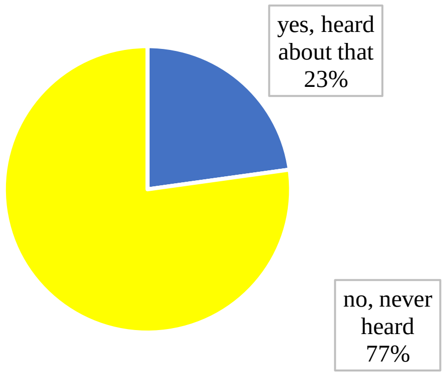

Fig. 6. Awareness of consumers in Ukraine about national initiatives such as "Tarilka", "Lunch without Trouble", #foodsharing, etc.

Another popular initiative is gradually conquering the world - the "Too Good To Go" application. The project was launched in 2016 and aims to reduce food waste due to the purchase at reduced prices of expired products and dishes. In 2021, Google joined the initiative with its "Waze" application (Dehtiarenko, 2021). Unfortunately, such an initiative is currently not available for Ukrainians. However, the prospects are still optimistic - the survey showed that only 13% of respondents categorically say that they will never buy food products at reduced prices, the expiration date of which will soon expire. While 13% of respondents do so often, 48% sometimes, and 26% do not currently buy, but do not rule out such a possibility in the future (fig. 7).

It is likely that a mobile application like "Too Good To Go" or "Waze" would gain popularity among domestic consumers. According to the results of the study, 25% of respondents indicated that they would definitely use such an application, 43% did not reject the possibility of using such an application (fig. 8)

A significant percentage of consumers (55.3%) are not against joining initiatives aimed at reducing food waste; 38.6% were undecided, and 6.1% of respondents indicated they were not interested in this issue. At the same time, the analysis of the factors that are a priority for consumers when deciding to buy food products showed that the determining factors are mainly factors that directly concern the consumer here and now – expiration date, product composition, manufacturer, etc. And such factors as the possibility of reprocessing packaging, environmental friendliness of production occupy the last positions (fig. 9).

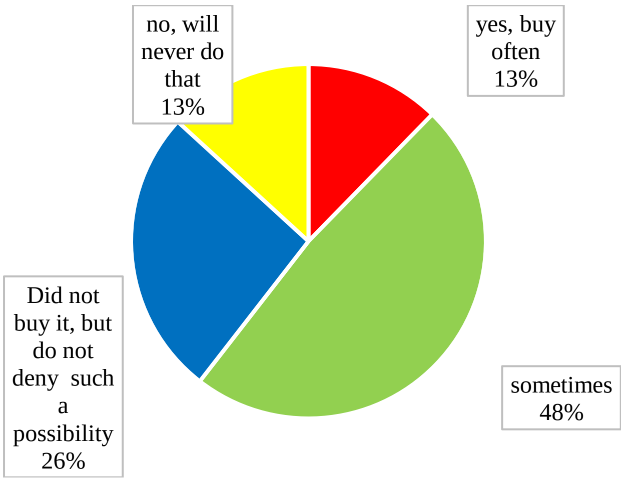

Fig. 7. Attitude of the respondents towards the purchase of food products at reduced prices, the expiration date of which will soon expire

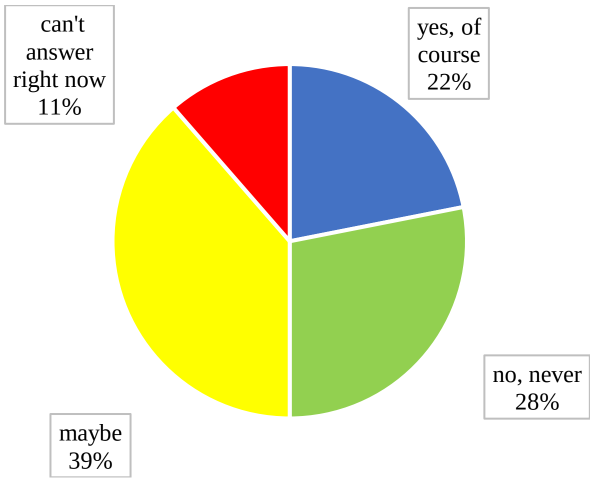

Fig. 8. Respondents' assessment of the likelihood of using an application with information that helps to purchase at reduced prices products or ready-made meals whose expiration date is coming up

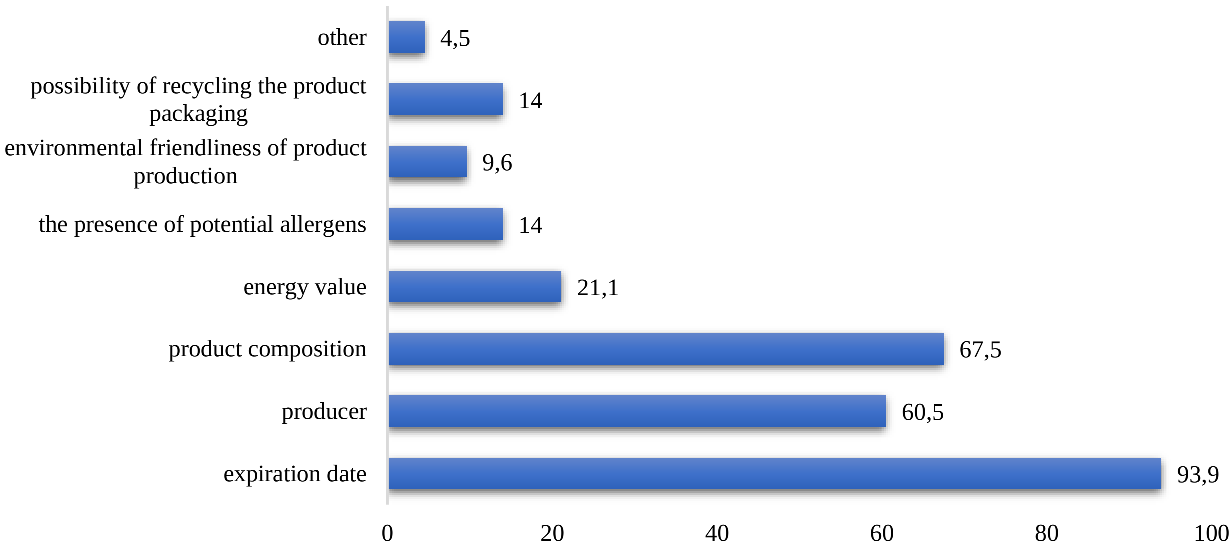

Fig. 9. Priority selection criteria for consumers when buying food products, %

Altogether, a socially responsible consumer, making a consumer choice, has to take into account a number of additional parameters, in particular (Kundieieva & Kulish, 2020): product quality and its impact on health; product safety for the environment at all stages of its life cycle; the service life of the product and the method of disposal after its end; the region of production and the distance over which the products are transported; the reputation of the company-manufacturer and the company-seller of the product, as well as the level of their social responsibility.

Conclusions. The problem of food security is closely related to climate change, waste sorting and processing, as well as other issues of humanity: ecological, economic, and social. An essential prerequisite for reducing the amount of food waste generation is the formation of a high culture of responsible consumption of food products. Changes in consumer behaviour can significantly reduce food waste.

The conducted research has shown that the culture of responsible consumption in the food sector is just beginning to take shape in Ukraine. This is due to a number of both subjective and objective reasons.

Firstly, a significant part of consumers is not familiar with the principles of responsible consumption and handling of food waste, does not have information about the real volumes of their generation and does not suspect the possible consequences of irresponsible handling of them. Educational activities, training and informing people are decisive in solving this problem. Understanding the problem of food waste will stimulate a reorientation of the economic behaviour of consumers with an emphasis on saving food, avoiding impulse purchases and planning one's grocery basket to minimize the loss of edible food.

Secondly, there is a problem related to the lack of infrastructure that would promote responsible food waste management. In particular, for example, such options for handling food waste as animal feed or composting are practically unavailable to city dwellers. On the other hand, in rural communities there are practically no waste sorting points, no access to food banks, etc.

Third, many consumers simply do not have information about government, corporate or public initiatives to reduce food waste. The study showed that the majority of consumers are not familiar with initiatives in this direction and, accordingly, do not have the opportunity to join them. As a rule, food retail chains build their communication strategies, starting more from their commercial interests than from the principles of responsible consumption.

Thus, the solution to the problem of food waste should be comprehensive. At the same time, the main efforts should be focused on forming a culture of responsible consumption among the population; creating a full-fledged infrastructure in the field of food waste management; building an effective communication system between consumers and entities whose activities are aimed at reducing the amount of food waste generation.

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SKYLINES OF SUSTAINABLE JOURNALISM; A FRAMEWORK FOR UKRAINIAN MASSMEDIA

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Abstract. *The article is aimed to study the development and prospects of the Ukrainian sustainable journalism, according to current challenges. Conditions of the full-scale invasion of Russia and long-term aggressive war put new problems before Ukrainian society and Europe, which are traditional for sustainable journalism of contamination of ecology, elimination of ecosystem, humanitarian disasters. Steady development of economy and social environment was violated.*

Authors provided a differentiation upon media problems of the sustainable journalism from regional to the international levels. The aspects of the sustainable journalism were considered such as journalism of ecological, social and economic problems, the issues were specified according to the war terms. In the process of development of the sustainable journalism in Ukraine there was shown a balance between illumination of the resulted problems.

Attention was concentrated on the conditionals for the successful sustainable journalism in Ukraine. Four conditions were determinated: freedom of press, economic stability for media, quality journalism principles that make high professional standards both for media-workers and media-owners, and international and global angle for journalists. All of them formed a stable scheme illustrating the framework of sustainable journalism for Ukraine.

Introduction. The concept of sustainable journalism, or journalism on sustainable development, arose in the scientific environment of Swedish media researchers and slowly circulated into the scientifical texts created by authors from developing countries of the African continent, Central and Eastern Europe, and Asia (Magnér, 2022).

Ukraine pursue being a sovereign European state taken seriously global problems. All the time it is. According to Sustainable Development Goal 16.10 (in the edition for Ukraine), it is necessary to expand public access to information and extend the protection of fundamental freedom (Sustainable Development Goals, 2017, p. 161), that demonstrates a great and remarkable role of journalism in information society. A public that has operational, reliable, accurate and independent information, and is aware of the tasks and importance of achieving the goals of sustainable development, is advanced and well-armed one. Definitely, such a society is ready to undo the difficult problems of the time and has the ability to quickly respond to global challenges, which is the key to the future.

In Ukraine, the issues of sustainable development have been studied for a long time, and journalists are also involved in this process (but still no selected works on sustainable journalism particularly). For example, in 2012, an all-Ukrainian competition was held, where analytical journalistic materials on the topic of sustainable development competed. On the initiative of the UN in 2016, 2017, 2018, etc. contests on sustainable development for journalists were announced in Ukraine. These are only few examples that we can receive from the announcements and press releases. We should not forget furthermore about the scientific study of the goals, tasks and opportunities of sustainable development both by specialists of a quite high profile and by groups of researchers applying an interdisciplinary approach to enrich the results that can be obtained.

Research methods. Allthough the concept of sustainable journalism exists since it was first presented by Ulrika Olausson, Peter Berglez and Mart Ots in 2017, there is no solid literature studying the idea according to the Ukrainian basics only. Mediastudies & medialogy, which means a scientifical multidisciplinary understanding media, almost avoid the theme. It simply makes a great demand to study the essense and prospects of Ukrainian version for sustainable journalism in its multidimensional fullness.

The aim of the study is to draw the systematic basics and perspectives of sustainable journalism in our state due to the Ukrainian media's development situation. There are many studies on certain aspects of the informational, sociological, political science, ecology and geopolitical issues of the states of Eastern Europe, but there is no holistic work that would explain the perspectives by interdisciplinary approaches in media studies. The authors used such methods of media research as observational method, method of analogy and comparative method. Among the methods of the research procedure itself, we would like to emphasize the use of abstraction and idealization methods, which were used to construct the proposed scheme logically.

Results and discussion. If we turn to the current situation, we will see that in fact the skylines of sustainable development simply for Ukraine, and for Europe in general, have been pushed back due to various aspects of the increased intensity of the Russian-Ukrainian war. Namely, after Russia's full-scale invasion to the territory of Ukraine, many achievements of our state that walked in the direction of sustainable development in a number of environmental goals were reduced to a minimum: we should name a destruction of ecosystems, environmental damage and pollution, changes in biodiversity. Since everything is connected, these problems will inevitably affect the intensity of progress in sustainable development for those European countries that are not among the belligerents. Today, the damage caused by Russia in this way on the countries of Europe is difficult to quantify. There are also related problems that will negatively affect Ukraine's ability to move towards sustainable development after a future victory and deoccupation of the whole territories. This issue is too large to be considered in the format of the article, so let's just take it into account as essential issue for our further presentation of the prospects for the development of sustainable journalism in Ukraine.

We deeply analyzed the latest data from Eurostat's reports released on 24 May 2023. The impact of the war in Ukraine is frequently referred to (Eurostat monitoring report, pp. 16, 20, 31 etc.), but no mentions in «Sustainable development in the European Union ; Statistical annex to the EU voluntary review». The question is figure heavily but it exactly is. As to the words of M-r Paolo Gentiloni, European Commissioner for the Economy, responsible for Eurostat, «no sustainable development is possible without peace and no peace without sustainable development» (Eurostat monitoring report, p. 4).

From the point of view of the concept that was proposed by Swedish scientists, sustainable journalism is not just the activity of mass media that provide the audience with journalistic materials related to the topics and issues of sustainable development (Berglez & al, 2017). As to the topics, sustainable journalism is located between environmental journalism reporting about various problems about ecology such as a climate change, loss of biodiversity and others, social journalism covering themes on peace, security, justice, human rights, democracy, equality, and economic journalism (Adjin-Tettey & al, 2021, p. 8).

It includes a coverage of economic, social, and environmental problems of the globalized world; the use of new advertising formats to promote the idea of sustainable development, which can earn the trust of the audience; finally, a regional tier of journalistic reports about the problems of the modern world should create a logical link to the perspective of global threats and their consequences. Mass media can play a «vital role in achieving the SDGs to create awareness about it» (Wagh, 2019, p. 1758). Media also could organize effective public discussions (Bodt, 2007, p. 495).

On our opinion, the task can be realized according to several levels of functioning of journalism messages, ranging from regional media with their coverage of local events, and ending with international journalism. Then, in this way, a relief horizontal+vertical format of sustainable journalism is designed as below:

Fig 1. Model of sustainable journalism by subjects and levels

Journalism becomes sustainable exactly «by balancing or ideally exchanging the production of "quick and dirty news" with information that enables future generations to meet their own needs» (Adjin-Tettey & al, 2021, p. 11).

Journalism not only helps to disseminate information about the necessary steps to achieve a balance of sustainability, but also turn the attention of the audience right by addressing people. «People are the center of sustainable development. Meeting more and more fully the material and spiritual needs of all classes of people, building a prosperous and prosperous country, a just, democratic and civilized society is a consistent principle in every stage of development» (Adamkolo, 2020, p. 5). It can also be noted that the center of journalism is people. Journalism «has always been functioning to serve human communities» (Al Sheikh & Al Serhan, 2022). It is society and the needs of people that are in the focus of attention of the media in any period of their activity. Without it, every media becomes inane.

According to the «Media Sustainability Index 2019 : Europe & Eurasia», Ukrainian media is detected as «near sustainability» (IREX, 2019, p. 15) with its 2.09 point from the scale of 2.01-2.50 and changed a little as a comparison to 2018.

Thus, we belong to the image: «Country has progressed in meeting multiple objectives, with legal norms, professionalism, and the business environment supportive of independent media. Advances have survived changes in government and have been codified in law and practice. However, more time may be needed to ensure that change is enduring and that increased professionalism and the media business environment are sustainable» (IREX, 2019, p. 15).

Taking under consideration the data presented in «Vibrant Information Barometer 2022» upon Ukraine only, we can see the score for Ukrainian media between 20 and 26. So it indicates Ukraine between «slightly vibrant» to «somewhat vibrant». Thus the description is as follows: «Quality information is available in this country and most of it is editorially independent, based on facts, and not intended to harm. Most people have the rights, means, and capacity to access a wide range of information, although some do not. Most people recognize and reject misinformation, although some do not» (IREX, 2022).

Funding support for the effective work of journalists and economic profitability of the media is important for maintaining a sustainable course of development of journalism, as it ensures the viability and further progress of the mass media.

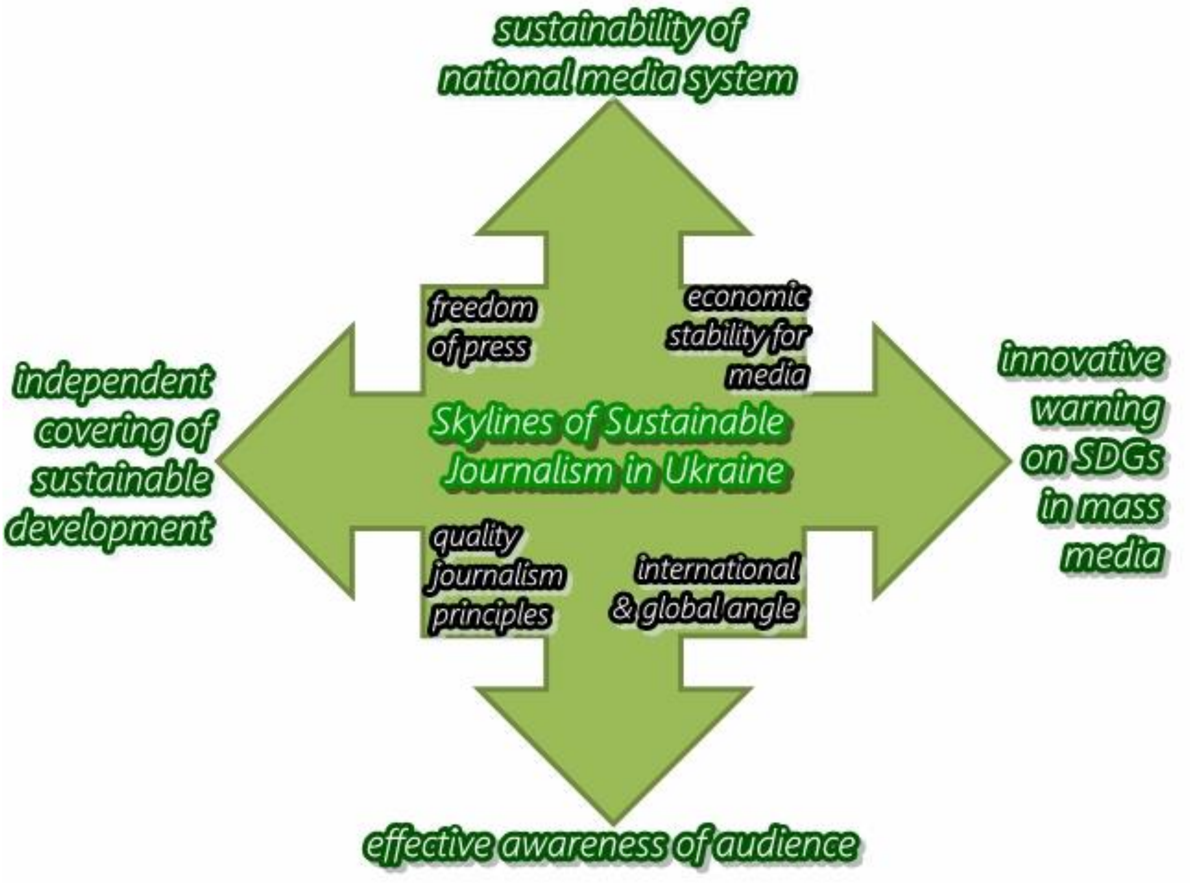

Fig 2. Framework of sustainable journalism for Ukraine

The speed of obtaining or verifying information, issuing printed copies, etc., often depends on the economic factor. While maintaining sustainability in everything, the government of the state should also take care of the stability of the economic condition of television, radio, press and new media.

Based on the foregoing, we present the scheme obtained as a result of the study as follows. The skylines of sustainable journalism in Ukraine should be based on four conditions: freedom of press, economic stability for media, quality journalism principles that make high professional standards both for media-workers and media-owners, and international and global angle for journalists to see and address.

While crossing each of these conditions, or taking the sum of the adjacent ones, the result follows as an essential circumstance, without which sustainable journalism in Ukraine will not be able to fully develop in the future. These are: independent covering of sustainable development (as the sum of freedom of press and principles of high-quality professional journalism), effective awareness of Ukrainian audience (principles+international & global angle), innovative warning on Sustainable Development Goals in mass media (which rooted from international angle+economic stability for media), sustainability of national media system (that arise upon freedom of press and economic stability).

Conclusions. The concept of sustainable journalism is one that can be implemented in Ukraine. Skylines for the development of sustainable journalism in Ukraine are significantly complicated in current circumstances. However, based on the data of international ratings that were examined in the study, it could be stated that media sphere in Ukraine shows significant potential. Coming as high as to the international level, the principles and quality of competent journalistic craft contribute to strengthening the stability of journalism.

In the study, the data on sustainable journalism were systematized and the authors' vision of the skylines was presented. Looking over trends in the development of the media sphere in a global sense, as well as the success of external assessment of Ukraine's achievements in the field of freedom and competence of the press, and an achievement of sustainable development goals also, the authors of the article proposed a nominal «compass» which is a framework of sustainable journalism for Ukraine. The outlined framework was developed on the basis of the studied information and official reports, taking into account the current situation in the media sphere. The framework is quite realistic and responds the positive forecast for the development of journalism in our country. The conditions and the circumstances originated from the very idea fit into a logical and understandable scheme.

The results of the study can be used by specialists in the field of planning, public administration, media experts and journalists.

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IDENTITY SEARCH: FROM DIVIDED TO PRO-EUROPEAN UKRAINIAN IDENTITY

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Abstract. *The article discusses a controversial issue of Ukrainian identity with a focus on its pro-European component as a factor in shaping consolidated identity and overcoming the "divided" identity. Based on interdisciplinary research on identity, Barthes' concept of mythologizing, and the approach to fields of memory from a narrative analysis perspective, the article reached the following findings. The narrative framework underlying the origins of pro-European identity among Ukrainians is presented through a schematic narrative template that combines structural elements of "affinity with European principles of state-building," "Ukrainians' participation in the development of European history," and "shared democratic values." These elements are based on six associated narratives derived from the fields of Ukrainian memory and the contemporary narrative of their "common values" with the democratic world.*

Tools for demythologizing the narratives that underlie the divided identity of Ukrainians are schematized in a narrative template of causal connection between "chosen traumas" and "liberation struggle", which integrates narrative plots, characters, and motifs of their actions into the structural components of Exposition, Complication, Resolution, Evaluation, and Code, and in the sequence of narrative functions: Deception, Villainy, Prohibition, Violation of Prohibition, Beginning of Resistance, Struggle, Persecution, Stigmatization, and Victory. At the linguo-pragmatic level, the consolidation of Ukrainian identity is achieved through strategies of value polarization of "us" versus "them", discrediting the mythologemes of "kinship" and "care" in their modern rearticulation during the wartime, restoring inverted roles and role players, and positive-re-evaluation of Russian derogatory labels for Ukrainians.

Introduction. Discussions about a divided or united Ukrainian identity, which became especially relevant in interdisciplinary studies at the turn of the XX and XXI centuries, take on a new dimension in light of the Russo-Ukrainian war, with a fresh perception of national identity as a factor of exceptional solidarity among Ukrainians. Obviously, there is an acceleration of the process of consolidating national identity, which displaces dual identity, consisting of "Central European" and "post-Soviet" identity (Himka, 2006, 483) – the result of regional divisions, linguistic differences, etc. In 2020, nearly 40% of Ukrainians were still searching for their national identity. However, in 2021, 62.6% had already embraced their complete national identity, and by 2022, this figure had risen to 79.7%. At the same time, 3.9% identified themselves ethnically (compared to 2.7% in 2021) and 1.4% - as citizens of the former USSR (compared to 2.8% in 2021) (Dembitskyi, 2023). However, as noted in the presentation of sociological monitoring, the formation of a civic nation does not eliminate the need to address the next important task at the national level – full European integration. This underscores the relevance of exploring the sources and means to strengthen the pro-European direction of Ukrainian national identity, which, according to monitoring, is still insignificant (1.6% of Ukrainians see themselves as citizens of Europe and 3.3% – citizens of the world) but tends to grow compared to 2021 (with indicators of 0.9 and 3.1, respectively) (op. cit).

The aim of the article is to trace the formation of pro-European Ukrainian identity by exploring the conflicting and integrative structural elements of national identity in the dynamics of their development and transformation within historical and social contexts. The research *objectives* are as follows: (a) to identify the origins of the "divided" identity among Ukrainians and specify the instruments of the contemporary Ukrainian discourse aimed at consolidating and unifying identity, (b) to determine the factors contributing to the formation of a comprehensive Ukrainian identity with a pro-European component. These stated goals define the two-component structure of the study.

The theoretical basis, materials, and methods. The article is based on research on (a) identities within various research paradigms, with an emphasis on a discursive approach, (b) the structure of narratives underlying ideologemes and mythologemes that shape identity, and (c) memory fields of a usable past (Brooks, 1918) underpinned by the idea of "expanding" the past from the present, selectively preserving events and facts from the past that hold symbolic significance in the present (Maines, 2001, 37).

The discursive approach focuses on the processes of identity formation, expression, and change in the social, political, and cultural contexts, defining identity as a discursive construct (Bamberg et al., 2011), which is transformed through the rearticulation of discourses (Hammack, 2008, 2) that create, maintain, and transform the values underlying identity. Different approaches to identity view it as a continuous (Cherrier-Murray, 2007), dynamic, and variable phenomenon, depending on global societal processes, history, discourse, and culture, as well as a narrative (Mikkonen et al. 2011) and symbolic-projective (Kravchenko et al., 2021; Mikkonen et al., 2011) phenomenon, constructed through language and symbols. The discursive approach is relevant due to the world-modelling properties of collective memory that affect the present and future (Huyssen, 2003, 6), including the formation of national identities (Smith, 1991, 9) based on shared "textual communities" in which the thinking and actions of collectives are "rooted" (Wertsch, 2002, 28).

In this context, the discursive approach correlates with the narrative perspective in the study of identities, with the representation of the historical, social, and political myths as texts – encoded mythological messages (William, 2000), the set of which forms myth spaces, "in which different myth communities are created and contested" (Bell, 2003). An important concept to consider is Smith's (2006, 335) theory on the significance of ethnic symbols, myths, values, and traditions in the formation and self-reproduction of nations, with subsequent adaptation of what nations consider their past through its repeated discovery, authentication, and appropriation of aspects (Smith, 2001, 83-85), which play a crucial role in shaping national identity.

The significance of symbolic and narrative codes in identity construction motivates the article's engagement with Roland Barthes' theory of political myth, which transforms history into ideology through the functioning of signs. Myth functions as a metalanguage and a secondary semiotic system, in which every sign becomes the signified of mythologeme or demythologeme, replacing the denotative meaning of events and phenomena (Barthes, 1973). In this vein, the article introduces the concepts of demythologization and identifies its tools in the Ukrainian identity-forming discourse to debunk Russian myths that underlie the pro-Russian component of Ukrainian identity.

The research material includes (a) the publications of the Public Educational Project "LIKBEZ. Historical Front" aimed at countering Russian propaganda and popularizing the history of Ukraine, "since it is precisely an adequate vision of the past that is the basis of Ukrainian identity" (Likbez, 2023), and (b) excerpts from academic historical discourse from the works of M. Hrushevskyi, Ya. Hrytsak, M. Kostomarov, I. Lysiak-Rudnytskyi, S. Plokhii, etc. (c) program documents of the Cyril and Methodius Brotherhood (Saltovskyi, 2002), (d) contemporary media outlets that cover the contributions of Presidents Viktor Yushchenko and Petro Poroshenko to the consolidation and unification of Ukrainian identity, as well as President Zelensky's speeches before the parliaments of European states in 2022-2023.

The interdisciplinary **methods** of the project includes (a) a narrative analysis of memory fields related to the formation of Ukrainian identity based on the approach to collective memory as a text, (b) semiotic analysis (Barthes, 1973) aimed at explicating the mechanisms of demythologization of narratives underlying Ukrainian divided identity, and (c) the elements of critical discourse analysis to identify the markers of the Ukrainian identity construction at the ideational and linguo-pragmatic levels of discourse of the war period (Kravchenko, 2022).

Narrative analysis (Alker et al., 2001; Wertsch, 2008), as the primary method aimed at constructing schematic narrative patterns based on narratives of both "divided" identity and the pro-European component of Ukrainian identity, is conducted in several stages: Identification of key narratives related to divided identity and the pro-European aspect of Ukrainian identity; Extraction of key narrative elements, symbols, and themes, focusing on their role in shaping identity; Construction of schematic narrative templates that represent the underlying structure and recurring themes within the narratives; Interpretation and meaning-making by highlighting the significance of the constructed narrative patterns in the formation of identity, including its pro-European dimension. Representation of historical events in the form of a narrative is based on characters/roles and the motivations behind their actions, the sequence of functions (following Propp's (1968) framework), and the plot-structural components common to a set of narratives: Orientation – Complication – Evaluation – Resolution – Coda (Labov, 1972, 363-393).

Results and Discussion.

I. Schematic narrative templates "*the origin of the pro-European identity of Ukrainians"* integrates the totality of its associated narratives underlying three structural elements such as (a) the establishment of federalist principles and a republican system in the Ukrainian statehood, which prove inherent kinship with European principles of state building; (b) the Ukrainian history as a part of the history of Europe, with direct or indirect participation of "Ukrainians of all classes and cultures in the development of European history," as pointed out by M. Drahomanov (Plokhii 2005, 156) and (c) the democratic values that underpin the pro-European component of Ukrainian identity.

The first structural element is based on (a) narratives about building a Ukrainian state based on European federalist principles of the Ukrainian statehood, from Vladimir Monomakh who formed by the middle of the 10th century a confederation of "city regions" united by Kyiv (East Slavic tribal unions with broad autonomy) – to Bohdan Khmelnytskyi. During the Ukrainian national liberation war of 1648-1654, he put forward his own program for building the Ukrainian Cossack state based on the principles of Ukrainian unity, with the new idea of Cossack statehood. As a precondition for full independence, he attempted to create autonomy for the Cossack region within the Polish-Lithuanian Commonwealth, and later in a confederate union of two independent states under the rule of the Romanov dynasty (Kostomarov, 1928), (b) the projective narratives in the program documents of the Kyiv Community (Hromada) and Cyril and Methodius Brotherhood of the 1860s that envisage a voluntary federation of equal Slavic nations (Saltovskyi, 2002), which the Central Rada later tried to implement, (c) narratives of the Ukrainian community as a free association of people based on mutual agreement and principles of moral regulation, connected with the role of the "veche" – a popular assembly of all free residents of the city as the highest legislative and judicial authority and the bearer of popular sovereignty (Kostomarov, 1861, 33-80), (d) the narratives related to the federalist concept of Ukrainian statehood during the period of the Central Rada (Lysiak-Rudnytskyi, 1994).

The second structural element “the European vector of the historical development of Ukraine” establishes conceptual and semantic relationships between the narratives (a) of the special role of the Varangians in the history of Ukraine (Plokhii, 2011, 296-297), supporting Hrushevskyi's idea of the Ukrainian people as a people of Western culture, “while the Great Russian, although Europeanized, is completely dominated by the oriental spirit and elements” (Hrushevskyi, 1918, 9); (b) of the crusades of the Ukrainian Cossacks against Islam, with a historiographical parallel between the European crusaders and the Cossacks. In the “Protestation” of 1621 by Job Boretsky, the Cossacks were presented as one of the oldest knightly orders in Europe (Boretskyi, 1988, 323), and (c) of Ukraine as a cultural border and a place of interaction between the worlds, first between the Eurasian steppes of nomads and settlements, then between the East and West (Plokhii, 2017; Hrytsak, 2022). It is important to note that the mythologeme of “border between worlds” is rooted in the memory field of the proto-Ukrainians, where it is manifested by the “plowed field” archetype as a symbol of the transformation of the chaos-associated steppe element into an “ordered” civilized space. It also relates to the legends about Boris and Hleb, who forged the first plow, chained the Serpent and plowed the Serpent's Walls – ancient earth fortifications on the border with the Wild Steppe (Plokhii, 2011, 92). The idea of “border between worlds” is projected in modern Ukrainian grand narrative as the ideologeme “Ukraine is the border between the world and its threatening aggressor”.

The third structural element establishes a causal relationship between the narratives that underlie the “democratic values” of the past and present of Ukrainians, which testify to their pro-European identity. They include (a) historical narratives evidencing the military democracy in the Zaporizhzhya Sich, (b) narratives from the creative heritage of the members of the Cyril and Methodius brotherhood (“Knyhy bytiia ukraïns’koho narodu”), who analyze the ethnonational identity of the Ukrainian people as based on values such as civic equality and freedom, democratic federalism, eradication of slavery and all forms of humiliation, brotherhood, respect for individuality, and self-respect, (c) a modern Ukrainian narrative promoting the European identity of Ukrainians.

In this context, it is important to highlight the contribution of those Ukrainian presidents who facilitated the development of modern Ukrainian society and statehood based on European values, political and organizational principles of closer alignment with Europe. The period of Viktor Yushchenko's presidency was significant for awakening national self-awareness and shaping the European dimension of Ukrainian identity. Yushchenko began to challenge the strongholds of the "russian world," dismantle russian-soviet myths, and emphasize the importance of Ukraine's national historical past. The President played a significant role in raising awareness about the crimes of the moscow soviet regime in orchestrating the Holodomor in Ukraine in 1932-1933, both at the domestic and international levels. In 2007, a special government institution was established with the task of preserving and restoring national memory - the Ukrainian Institute of National Memory. The topics of Baturyn, the Cossack era, the Trypillian culture, the reevaluation of the activities of the OUN-UPA, and a range of other important issues were brought to a broad societal level, awakening national consciousness.

An even more significant contribution to strengthening national identity and its pro-European direction was made by Petro Poroshenko during his presidency in Ukraine. On June 11, 2017, a visa-free regime for Ukrainian citizens with the European Union came into effect. Significant preparatory work for the visa-free regime with the EU had been done under previous presidents, but the final and most crucial decisions in many areas were implemented after 2014. In the first month of his presidency, Petro Poroshenko signed the Association Agreement with the European Union, a process that had been ongoing since the time of Viktor Yushchenko (Zanuda, Chervonenko, 2019).

The Association Agreement with the EU is a massive document with seven sections and over a thousand pages, which clearly regulates the gradual economic and political convergence of Ukraine with the European Union. Disputes surrounding the agreement were a catalyst for the start of the Euromaidan protests in Kyiv, which led to a complete change of government in Ukraine in February 2014 (Chervonenko, 2017), and to further fundamental transformations in the national identity of Ukrainians

During Petro Poroshenko's five years of presidency, the Ukrainian Parliament (Verkhovna Rada) passed changes to the legislation that significantly promoted the use of the Ukrainian language on radio and television. During Poroshenko's presidency, Ukraine banned Russian social networks and practically all Russian television channels.

The pro-European direction of Ukrainian identity, based on shared values and narratives, was explicitly emphasized in President Zelensky's speeches before the parliaments of European countries in 2022-2023.

The common values underlying the historical narratives of democratic countries are voiced in President Zelenskyi's speeches before the Polish Sejm (brotherhood), the Bundestag (responsibility and reunification), the Baltic states (European values and shared suffering under communist regimes), the Portuguese parliament (fighting against dictatorship and allusions connecting the Carnation Revolution and the Ukrainian Revolution of Dignity), and the National Assembly of France (liberty, equality, fraternity associated with the slogan of the French Revolution), with drawing a historical parallel between Mariupol and the ruins of Verdun during World War I. In his speech to the House of Commons, Zelensky emphasizes the connection between "freedom" and "heroism," specifically referring to "heroism in the name of freedom", by paraphrasing Churchill's words and adopting the syntactical peculiarities of his famous speech: "We shall not give up and shall not lose! We shall go the whole way. We shall fight in the seas, we shall fight in the air, we shall defend our land, whatever the cost may be. We shall fight in the woods, in the fields, on the beaches, in the cities and villages, in the streets, we shall fight in the hills". The value-based keywords of the address were "truth", "holy', "responsibility', "dignity", with historical parallels to the battle of the British for Britain against the Nazis (Zelenskyi, 2022). In his address to the Bundestag, Zelenskyi uses the Berlin Wall metaphor, symbolizing the reunification and conceptualized as the Wall between freedom and slavery that Zelensky, citing the President Reagan, calls to tear down.

II. *The ideational and linguo-pragmatic tools for constructing a pro-European identity.*

The events of 2014 and especially the Russian-Ukrainian war have dramatically changed Ukrainian identity due to anti-russian sentiments as a main consolidating element of Ukrainians. A significant part of the modern Ukrainian grand narrative includes tools for demythologization of narratives that underlie the divided identity of Ukrainians and are based on the mythological symbolic structures of the "usable" past, substantiating the imperial narrative in its narrative template "of kinship, forced separation, protection, the shared desire for unity, and common enemies".

Of particular importance in shaping the pro-russian component of the divided identity of Ukrainians are narratives of (a) a united Slavic-russian people, enshrined in the "Synopsis" of the Kiev-Pechersk Lavra (1670s); (b) the "gathering of russian lands" (Liprandi, 1893), based on the mythologeme of a common “ancient russian people” as the ancestor of the East Slavic peoples (which gave rise to the mythologeme of a “common russian nation” from the 1860s), which lived in the same old russian state but were “unfortunately divided” “through the Mongol-Tatar, Lithuanian, Polish” aggressors (Kogut 2004, 161-162), (c) the “common enemies” of Ukrainians and russians who have always fought together, (e) russia as the defender and liberator of Ukrainians, who have always sought to reunite with the russian people in a single state, underpinned by the mythologemes of “protection” and “reunification”, which manifested itself in sub-narratives of liberation from the oppression of landowners and capitalists, from Polish occupation, from the oppression of Romanian landlords, from the Nazis, (f) the disappearance of Ukrainians and Ukraine without an alliance with russia / USSR – in the face of the threat of external aggression, whether it be the Commonwealth and the Ottoman Empire or the First and Second World Wars.

The debunking of such narratives and underlying mythologemes is one of the tools of modern Ukrainian counterpropaganda at its ideational level and is based on a two-component narrative template: “Chosen traumas” in causal connection with “Liberation struggle with russia/USSR”.

The narrative template integrates narrative plots, actors (Ukrainians/Ukraine as victims and hostages, russia as a villain-aggressor and oppressor; Ukrainians as heroes-fighters for freedom and national identity, russia as a villain-aggressor and oppressor) and motives for the actors’ actions (suppression and destruction of everything Ukrainian in narratives of trauma and struggle for the preservation and revival of national identity in narratives of "liberation struggle”).

The structural element of “Orientation” corresponds to the historical context of various homogeneous narratives, their spatial-temporal localization, and main actors. "Complication" is linked in all narratives to the “causal” component of the narrative scheme, while the "Resolution" forms a consequence. Depending on “Orientation” - the context of the unfolding narratives, the “Complication” relies on such culminating moments of the “trauma” narratives as: conscription after the liquidation of the Hetmanate institution, the forced unification of Ukrainian territories with the rest of russia, denationalization, turning Ukrainians into little russians, russification (Valuyev Circular and Ems Ukase), the Bolshevik occupation of Ukraine in 1922, the repressive soviet regime (the Red Terror, the Holodomor of 1932-1933, the famine of 1946-1947, deportations, the executed Renaissance, russification in the Soviet period, putin's war as the last attempt to destroy Ukraine and Ukrainian identity, based on the equating of the semantic scope of the mythologemes of denazification and deukrainization. The “Resolution” is manifested by the “liberation movement” of Ukrainians, the struggle of the Cossacks, the national liberation war for independent Ukraine under the leadership of Simon Petliura, 1917-1921, the peasant insurgent movement led by Nestor Makhno and Ataman Zeleny, 1918-1921, the movement of Ukrainian peasants against collectivization in 1930, the struggle of the Ukrainian Insurgent Army for independent Ukraine in 1942-50, the movement of the Sixties, the Ukrainian dissident movement, and the heroic struggle of Ukrainians in the ongoing russian-Ukrainian War. The Evaluation that unites the narratives in terms of values and meanings contributes, on the one hand, to the demythologization of russian narratives of kinship and protection, and on the other hand, to the formation of the ideologeme of Ukrainianism. Coda entails establishing a connection between the narratives and the present and future of Ukrainian identity based on the fundamental idea of continuity in Ukrainian nation-building, rooted in a spirit of freedom and democratic values.

All narratives are characterized by a sequence of such functions: Deception, Villainy, Prohibition, Violation of Prohibition, Beginning of Resistance, Struggle, Persecution, Stigmatization (in a metaphorical sense - such as imprisonment, exile, execution, etc.). The final function of "Victory" in the narratives of struggle and liberation can be seen at an ideational level as transfiguration of the Hero actor. In this sense, achieving Victory is associated with the archetypal narrative motif of the Hero's journey (Campbell, 2008), for whom the "past" phase of trials, struggles, and overcoming is necessary for transformation and rebirth, possible only in opposition to the status that the Hero had in the past. In modern Ukrainian discourse that underlies development of the national identity, the function "Victory" is underpinned by narratives about the Revolution of Dignity, the consolidation of Ukrainians during the war, including based on a sense of unity with the democratic world, with the strengthening of the pro-European dimension of Ukrainian identity.

At a lingistic-pragmatic level, the consolidation of Ukrainian identity is achieved through the strategies of (a) value polarization of WE-THEY; (b) discrediting the mythologemes of "kinship" and "caring for the population of the occupied territories", which involves the restoration of reversed roles and role actors. Specifically, the shift from the roles of "defender-victim" to "genocider-victim" is achieved through the activation, via mass media, of predicates denoting inhumane actions by the agent towards the population of the occupied territories: forced deportation, forced mobilization, filtration camps, slavery, as well as metaphors such as "cannon fodder" and 'human shield", which expose the mythologemes of "kinship" and "care" as signifiers with distorted meanings; (c) positive reevaluation of negative russian labels associated with derogatory terms for Ukrainians. In particular, designations such as "ukropy" and "ukry" are based on allusions to "ancient Ukrainians", who, according to pseudo-historical research, lived in modern-day Germany, which has nothing to do with the ethnogenesis of the Ukrainian ethnicity. The meanings activated by this allusion indicate a lack of connection between ancient Ukrainians and Ukrainian territory, which implicitly reinforces the mythologeme of Ukrainians as a pseudonation. On the other hand, the internal form of the metaphor is based on the input space of "plant" (dill), which embodies a strategy of blatant dehumanization with the substitution of the living for the lifeless. At the same time, in Ukrainian counter-propaganda, the word "ukrop" is reinterpreted as an abbreviation of the phrase "Ukrainian opir" (Ukrainian resistance), transforming the negative connotation into a positive one and having a consolidating value for the self-awareness of Ukrainians.

Conclusions. Based on recurring themes and elements in the narratives, the motives of role-playing agents, the grouping of similar codes or themes to form broader categories or clusters, as well as contextualizing the narratives within their broader social, cultural, or historical context to understand the factors influencing their construction and interpretation, the article identified the origins of Ukrainians' pro-European identity in the structural components of "proximity to European principles of state-building," "Ukrainians' involvement in the development of European history," and "shared democratic values." The demythologization of narratives underlying the divided identity of Ukrainians is based on Ukrainian narratives of "chosen traumas" and "liberation struggle," integrated into a narrative template consisting of homogeneous narrative plots, characters, and motifs in the structural elements of Exposition, Complication, Resolution, Evaluation, and Codes, as well as in the sequence of narrative functions: Deception, Villainy, Prohibition, Violation of Prohibition, Onset of Resistance, Struggle, Persecution, Stigmatization, and Victory. At the linguo-pragmatic level, demythologization is achieved through strategies of value polarization, discrediting the mythologemes of "kinship" and "care" in their contemporary interpretation by restoring inverted roles. It is also accomplished through positive rearticulation of derogatory russian labels used to refer to Ukrainians.

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PRIORITY AREAS OF PUBLIC PARTICIPATION IN THE IMPLEMENTATION OF PUBLIC BUDGET COMPETITIONS IN MARIUPOL (2018-2021)

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Abstract. *In 2018, Mariupol joined the Public Budget program, where local residents were invited to propose projects that would improve the city. When funded, these projects received funding from the city budget, a key step towards participatory decision-making in Mariupol.*

The article conducts a comparative study of the participation of Mariupol residents in the implementation of joint public initiatives, that is, which local problems were the projects of Mariupol residents aimed at solving. For this, a system of modern scientific methods of cognition was used for in-depth analysis of the chosen problem. In order to determine the likely directions of implementation of future initiatives, we conducted a survey among project authors who participated in the "Public Budget" competition, analyzed statistical data on the competition platform for 4 years, and based on the received data, made a forecast of the likely directions of future projects.

Finally, the article argues that the key challenges that might arise in the process of planning the reconstruction of Mariupol are the following: trust in local authorities; selection of heritage sites to be restored together with critical infrastructure; protracted war; changes in the population structure of post-war Mariupol and problems with the housing stock.

Research context. *Mariupol is a Ukrainian city of regional importance in the Donetsk region. It is located in the southeast of Ukraine, close to the border with Russia. Mariupol is a climatic and mud resort on the shores of the Sea of Azov. In Soviet times and already after gaining independence, Ukrainian Mariupol was frequented by Russian tourists. This affected the way residents see the city and became the basis for the formation of conflicting political-ideological views.*

At the beginning of 2022, Mariupol had a powerful economic and intellectual potential, the city was the cultural center of the region with a historic central area. The post-2014 development of Mariupol was impressive, it was noted by everyone who visited the city. Especially those who came to the city from the occupied territories of Ukraine. Everything changed on February 24, 2022, after the start of a full-scale invasion of Russia on the territory of Ukraine. Now the city is destroyed. But we are confident in the victory of Ukraine and are already planning the reconstruction of Ukrainian Mariupol.

There has always been a diversity of political views in Mariupol. This manifested itself at the end of 2013, when conflicts of views began in the city, among the residents there were those who supported Euromaidan and those who later went to Anti-Maidan rallies. Already in the spring of 2014, the city was under occupation. Militants of the self-proclaimed Donetsk People's Republic captured the city council building. As a result of anti-terrorist measures, the city, which was under occupation for a month, was liberated.

These events defined the future of Mariupol. Currently, more and more Mariupol residents identify with the pro-Ukrainian vector of social development, but there were also those who were waiting for the return of "Soviet life". During this short period, from 2014 to 2022, Mariupol received *many immigrants from the entire Donetsk region who wanted to live in free Ukrainian territory. Life in the city quickly began to recover. At the same time, the development of civil society began, thanks to international organizations and foundations, and people realized what power they have when they unite. The people of Mariupol became interested in democratic tools of influence on local authorities.*

The relevance of the topic. The closest level of public authority to citizens is local government. The fairly low level of participation of Mariupol residents in participatory practices poses a challenge to representatives of the local government and city residents to use this potential during the reconstruction and restoration of the city, thus implementing direct democracy.

Existing research on the topic. There is a substantial literature on participatory urban governance in Ukraine, including public budget programs. The work of Briui A., Stokluska E., Donos L., Ploskyi K., Sotnyk I., Us Y. Agata Briui and Eva Stokluska in their manual for practitioners " Participatory (public) budget step by step. A guide for practitioners" [1] made a description of individual elements of the Public Budget procedure and various methods of their implementation, and also gave examples of specific decisions and their possible consequences or results on the example of Poland. In their manual "Implementation and Improvement of the Public Budget: Practical Recommendations" [2] Leonid Donos and Kostiantyn Ploskyi considered the phenomenon of the Public Budget and studied the experience of four years of implementation of the competition in Ukraine (from 2015 to 2018). Iryna Sotnyk and Yana Us in the article "The Participatory Budget: Experience in Application and Prospects of Improvement in Ukrainian Cities" [3] analyzed the influence of the Public Budget on the development of the city using the example of Sumy. D. Khutkii, K. Avramchenko, M. Izyumskyi, and S. Omelichkin also studied public participation in Ukraine in their work "Assessment of the impact of the participation budget in Ukraine" [4] Dmytro Khutkyi and Krystyna Avramchenko investigated the impact of the Public Budget on the community: the quality of its life, residents and local self-government. In the manual "Road map for the implementation of the participation budget" [5] Mykhailo Izyumskyi and Serhiy Omelichkin made a descriptive part of all stages of the competition and created a visualization of the tool in the form of an "interactive" stand, with the help of which you can holistically imagine the entire road map for its practical application by communities. Despite the fact that there are already studies of the results of the introduction and implementation of the participation budget in Ukrainian communities, both at the level of the entire country and individual local cases, this tool of public participation requires further scientific research, which led to the choice of the topic of the article. Using Mariupol as a case study, furthermore, is especially significant, because the city has been a key example of post-Maidan policy change between 2014 and 2022, and the impact of such inclusive programs has not been fully understood yet.

The purpose of the article is to identify the priority areas of public participation, analyze the collected data, and forecast potential areas of public interest in the implementation of joint social initiatives in post-war Mariupol.

Methodology. The first part of the article presents the results of the analysis of statistical data from the competition platform for 4 years. The data were provided by the SocialBoost organization, which manages the electronic platform "Public Budget", on which voting for projects in the city of Mariupol took place.

The second part of the article presents the results of a survey of the authors of the projects that participated in the competition from 2018 to 2021. The survey was conducted between December 4 and 14, 2022. Online questionnaire method, with respondents using a computer or smartphone. 25 respondents over the age of 18 were interviewed. Such a number of respondents may be due to the consequences of the Russian full-scale invasion, in particular, the forced displacement of hundreds of thousands of Mariupol residents.

In the third part, a forecast of probable directions of future projects is made. Methods of analysis include the study of descriptive and logical statistics. As I mentioned above, the idea of my research is determined by the desire to understand what were the priority ways of public participation in the implementation of joint initiatives and what they can be during the restoration and reconstruction of the city. Participatory budget is a tool of democracy. One of the most important values that affects the effectiveness of this tool and development prospects is the trust of residents. Public projects are always a signal to the authorities about weak areas in their work. Mariupol local self-government and public activities have been convinced for 4 years that this tool is useful for the community.

Mariupol is a city of transformation. The pace of change motivated and inspired not only the residents of Mariupol, but also residents of all of Ukraine. Every day the city became better, changed and developed, and its residents had the opportunity to participate in this process. And it was the participatory budget that revealed these possibilities the best.

Personally, I acted as the author of 3 district projects and was a co-author of 3 more projects of city significance. Thanks to the support of the people of Mariupol, they all won. We did not manage to implement all the ideas, but I have the experience of implementing 5 projects within the framework of the "Public Budget" competition. I think it helped me adequately conduct research and draw conclusions.

Research background. Participatory budgeting (this tool of democracy is also called public budget or participatory budget) has been implemented in the world for more than 30 years, and every year it is gaining more and more popularity. This is not surprising, because participatory budgeting makes it possible to solve the urgent needs of the community in a relatively short period of time, stimulates economic development at the local level, and improves relations between institutions and representatives of civil society and authorities. In addition, the public budget contributes to the effective use of budget funds and the activation of the public, its participation in decision-making regarding the use of financial resources of local budgets. Also, this tool of direct democracy helps the socially protected majority to take care of the vulnerable minority: for example, the disabled, the unemployed, internally displaced persons, the elderly, the homeless, and orphans [6].

Participatory budgeting can be an effective tool for education and training in the field of self-government - it encourages residents to familiarize themselves with the mechanisms of building and spending the local budget, forces them to make balanced decisions regarding the rationality of using budget funds, as well as to think about the prospects and general vision of the development of this area. All this is reflected in the way the budget is constructed. Therefore, the participatory budget should be considered not only as a tool that can be applied in any circumstances, but also as an element of a specific philosophy of self-government as a community, i.e. a set of authorities and residents of one territorial unit who cooperate with each other for the sake of the development of the latter [7]. In Ukraine, the history of participatory budgeting (public budget, participatory budget) dates back to

2015. This mechanism became a kind of "good deal" between local authorities and the public, as well as a new opportunity for dialogue.

Authors of projects, representatives of authorities and public organizations, residents learn to interact and build new connections, so more and more initiatives to improve living space and solve other local problems are implemented. The participatory budget is increasingly being considered as a platform for strengthening social cohesion, implementing the principles of inclusiveness and accessibility in communities [2]. The Law of Ukraine "On Local Self-Government in Ukraine" gives territorial communities the right to participate in the process of developing and making decisions on issues of local importance, in particular, the Law introduces such a mechanism as local initiatives.

In the city of Mariupol, for the first time, the regulation on the Public Budget was approved by the decision of the Mariupol City Council dated 28.02.2018 No. 7/28-2437 Regulation on the Public Participation Budget of the City of Mariupol. Its goal was development of a democratic society, improvement of the dialogue between the authorities and the territorial community, the involvement of the community in solving issues of local importance, the implementation of innovative mechanisms for involving the public in the distribution of funds from the city budget of the city of Mariupol, the solution of socially significant issues, the implementation of the best European practices of participatory budgeting [8].

The regulation provides that large and small projects can be implemented at the expense of the funds of the public (participatory) budget of the city of Mariupol. Large projects are projects of inter-district, city-wide significance, the total cost of which is from UAH 300,000.01. up to UAH 600,000.00. 40% of the funds allocated for each type of project are allocated to such projects. Small projects are projects of street, quarter, and district importance, the total cost of which is from UAH 20,000.00. up to 300,000.00 UAH. For such projects, 60% of the funds allocated for each type of project are allocated, which are evenly distributed among the districts of the city (15% of the total volume of the public budget of the city of Mariupol for each district).

Data from the SocialBoost organization was used to analyze the Mariupol experience of implementing the Public Budget. It is a technological public organization that develops IT projects with social impact, tools for e-democracy, e-government and open data [9]. Summary statistics of each stage of the competition were always available on the city's competition website, but due to security reasons, after the full-scale invasion of Russia into the territory of Ukraine, the organization closed the sites in the occupied territories. At the same time, SocialBoost provided information on my request regarding general statistical data for 4 years for Mariupol.

The volume of the Public Budget is determined annually in accordance with the decision of the City Council on the City Budget. According to the Law of Ukraine "On Local Self-Government in Ukraine", the amount of the competition should be up to 1% of the total budget, but not less than 7 million UAH. The budget of Mariupol for 2021 is 4 billion 678 million UAH. One percent of the city budget is 46.7 million UAH. At the same time, the budget of the Public Budget competition in Mariupol in 2021 was not so large, but only 7 million UAH.

In 2018, the total budget of the competition was the maximum, and amounted to UAH 13,585,000. In 2020, the competition budget was 8 million UAH, and in 2019 and 2021 the amount was the same and amounted to 7 million UAH. The decrease in the overall budget of the contest led to an increase in competition among the contestants. In general, the total budget of all submitted projects grew every year, with the exception of 2020 (Table 1).

Table 1.

Competition budget Public budget of Mariupol

Year	Population size	The total budget of all submitted projects, UAH.	The total budget allocated for the competition, UAH.	Competition for 1 UAH. Budget
2018	436 569	16 290 217	13 585 000	1,20
2019	436 569	36 159 318	7 000 000	5,17
2020	436 569	33 983 791	8 000 000	4,25
2021	436 569	53 199 635	7 000 000	7,60
Total	436 569	139 632 961	35 585 000	3,92

The results of the analysis of the use of the Public Budget in Mariupol show an increase in the number of initiatives, which reflects the interest of the public and local authorities in its further implementation (table 2). The exception was 2020, partly due to the impact of the 2020 crisis due to the coronavirus epidemic.

Table 2.

Activity of residents in the Public Budget in Mariupol

Year	Number of submitted projects	The number of projects participating in the vote	The number of rejected projects	The share of projects that participated in the vote	Number of winning projects
2018	61	34	27	55.74	30
2019	146	123	23	84.25	32
2020	137	98	39	71.53	33
2021	161	133	28	82.61	26
Total	505	388	117	76.83	121

As of 2018, the total number of residents who took part in voting in the contest was 1,793, and already in 2021 it reached 38,278 people. Over the past 4 years, there has been a sharp increase in the level of involvement of citizens in voting for projects (Table 3), which reflects the desire of residents to directly influence the areas of city budget spending.

Table 3.

Number of people who voted by category

Categories	2018	2019	2020	2021	Total
Environmental protection	1	237	233	419	890
Creation of sports and entertainment grounds	861	1 694	2 140	1 350	6045
Improvement/equipment of healthcare institutions	322	694	360	0	1376
Landscaping of the surrounding area	0	194	407	766	1367
Improvement/equipment of social welfare institutions	89	169	263	210	731
Improvement of road and transport infrastructure	59	621	428	15	1123
Creation of recreation areas	405	1 564	1 156	488	3613
Improvement/equipment of educational institutions	0	2 828	4 845	14 268	21941
Improvement of beach infrastructure	0	0	0	0	0
Improvement/equipment of cultural institutions	0	77	168	134	379
Street lighting	56	600	63	18	737
Other	0	0	5	71	76
Total	1793	8678	10068	17739	38278

The competition presents a fairly wide range of various categories of citizen participation in various spheres of the city. In total, 12 categories were selected, namely "Environmental protection", "Creation of sports and entertainment grounds", "Improvement/equipment of health care facilities", "Improvement of the surrounding area", Improvement/equipment of social protection institutions", "Improvement of road transport infrastructure", "Creation of recreation areas", "Improvement/equipment of educational institutions", "Improvement of beach infrastructure", "Improvement/equipment of cultural institutions", "Street lighting" and "Other".

The priority categories of public participation in the implementation of joint initiatives in 2018 were - "Creation of sports and entertainment grounds" (861 votes), "Creation of recreation areas" (405 votes) and "Improvement/equipment of health care facilities" (322 votes). And since 2019, the category "Improvement/equipment of educational institutions" has become the leader in the number of votes.

Different authors have different opportunities, including administrative ones, to promote their projects. Of course, it is easier to connect your resource to educational institutions than to collect the votes of an activist. In recent years, group chats have been very popular in Mariupol, including in educational institutions. For example, each class of the school had at least one separate chat in the messenger to improve communication between the teacher and parents. They became especially popular during the quarantine with the start of the coronavirus pandemic in 2020 in Ukraine. Issues related to children's education and organizational aspects were discussed there more often. Of course, when teachers once a year posted information about the school taking part in the "Public Budget" competition and how this school initiative will improve the conditions of stay at school for children, most parents supported their request to vote for the project.

In connection with the considerable popularity of the competition among educational institutions in comparison with other categories and the complaints of public activists from other spheres, the city council made amendments to the Regulation on the public budget of the city of Mariupol. Educational projects are projects submitted by the author with the selected category "Improvement / equipment of educational institutions", the implementation of which concerns the premises or territories of schools, preschool institutions, other educational institutions. No more than 50% of the total public budget of the city of Mariupol is allocated to such projects [5]. This decision was well received by the public and closed the issue of disproportionality of resources.

As for the gender indicator of activity, the authors of the projects were more often women (Table 4). The average rate of their participation over 4 years was 77.54%, while the average number of male authors was only 22.46%. At the same time, this ratio became larger every year. Thus, in 2018, the number of male authors was 17 people or 30.36%, and already in 2021 there were 23 people or 16.08%. At the same time, the number of female authors only increased. If in 2018, 39 women or 69.64% submitted their projects to the competition, then already in 2021 this number amounted to 120 people or 83.92%.

Table 4.

Gender of project authors in Mariupol

Year	Total number of authors	Number of male authors	Percentage of male authors	Number of female authors	Percentage of female authors
2018	56	17	30,36	39	69,64
2019	139	33	23,74	106	76,26
2020	117	23	19,66	94	80,34
2021	143	23	16,08	120	83,92
General	455	96	22,46	359	77,54

The age distribution among project authors was also uneven. People aged 46 to 65 showed the greatest activity. Nevertheless, people aged 36-45 turned out to be quite active. The smallest number of authors under the age of 25. After 2020, interest in the contest for authors over 65 years old began to decline.

According to the terms of the Public Budget competition, city residents who have reached the age of eighteen and are officially registered as living on its territory can submit and vote for projects.

In the event that a person is registered outside the city, but actually lives in the city of Mariupol, in order to participate in the process, he must provide a certificate confirming his residence in the city. Examples of such documents can be a student card or a certificate of an internally displaced person.

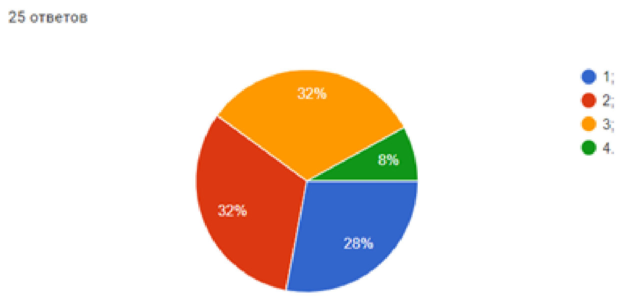
It was possible to vote in one of the city's Administrative Services Centers using a paper voting form. Each resident of the city could choose two projects (one large and one small), or one of these two categories. Voting also took place on the website https://pb.org.ua/. The electronic form of such voting was aimed at strengthening digital transformation, decision-making processes, involvement of citizens and civil servants in the context of electronic democracy. The winners of the voting were the projects that received the largest number of votes according to the rating system. Voting results are approved by the Expert Council on Public (Participatory) Budgeting of Mariupol. The projects supported by the citizens during the voting were implemented by the city authorities in the following year, and in parallel, a new cycle of the public budget began.

Analysis of data collected via survey. The data cited in the next part of the article was obtained as a result of a survey of Mariupol activists who took part in the "Public Budget" competition. It was possible to attract 25 project authors to the survey. This number is related to the situation that occurred in Mariupol after the full-scale invasion and the horrors that the city's residents had to experience. A large number of survivors of Mariupol, including activists, are now adapting to a new place, so they do not have time, resources and motivation to answer questions. Encouragement to take part in the study took place through an appeal on my pages in social networks and through personal contacts with activists.

The survey questionnaire consisted of two parts, each of which contained 7 questions. The first block included questions about the experience of the respondents during participation in the "Public Budget" contest. In the second block, I wanted to find out the opinion of activists about the future of Mariupol. At the same time, the answers to the questions of the second block were not mandatory, because I understand the painful attitude of the people of Mariupol to the questions of the future.

During the research, 25 public activists of Mariupol, who took part in the "Public Budget" competition, were interviewed. Among them, 7 people or 28% took part in the contest only once, 8 people or 32% of the respondents were authors two and three times, and 2 people or 8% - every year, that is, 4 times.

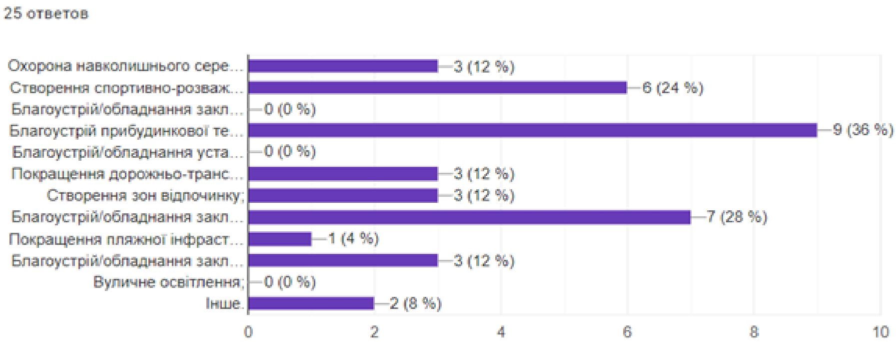
Diagram 1. How many times have you participated in the "Public Budget" competition as an author?



The greater number of respondents, 20 or 84%, had experience in implementing projects at the expense of the city budget. The largest number of respondents implemented 2 initiatives - 9 people or 36%. One idea was implemented by 8 interviewees or 32%. 12% or 3 people to implement 3 projects. And only one interviewee had the experience of implementing 4 ideas within the framework of the Public Budget competition. Not all project authors managed to gain experience in implementing their initiatives, namely 4 persons or 16% of the respondents. Some of them were first-time winners of the competition in 2021, but Russia's full-scale invasion of Ukraine prevented them from doing so.

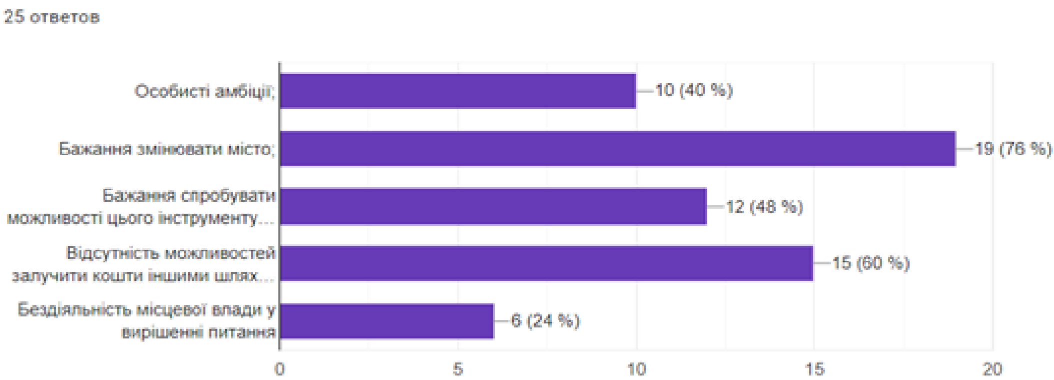
Survey participants were most often motivated to take part in the contest by the success of their first participation; transparency of the competition; available time and knowledge; the opportunity to gain experience in project management; professional interests; the desire to improve the city, street or neighborhood. Survey participants were discouraged from taking part next time - lack of time; a complex voting system for competition projects; people's passivity when voting; prolongation of project implementation deadlines by representatives of utility companies.

Diagram 2. Projects from which category did you submit to the competition in previous years?



The greater number of respondents, 9 people or 36%, submitted projects classified under the category "Improvement of the area around the house". 7 respondents or 28% initiated projects in the "Improvement/equipment of educational institutions" category. 6 people or 24% submitted their initiatives to the "Creation of sports and entertainment venues" category. An equal number of 3 respondents or 12% each initiated projects from the following four categories: "Environmental protection", "Improvement of road and transport infrastructure", "Creation of recreation areas" and "Improvement/equipment of cultural institutions". 2 persons or 8% of respondents submitted projects from the category "Other" and only one among the respondents - "Improvement of beach infrastructure". Survey participants did not initiate a single project from the categories "Improvement/equipment of health care institutions", "Improvement/equipment of social protection institutions" and "Street lighting".

Diagram 3. What motivated you to submit projects to the "Public Budget" competition?



Ranking by priorities of the motivation of survey participants from the most important:

1. The desire to change the city
2. Inability to raise funds in other ways
3. The desire to try the capabilities of this tool in practice
4. Personal ambitions
5. Inaction of local authorities in resolving the issue.

It should be noted that not a single participant of the survey offered his motivation option, all chose from the proposed ones.

The next two survey questions related to the shortcomings and difficulties of the "Public Budget" competition and the ways to solve them according to the opinions of the authors of the initiatives. Among the difficulties, survey participants most often singled out such shortcomings as the search for subcontractors and quality equipment; long paperwork and therefore the projects were implemented in the winter; difficulties with the set of votes. Regarding ways of solving these shortcomings, the following options were proposed: to introduce a base of proven contracting organizations; establishment of cooperation between authors, representatives of the responsible department and project contractors; reduce the terms of project implementation, conduct a broader information campaign because many Mariupol residents do not know about the competition. Three of the interviewees did not experience any difficulties during all stages of the competition.

The second block of questions, regarding the activists' vision of the city's future, included 7 optional questions. The first question was whether the respondents left occupied Mariupol. And most of those who answered, namely 18 people or 85.7% answered that they had left, 2 people or 9.5% had already returned to live in the occupied city and one person had not left at all.

Only 15 respondents answered the following question. At the same time, 13 people or 86.7% indicated that they plan to return/stay in Ukrainian Mariupol, and 2 people or 13.3% do not intend to do so. 20 people or 95.2% gave a positive answer to the question about the need to resume the Public Budget competition in free Mariupol. Arguing this by the fact that the Public Budget is an absolutely real and effective tool for the improvement of the native city, within the limits of its competence; it is a tool that helps to activate public activity and improve the city; it is the realization of individual dreams but for the development of the city. At the same time, only 1 person considers it impractical, justifying his choice by the fact that mostly the authors of the projects waste their own time and do not have sufficient motivation, and after what they have experienced, it will be unrealistic at all.

10 people or 71.4% of those who answered the question would take part in the Public Budget competition as the author of the project again, and 4 people or 28.6% do not plan to do so anymore. At the same time, relevant categories of projects in their opinion will be - "Restoration of the housing stock", "Restoration of housing and communal services (water, gas, energy supply, etc.)", "Restoration of road and transport infrastructure", "Restoration/equipment of educational institutions" and " Restoration/equipment of health care facilities". At the same time, the respondents are ready to initiate projects from the following categories: "Restoration of housing and communal services (water, gas, energy supply, etc.)", "Restoration of the housing stock" and "Environmental protection".

Discussion and Conclusion. As the experience gained to date shows, the participatory budget allows many residents to be heard and contributes to the involvement of those citizens who previously did not participate in solving local problems in local self-government. When reviving the Public Budget in Mariupol, Ukraine, one must remember that the trust of the residents must always be the value that must be taken care of so that the spent resources, time and efforts bring sustainable long-term results.

Planning the future of Mariupol after the deoccupation of the city and the end of the war is a necessity of the present time. Experts have already started working on the Mariupol Rebirth Strategy "Mariupol Reborn" because there is a lot of work ahead. The basis of the work will be the Mariupol Development Strategy — 2030, adopted shortly before the start of a full-scale war. The new plan will include the best international expertise, leading and modern technologies in operation, and most importantly - a comprehensive and civilized approach in the large-scale construction of the city.It also foresees key priority steps aimed at restoring the critical infrastructure of Mariupol. At the same time, it is important to look at the past in order to develop the future. Because what we bring from the past defines who we are. Do not neglect this when making plans.

Summarizing the results of the research, I would like to note that the five priority areas of public participation in the implementation of joint initiatives in the city of Mariupol for four years (from 2018 to 2021) were "Improvement/equipment of educational institutions", "Creation of sports and entertainment grounds", "Creation of recreation areas", "Improvement/equipment of health care facilities", "Improvement of the surrounding area".

At the same time, all three types of priorities (which were, which are relevant now, which the respondents are ready to initiate) differ from each other. And this is not surprising, because the projects proposed by residents in Mariupol from 2018-2021 were aimed at improving the city. The categories that the authors called relevant in the future in Mariupol, namely initiatives to restore normal conditions for life, which the city does not currently have. And the last group of priorities for the authors of past projects is related to their personal motivations.

In connection with the brutal acts of violence and the humanitarian catastrophe that resulted from the blockade of the city, it is necessary to understand that not all residents of Mariupol will survive this and return to live in the city even after the end of the war. Now there are approximately 100,000 Mariupol residents in Mariupol [10]. One part of the residents who decided to leave the occupied city now lives in Ukraine, and the other part lives abroad. The longer the war continues, the more likely it is that people will get used to a new place and return to their hometown will not be so desirable for them. Mariupol residents are already finding a new job, a new home, finding loved ones and new friends. Most likely, young families with children will settle down, and it is precisely for their sake that they will stay.

And this must be taken into account when planning the future of Mariupol, because it is the return of young people, experts and specialists who will not only want to restore it, but also plan their future life there, will give the city a revival. It is also necessary to take into account the factor of changes in the population structure of post-war Mariupol. Currently, almost half of Mariupol residents who remain in the city are pensioners. At the same time, the share of their participation in the Public Budget in 2021 amounted to only 4.9%. Which shows that this age group is not interested in using this tool.

Before the full-scale invasion of Russia, residents of each house in Mariupol tried to improve it and their yard, creating comfortable conditions for all residents of the house. To do this, the people of Mariupol took part in various programs, grant competitions and the Public Budget. For example, the yard of my high-rise building always attracted the attention of passers-by. Because one part of it resembled a park with avenues of roses, on the other - there was a modern children's playground, and at the end of the yard, we and our neighbors, including thanks to participation in the Public Budget competition, built a universal sports ground. Where you could play football, basketball, volleyball and tennis. In 2021, thanks to the second victory in the competition of my project "Sport next door", we added a playground with a complex of street simulators to it. In the summer, more than 100 people sometimes spent time in our common yard at the same time. We celebrated public holidays, New Years, special dates and birthdays outside with our neighbors. During the blockade of the city, the courtyards of the houses turned into common field kitchens, humanitarian headquarters and psychological assistance centers. What helped many to survive this terrible period. Unfortunately, there were not isolated cases of the transformation of the courtyards of high-rise buildings into cemeteries, sometimes with mass graves.

The survey participants noted that, in their opinion, future relevant areas of joint public initiatives could be "Restoration of the housing stock", "Restoration of housing and communal services (water, gas, energy supply, etc.)", "Restoration of road and transport infrastructure". And I agree with them, to confirm these forecasts I will provide data from the Mariupol City Council. In Mariupol, 2,257 apartment buildings were damaged by Russian shelling. In total, more than 50% of high-rise buildings were destroyed, which is 1,356 buildings. More than 38,000 private houses have various damages, of which more than 11,000 have been destroyed by more than 40% or destroyed [11]. The data and results of the study indicate the need to pay priority attention to this problem. Because problems with the housing stock can prevent even those who want to return to the city. And only when there is improvement in these areas, other categories of projects will start to interest the Mariupol community.

At the same time, I believe that it is absolutely necessary to immediately renew the Public Budget competition in the liberated Mariupol. Because the projects implemented within the limits of this tool acquire special value not only for the author but also for those who voted for him, because they will give a feeling of participation in the revival of the city.

In my opinion, a long war can be a problem for the return to the city, but not for its revival. Returning to Mariupol is not a return to a past life. And whether the "old" residents of Mariupol will want to live in post-war Mariupol is an open question.

While the city is still under occupation and there are many unknown and unpredictable factors, I want to conduct additional research opportunities and developments in this topic. For example, the impact of participatory budgeting on various spheres of public life in Mariupol; the influence of civil society institutions on urban changes in the city of Mariupol; how to use the existing experience of Mariupol residents living abroad or in other cities of Ukraine to improve the environment of Mariupol.

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RUSSIAN AGGRESSION AS A THREAT TO THE SUSTAINABLE DEVELOPMENT OF EUROPE: THE UKRAINIAN DIMENSION

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Abstract. The article deals with issues related to Russian aggression against Ukraine in the context of the existing threat to sustainable development of Europe. Particular attention is drawn to the treachery of aggressive Russian policy towards not only the Ukrainian people but also the peoples of other countries which are traditionally considered to be the zone of influence and interests of the Kremlin. The authors have concluded that as long as the current Russian political leadership is poised to stay in power, it is impossible to expect any democratic changes in this country. The mentality of war professed by both the Russian authorities and Russian society is in opposition to the existing basic European values and democratic freedoms. At the same time, even the replacement of the current government will not automatically improve the political situation in the country. Only the disintegration of Russia into separate independent states will deprive it of its imperial status. Ukraine is considered not only in terms of the necessary support and assistance from the perspective of the legal and moral foundations of human civilization but also as a likely candidate for an active role in the post-war political configuration of Europe. This conviction, as stated in the article, is based on the significant achievements made by the Ukrainian people in recent years in the context of meeting European standards of life and work in the demonstrated success in protecting national interests, the very idea of the existence of an independent Ukrainian state.

Formulation of the problem in general. Analysing the recent events related to Russia's aggression against Ukraine a number of issues related to threats to Europe's sustainable development should be highlighted. Aggressive Russian policy threatens not only the Ukrainian people but also the peoples of other countries that are traditionally in the Russian sphere of influence and interests. The mentality of war that pervades both the Russian government and Russian society contradicts basic European values and democratic freedoms, and thus, under the current Russian political leadership there is little hope for democratic changes in Russia. The collapse of the empire as a result of the victory of the Ukrainian people in the current war with the enormous support and comprehensive assistance of Western partners will naturally prevent a threat to the sustainable development of European states, promote democratic changes in other countries and finally create the necessary conditions for Ukraine's political and economic rise in the context of building a sovereign democratic state.

Analysis of recent research and publications. In many contemporary scholarly studies, the problem of the development of Ukrainian statehood is intertwined with the analysis of sustainable development and components of political life, such as the study of the policy of appeasement of the aggressor, Russia's past and present imperial policy and its totalitarian legacy. Among others, we would like to highlight the well-known works by T. Snyder, A. Bezanson, Z. Brzezinski, A. Kappeler, A. Novak, George O. Liber, F. Fukuyama, and others. [Snyder, 2021; Bezanson, 2017; Brzezinski, 2022; Kappeler, 2022; Novak, 2021; Liber, 2019; Fukuyama, 2020].

In order to characterise the main features of the current situation, the research focuses on the analysis of Russian hostility that has developed historically, its accentuated impact on the Ukrainian nation and European political reality and the gradual political "awakening" of the Ukrainian people [Brzezinski, 2022: p.18]. In particular, T. Snyder, drawing attention to the categorical denial by the Russian authorities of the possibility of the Ukrainians having an independent nation, writes that “in the last quarter of the nineteenth century the idea that Russia was a single nation and all Eastern Slavs were Russians became dominant" [Snyder, 2021: p.154]. The attitude of the Western political elite to the Russian state is somewhat explained by A.Bezanson's words about the fascination with Russia and fear of it, attempts to let it into their world and attempts to expel it from there which failed [Bezanson, 2017: p.5]

Studies by Ukrainian scholars such as S. Plokhy, E. Magda, I. Rushchenko and others deserve considerable attention. The researchers are of the opinion that Russian aggression against Ukraine not only threatens the security and territorial integrity of Ukraine but also has a broader impact on European stability and threats to the sustainable development of Europe and the world. Thus, E. Magda emphasizes that "Russia seeks to subjugate the 'model democracies', to push the united Europe off the political map of the world, depriving it of the status of one of the centres of influence in order to take its place and strengthen its positions" [Magda, 2017: p.215]. The Ukrainian people themselves became one of the main targets of imperial policy their mental characteristics which are manifested not only through hostilities but also through an unleashed hybrid war.

Special mention should be made to the scientific works prepared by scholars in the context of the full-scale Russian aggression against Ukraine. It is worth paying attention to the collective monograph "Ukrainian Society in the Context of War" (S. Dembitskyi, O. Zlobina, N. Kostenko and others edited by Corresponding Member of the National Academy of Sciences of Ukraine, Doctor of Philosophy E. Holovakha, Doctor of Social Sciences S. Makeyev) as well as to S. Plokhy's fundamental work "The Russo-Ukrainian War: The Return of History." In particular, the latest study highlights the determination of the Western democratic alliance led by the United States "...to eliminate the Russian threat to peace not only in Ukraine but throughout the world by ensuring Russia's defeat in the current war and reducing its ability to wage war in the future" [Plokhy, 2023: p.269].

The humanitarian crisis and human rights violations in Russia itself have become a decisive factor in the escalation and unleashing of full-scale aggression against the Ukrainian people with the aim of destroying national identity, as it happened before during the tsarist and Soviet periods. Today it is the persistent awareness of the threat to sustainable development and the principles of collective security that encourages European countries to cooperate and confront the military and economic resources used by Russia to expand its interests and change the geopolitical situation in the region.

The purpose of the article. The purpose of the article is to provide a comprehensive study of Russia's aggressive and insidious policy which has been embodied in the unleashing of full-scale military operations throughout Ukraine. The main methods of studying this problem were the comparative historical method and the method of extrapolation. Together with other methods they contributed to a comprehensive analysis of the political relations between the national state administrations during their independent existence in various historical periods and Russian tsarism. The methodological basis of the study was strengthened by identifying key threats to the sustainable development of democracy, outlining important aspects of the crisis shifts that led to full-scale aggression and threaten stability, security and European values, and studying geopolitical factors that influence the process of transformation of the country's modern social development.

Presentation of the main research material. History doesn't know other times when having first appeared on the political scene Ukraine would not have attracted the attention of European states. This attitude was due not only to its strategically important geopolitical position but also to the gradual acquisition of considerable political, economic and cultural weight in the context of the emergence and development of national state associations.

Even during the existence of Kyivan Rus, long before the emergence of the Russian Empire, there were developed trade and economic relations with the countries in the West and the East, powerful military and political alliances were formed, family and dynastic marriage contracts were concluded, etc. The sources and literature of those times provide us with vivid evidence of great respect, emotional admiration and outright sympathy of contemporaries for the Ukrainian people who already played an important role in the development of Europe at that time. Remaining a highly cultured ethnic community, Ukraine in terms of its development was much closer to the foundations of civilization and democracy than Russia.[Minosian, Varypaev , Yurchenko, 2021: p.62]

Later, in the times of the Cossacks which researchers considered a "brave and untamed nation" Ukraine also came into the spotlight of Western attention [Kappeler, 2022: p.63]. The national liberation struggle of the Ukrainian people for the creation of an independent state in the 17th century was an organic continuation of a series of European revolutions that marked the beginning of capitalist relations. In the context of solving complex political tasks of that period, Ukraine found itself under the pressure of external aggression from its northern neighbour which used the powerful human, economic and cultural potential of the Ukrainian people in its own interests. Modern researchers, drawing historical analogies with the current full-scale invasion of Ukrainian lands, note that even then "Moscow uses the protection of the Orthodox in Ukraine as a pretext for war with Poland" [Kappeler, 2022: p77]. Nevertheless, under certain conditions, it was possible to preserve the signs of an independent Ukrainian state in the struggle against Russian tsarism thanks to the support of European allies, in particular the Swedes, and the unbroken spirit of the nation itself..[Kappeler, 2022: p.137-138] .

For several centuries, Ukraine, overcoming numerous difficulties and obstacles, through hard struggles, losses and trials, has been trying to realize the inherent right to exist as an independent state. A copy of Pylyp Orlyk's letter dated in Stockholm on April 30, 1720, points to the insatiable expansionism of the Russian Empire, emphasising the difference between Russia and Ukraine, whose people "yearn for their freedom and only expect to find protection and help to rise up against Russia".[Novak, 2021: p.82].

Considering Ukraine only in the context of adherence to a pro-Russian position, fiercely defending the interests of the empire in relation to the so-called periphery, repressing anyone who demonstrated a distinct Ukrainian identity in the political or cultural sphere [Liber, 2019: p.64], Russia assessed its alleged independence as a temporary anomaly, a sign of undemocracy and the result of intrigue by foreign forces based on narrow nationalism. [Novak, 2021: p.303-304]. Later, continuing the traditions of imperial power, [Bezanson, 2017: p.84-85], the Bolsheviks were not ready to give up control over the whole of Ukraine with its economic and strategic importance [Novak, 2021: p.129], considering their aggressive actions as a sacred mission of liberation from the imperialists.[Johnson, 2022: p. 63]. For example, in the international arena, the "eternal" desire of the Ukrainians and the Belarusians to live in one state was used as a justification for the Soviet annexation of parts of pre-war Poland, Romania and Czechoslovakia [Plokhy, 2019: p.98]. A similar scenario occurred when the modern Russia occupied certain territories of Donetsk and Luhansk regions in 2014.

The West's interest in our country was largely based on the understanding of support for the Ukrainian national movement in the struggle for independence and freedom, because "if Ukraine was made up of its people, then the Ukrainian state had to extend within its borders"

[Snyder, 2021: p.165] as well as the danger of Russian and later Soviet expansion in the context of an unstable political situation in the world. On the other hand, indecision and excessive fears of considering the Ukrainian question separately from the Russian/Soviet state made it much more difficult to establish the Ukrainian people as a real nation with an unconditional right to independent development [Minosian , Varypaev , Yurchenko, 2023: p.95].

In this struggle the Ukrainian people had to rely on the support and assistance of the countries that had freed themselves from the long-term Russian occupation, includung Poland and the Baltic states. "In the fight against Russian expansion... we will not be supported by a coalition but only by those nations that, like Poland, and maybe even more are under threat from all great Russia. Therefore, it is a matter of crucial importance for Poland to orientate and oblige Ukraine to the west, i.e. to Poland, and not to the east, i.e. to Russia." [Suleya, 2018: p.278]. In view of Poland's enormous fraternal assistance to Ukraine in overcoming the current Russian aggression, the words of the prominent Polish statesman and statesman Józef Piłsudski about the need to "correct the mistakes of our ancestors by giving our outlying brethren the opportunity to self-determination and governance for their own nation", the opportunity to "win their own will and ensure happiness and prosperity for the fertile land of their homeland" are deeply symbolic. [Suleya, 2018: p.296]

The Anschluss of Austria, the seizure of Czechoslovakia, and the partition of Poland took place with the tacit approval and unwillingness to abandon the policy of appeasement of the aggressors, which were the Soviet Union and Nazi Germany, as well as fascist Italy. [Minosian, Varypaev, 2021: p.199]. Considering the policy of appeasement unacceptable and absolutely senseless from a strategic point of view because all totalitarian regimes should be resisted the prominent British politician Winston Churchill in his address to the House of Commons after the Munich Agreement on September 30, 1938 emphasized: "... we have crossed a terrible historical line, when the balance on the European continent was completely destroyed and now the Western democracy received a terrible ancient sentence: "your capabilities have been weighed in the scales and found weak." And further: "And do not hope this is the end. The reckoning has only just begun. This is only the first sip, the first taste of the bitter glass from which we will drink year after year if we do not restore our mental health and fighting spirit, if we do not rise again to fight for our freedom as we have done since ancient times." [Axelrod, 2022: p.151]. Contemporary Western politicians should keep this in mind when it comes to coordinated and decisive action to overcome Russian aggression against Ukraine and to provide the latter with the opportunity for a future equal partnership in the post-war European space.

The confluence of circumstances that arose from the collapse of the Soviet system in 1991 contributed to the peaceful nature of Ukraine's independence, as the Russian authorities were distracted by their own needs to resolve the complex political processes taking place in that country, but did not guarantee that the northern neighbour would not take a "brotherly interest" in the political future of the Ukrainian people, which eventually happened. Almost immediately, Ukraine faced undisguised Russian hostility to everything that arose in Ukrainian society on national grounds.

This was facilitated by the presence of a variety of pro-Russian parties and organizations in the political space of our country, representation of outspoken apologists for the "Russian world" in the pro-government structures, the presence of agents of the Russian special services, their actual control over the media, and others. At that time, Ukrainian society was at the stage of transition to the development of a national model of the state, strengthening its priority, filling it with traditions of the national heritage, overcoming Soviet narratives which caused considerable opposition from the conservative part of the population which was in difficult socio-economic conditions of life at the end of the 20-th century and accused the national authorities for this.

Even then, the previously formed "historically justified" claims of the Russian authorities to Ukrainian territories were renewed, as well as slogans about the alleged artificiality of the formation of our state, the accidental and unnatural severance of ties with the "brotherly" Russian people. Later, this was supplemented by demands to resolve existential issues that denied the very possibility of the existence of the Ukrainian nation.

It coincided that Europe was also in a state of rethinking the processes observed in the Eastern European countries, which largely prevented it from taking a closer look at the significant political, economic and cultural potential that Ukraine possessed. There was also a lack of responsible politicians who would be able to free themselves from Russian influence on the formation of a new political reality. The political systems of European states have become the object of targeted influence of Russian resources, agents of influence, and manipulative tools. [Magda, 2017: p.215]. The active interference of Russian politics in the life and activities of Western countries, strong financial support for certain political parties and movements, the presence of "sympathisers" in the pro-government structures - all this not least influenced the preservation of the status quo in relation to Ukraine as an "indigenous" Russian zone of influence with signs of ownership. Later investigations and revelations related to this problem became a real shock for the European political community.

Communication with the West was also significantly hampered by the uncertainty of the Ukrainian authorities regarding the choice of political development paths, the search for "multi-vector", and their excessive expectations of compliance with international treaties on support and guarantees of security, sovereignty and territorial integrity as in the case of the Budapest Memorandum. Remaining in the grip of Soviet stereotypes, Ukrainian society has made very slow progress in resolving issues related to Ukraine's localization in the European space.

The post-war world, which gained its sustainable stability after 1945 and of which Europe remained a part, was largely based on the legal order that had been built by the efforts of the leading democratic countries, newly created international organizations such as the UN and NATO, and the collective awareness of the threat of a new world war, which, if it did happen, would be significantly different from the previous one in the context of the emergence and proliferation of nuclear weapons. The Soviet Union, despite its aggressive militaristic nature, was always forced to come to terms with the new political reality, being unable to compete economically in the field of the latest technologies. In addition, the test of democracy through the victorious actions and successes of Western countries in various spheres of life, the collapse of the colonial system and the strengthening of political independence of Eastern countries seemed to allow for a fixed balance in decision-making in overcoming global problems.

The Russian aggression, which began in 2014 and continued in 2022 with a full-scale invasion of Ukrainian lands, has created completely new realities for the existence of the civilized world. The armed attack on Ukraine has finally undermined the collective security system established after the end of World War II. The weakness and indecision of the international community, which became apparent at the beginning of the twenty-first century during the territorial seizures of Georgia, the annexation of the Crimea and the occupation of a part of Donbas, did not contribute to the adoption of decisions that would prevent the destruction of the existing world order. The bitter experience and important lessons learned from the policy of appeasement of the aggressor, which was historically observed in the twentieth century, did not become a guarantee of more decisive actions by Western politicians to curb Russian state expansion.

As in the past, fluctuations in European policy were largely due to an overestimation of the existing threat posed by the nuclear power that remains Russia and unjustified expectations from it to strictly comply with international legal norms and rules. In addition, in the current conditions there has been a significant shortage of the most responsible politicians capable of being consistent and convincing in defending basic democratic values.

Through its national resistance in this war, Ukraine has set an example for the entire world of the unity of society around the idea of sovereignty and territorial integrity of the state, preservation of national identity and the priority of the rights and freedoms of every person. Russia's rejection of the European choice of the Ukrainian people, the deliberate destruction of everything related to its cultural and historical heritage, ethnic characteristics have created a situation where the practice of depriving one people (in this case, the Ukrainian people) of its independence and autonomy by another state through forceful intervention has been introduced, which has led to violations of universal human values and international law and, accordingly, has affected the willingness of Western politicians to revise existing international obligations in the context of military and political adventures of the Russian authorities. [Ukrainian Society in the Context of War…, 2022: p.31], returning the West to the historical arena in full force. [Plokhy,2023: p. 286]

Today, we are witnessing an increase in the Western political establishment's sustained interest in the Ukrainian people's resistance to Russian aggression. Ukraine demonstrates a high level of political consciousness destroys the ideology of the "Russian world" and categorically rejects the post-war reconstruction of Ukraine outside NATO and the EU.

The Western democratic alliance, not counting on the probability of fundamental changes in Russian society in the presence of the existing political leadership, demonstrates awareness of the need to break up the Russian empire into separate independent state formations on a national basis. It is making unprecedented efforts to provide comprehensive military, economic, political assistance and support to the Ukrainian people and its state in their efforts to confront and defeat a powerful aggressor, aiming to restore the system of collective security in the world, to affirm the inviolability of the rights and freedoms of all peoples, the rule of democracy and the priority of universal human values. It is important that "Washington and its European allies have managed to develop a common platform united by Russia's aggression and the threat it poses to Europe and the international order" [Plokhy, 2023: p. 286]. It is also absolutely clear that "the war buried Russia's hope of becoming a new global centre in a multipolar world, which Russian politicians and diplomats had dreamed of since the 1990s" [S. Plokhy, 2023: p. 315]. Last but not least, in the new political configuration that is being formed today, which involves the world's leading democracies, Ukraine is seen as a powerful link that will help shape a new European reality free from any existential threats.

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GEOTOURISM: DEVELOPMENT BASED ON GEOHERITAGE (CASE OF KOROSTYSHIV QUARRY)

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Abstract. *This study considers geological tourism as a means of exploring the geological resources of a certain territory. An example of the arrangement of a local abandoned quarry is presented, taking into account the recreational and tourist needs of the city's residents. The importance of geological tourism as a destination that provides tourists with the opportunity to explore the environment in synergy with culture and history will grow every year. In 2022, the share of international trips related to the environment was 25%. Geological tourism often encourages travelers to delve into the cultural heritage and traditions of little-visited regions. There are two approaches to studying this area of tourism: geological and geographical. It is the latter that provides a comprehensive description of the territory, not only through the prism of its geological significance but also an understanding of the impact of the environment on the way of life of local residents. For example, in areas where volcanoes are common, understanding their origin and the consequences of their activity has a great impact on the development of agriculture and the well-being of the population. In this article, geological tourism goes beyond the simple assessment of geological sites. After all, modern tourists who choose nature-oriented forms of leisure still want a combination of services and amenities, even in the countryside. Accordingly, the project, within the Korostyshiv quarry, combines geological research with recreational opportunities.*

Introduction. One of the first to explain the concept of geotourism was T. Hose, who explained it as «Geotourism is tourism in which interpretation and service allow tourists to gain knowledge and understanding of geology and geomorphology beyond the level of simple aesthetic appreciation» (Hose T.A., 1995). Over the following years, this definition was modified by various scientists, but the common thread was that geotourism should not only give tourists a sense of admiration for a particular area but also enrich their knowledge of certain geological processes and phenomena. In 2011, the International Congress on Geotourism was held in Arouca (Portugal) under the auspices of UNESCO, which formed the following definition: «Geotourism is tourism designed to maintain and strengthen the identity of a territory, taking into account its geology, environment, culture, aesthetics, heritage, and well-being of its inhabitants» (Arouca Declaration, 2011). Currently, geotourism offers travelers the opportunity to explore geological formations, national parks, UNESCO World Heritage sites, and other geographically important places. It promotes interaction with local communities, supports conservation efforts, and contributes to the economic development of various regions. Geotourism has the potential to develop in any territory that has unique geographical resources and attractions.

In addition, geotourism is not limited to a specific season, as geological formations can be explored throughout the year. For example, in autumn or winter, visible geological details such as stone structures, rocks, granite formations, etc. can be seen more clearly due to less overgrowth of natural vegetation. In the spring or summer, you can observe the activities of rivers: erosion, transport, and deposition of material. Specific examples include Yellowstone Park, a UNESCO World Heritage Site, which in winter can be of interest to tourists for its geothermal sites (geysers, hot springs, mud volcanoes) that can be seen while snowshoeing or cross-country skiing (Yellowstone National park, 2023). In the warmer months, you can visit another UNESCO site, the Plitvice Lakes National Park (Croatia), known for its interconnected lakes and waterfalls. In summer, visitors can explore the park's hiking trails, take part in geological excursions, and enjoy boat trips (Plitvice Lakes National Park, 2023). Geotourism is a market niche that allows travelers to increase their awareness of natural resources and how to preserve them through active recreation. This geotourism approach creates a synergistic effect that is not available for such types as ecological, historical or adventure tourism, as it allows attracting people with different interests. It is worth noting that there are currently two key approaches to the development of geotourism: geological (consideration of geological sites through the study of their morpholithogenic basis, collection of minerals) and geographical (comprehensive study of a geological site through the prism of culture, territory, local crafts, etc.) Currently, the development of geological tourism, with a geographical approach, demonstrates the close connection between recreation and the geological environment. Since what is meant by the modern understanding of geotourism gives tourists the opportunity to gain some knowledge about the landscape, geology and history of the Earth through recreation. Accordingly, the concept of geotourism covers many objects that may interest tourists to spend their vacation as a health and recreation destination, as well as cultural and educational. It means that thermal springs, volcanoes in Japan, Iceland or New Zealand, which can be associated with volcanic geotourism, and spa organizations at resorts, can be of value for this type of tourism.

Materials and Methods. As of today, almost 25 years have passed since the first formalized definition of geotourism was published in the journal Environmental Interpretation. The first professional national conference on geotourism: «Tourism in Geological Landscapes», was held in Belfast at the Ulster Museum in 1998 (Sadry B., 2020). After reviewing the scientific publications of Ukrainian scientists on the prospects of including quarries in geotourism routes, it can be noted that this issue has not yet received sufficient research. The main specialists on this topic are: V. Maniuk (2006; 2007), the representative of Ukraine in the European Association for the Protection of Geological Heritage (ProGeo), Y. Zinko (2020), Y. Kravchuk (2018). Among the researchers of Korostyshiv who study its historical component, which can be used to create excursions and familiarize tourists with the quarrying industry, it is worth noting: E. Dubivka, O. Tunik-Mozgovenko, V. Slivinskyi, O. Tarabukin (2021), Z. Weidner, V. Yershov (1994), I. Dovbysh. Thanks to them, a local history group on Facebook («Historical Korostyshiv») is functioning and articles and textbooks about its cultural and economic life are being published (Korostyshiv istorychnyi, 2023).

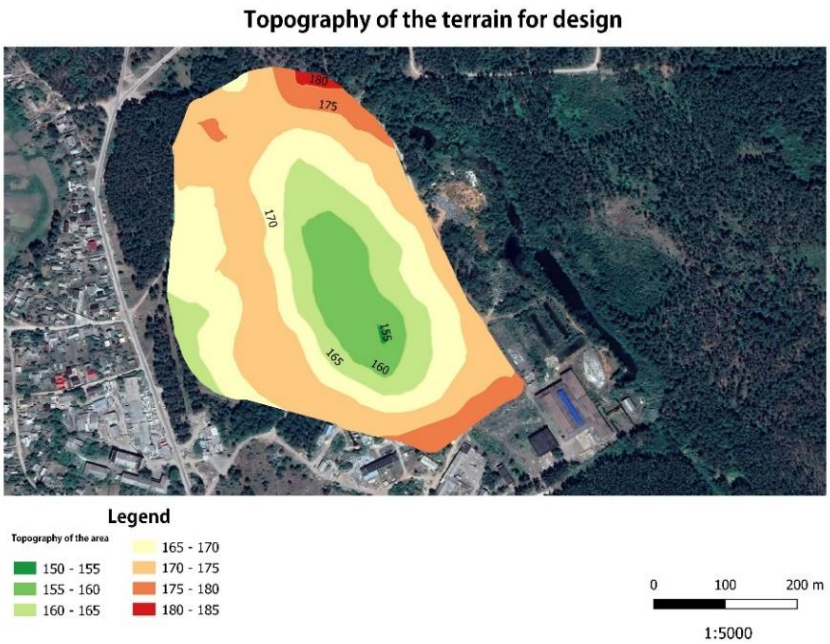
Among the foreign representatives it is worth mentioning R. Dowling (2010), C. Coelho, N. Farsani, C. Costa and Neto de Carvalho (2011), Slomka and Kicinska-Swiderska (2004), T. Hose (1995), E. Joyce (2006). Journals that publish professional articles on geotourism are: Earth Heritage (1994), Geotourism (2005), Geojournal of Tourism and Geosites (2008), Geoheritage (2009), Geoconservation Research (2018). To achieve these goals, the authors used the following methods: geographic information processing (analysis of scientific literature), mapping: Google Earth Pro, Realtime Landscaping Architect (creation of terrain, visualization of proposed measures), QGIS, and descriptive (assessment of the quarry, characterization of flora and geological features of the territory).

Results and Discussion. The unique geological heritage of Ukraine includes various geological formations and landscapes and attracts the attention of tourists interested in exploring and evaluating its geological monuments. According to the information and educational system Geological Dictionary: Open Educational and Scientific Web Resource, there are more than 400 geological monuments in Ukraine (Heolohichna pamiatka pryrody (b.d.) Heolohichnyi slovnyk). Some famous geological sites in Ukraine: The Carpathians, a mountain range in western Ukraine, is known for its geological diversity, including spectacular landscapes, mineral deposits, and unique rock formations. The Dniester Canyon, where the Dniester River has carved out a deep and picturesque canyon over millions of years, creates opportunities for geological exploration and natural resource management. Donetsk Coal Basin: This region is known for its coal mines and associated geological formations, which provide an opportunity to explore the country's industrial heritage. Kamianets-Podilskyi Castle (or «flower on a stone») is separated by a canyon from the central historical part of the city. The geological basis of Kamianets-Podilskyi Castle is limestone rocks that were formed millions of years ago as a result of natural geological processes.

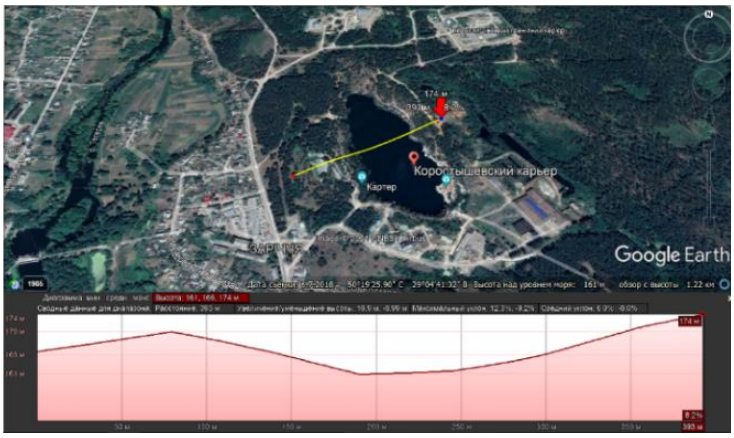
Therefore, the geological heritage of Ukraine includes numerous sites that can be included in excursions and various geotourism activities. The Zhytomyr region, with its spent granite quarries in Korostyshiv, is the basis of this study. The current situation with quarries in the Zhytomyr region is characterized by the fact that most of the land with anthropogenic heritage is not used or reclaimed. Most of the facilities are located near cities, and this proximity affects the ecology of the area. Therefore, part of the territories of quarries that have exhausted their resources should be allocated for recreation, which will have both a positive trend for tourism in the entire region and increase its budget revenues. Today, the Zhytomyr region does not have a single tourist and recreational area that is fully localized to the stone processing and granite mining industry. It is worth noting that the secondary use of granite quarries is quite interesting for both mass tourism and individual representatives. After all, granite is considered the hallmark of the planet and is found only on planet Earth. The first important rock on our planet is basalt, and the second is granite, which actually makes up our continents.

The interest in geology is noted at the international level, where the International Mineralogical Association (IMA) has declared 2022 the Year of Mineralogy, which will be held as part of the International Year of Basic Sciences for the Sustainable Development of our entire planet. The activities envisaged by this organization are scheduled for mid-2022 and will continue until mid-2023. According to the fact that the use of environmental resources, on which geotourism is based, is a rather promising tourist product. In the framework of this study, we have considered one of the flooded granite quarries in Korostyshiv for improvement as a recreation area. The appearance of the quarry is a freshwater lake surrounded by high, both steep and gentle cliffs with a pine forest around the perimeter. Approximately, the area of the lake is 48,803.58 m^2, 500 m long, 150 m wide, 20-40 m deep, and 10 m high. The natural vegetation is represented by pine, oak and birch trees. Vegetation cover is characterized by adaptation to special conditions of moisture (near a water body) and light (among trees). Accordingly, there are groups of biennial and perennial plants, grasses, shrubs, and trees. The specific types and extent of vegetation cover in a quarry depend on factors such as the age of the quarry, the nature of the rock formations, and the level of disturbance caused by quarrying activities. At the moment, it cannot be said that the quarry is uncontrolled and has numerous tourists. However, due to the lack of equipped trails, the vegetation is still affected by trampling. Currently, the quarry area is used mainly for summer and winter recreation, namely as a beach and ice skating area. The granite outcrops at the quarry have a homogeneous gray color with inclusions of light gray microlite, oligoclase, quartz, and biotite. The mineral composition of the rock is as follows: microlin (28.1%), plagioclase (32%), quartz (28.1%), biotite (7.1%), magnetite (0.6%), ilmenite, apatite (0.3%) (Korostyshivske rodovyshche). Despite the inclusions, the bulk of the rock is characterized by light gray feldspar against a background of gray quartz and black biotite. Taking into account all other parameters (density, porosity, water absorption, etc.), this stone is used for the manufacture of decorative facing products, side stone, rubble, and crushed stone. The yield of blocks from the rock mass to the surface is 18.6%. Granite rocks are generally characterized by fractures, which are divided into 4 groups: transverse sub-vertical, longitudinal sub-vertical, diagonal, and strata. The social infrastructure of the quarry includes the «Domashna Kuhnia» restaurant (280 m), the «Kavyarnia» cafe (550 m), and the «Shashlychok» barbecue restaurant (350 m). The facility itself is also located closer to the entrance to the city, which contributes not only to better accessibility to infrastructure but also to the opportunity to visit other local destinations. In particular, a dam across the Teteriv River and the Korostyshiv Stone Sculpture Park is located near the quarry.

The development of solutions around the reservoir was based on State Building Regulations B.2.2-5:2011 (sections: «Improvement of the territories of water protection zones and coastal protection strips»: 8.1. Natural and artificial reservoirs within settlements and «Improvement of public areas»: 5.6. pedestrian and bicycle paths;), according to which landscaping around an artificial reservoir should be carried out only on one bank, leaving the natural base on the opposite side undisturbed (s.8.1.3); installation of garbage containers and sanitary facilities (s.8.1.4), arrangement of bicycle parking (s 5.6.6); lighting of paths (s.5.6.7.) (Planuvannia ta zabudova mist, 2011). According to this, the design solutions cover the northwestern part of the reservoir, maintaining a balance between the use and preservation of the landscape. Given the recommendations described in the document, they were followed when choosing a place for each of the activities. We also took into account the orographic features of the territory, which has a somewhat steep slope in the southern part, so the range of measures to be implemented here is limited. The other side of the lake has a wider and flatter land plot for development (see Fig. 1 a; b).



a)



b)

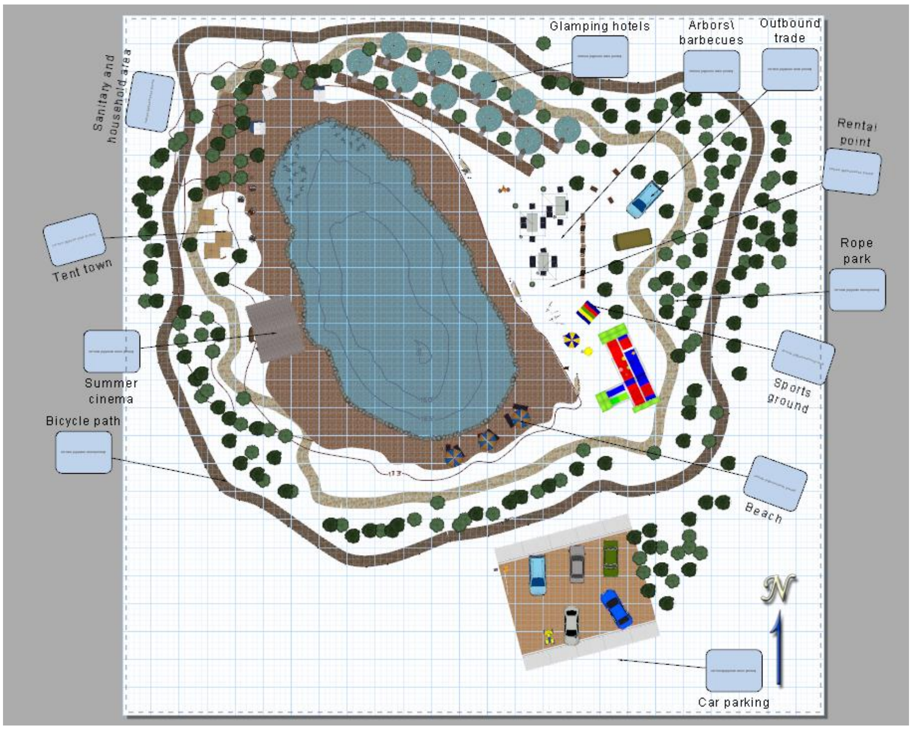
Fig. 1. Korostyshiv quarry:

a) terrain for design

b) height of the relief section from north to south

Source: developed by the authors using Google Earth

According to the developed project, the following activities are planned: arrangement of glamping, observation platforms, and cable railings, installation of wooden benches, arrangement of an access road to the parking lot, installation of anti-parking bollards, organization of a suspension bridge, arrangement of a children's area, installation of LED lamps, gazebos, and toilets, swings over the water, organization of a cable descent, rock climbing, organization of souvenir sales, garbage collection, installation of wooden stairs, installation of a tourist sign with a Q-code, workstations on trees, organization of a summer cinema and a beach area (see Fig. 2 a; b.)



a)

b)

Fig. 2. 3-D visualization of the preliminary design:
a) preliminary design proposal
b) preliminary design
Source: developed by the authors using Realtime Landscaping Architect

In accordance with the above measures, we have developed 6 functional zones that provide public access to both the lake and various types of recreation that do not have a threatening impact on natural resources (see Fig. 3). Thus, the following zones have been identified: a stationary recreation zone, a food court zone, an active zone, a passive zone, a water area zone, and a business zone.

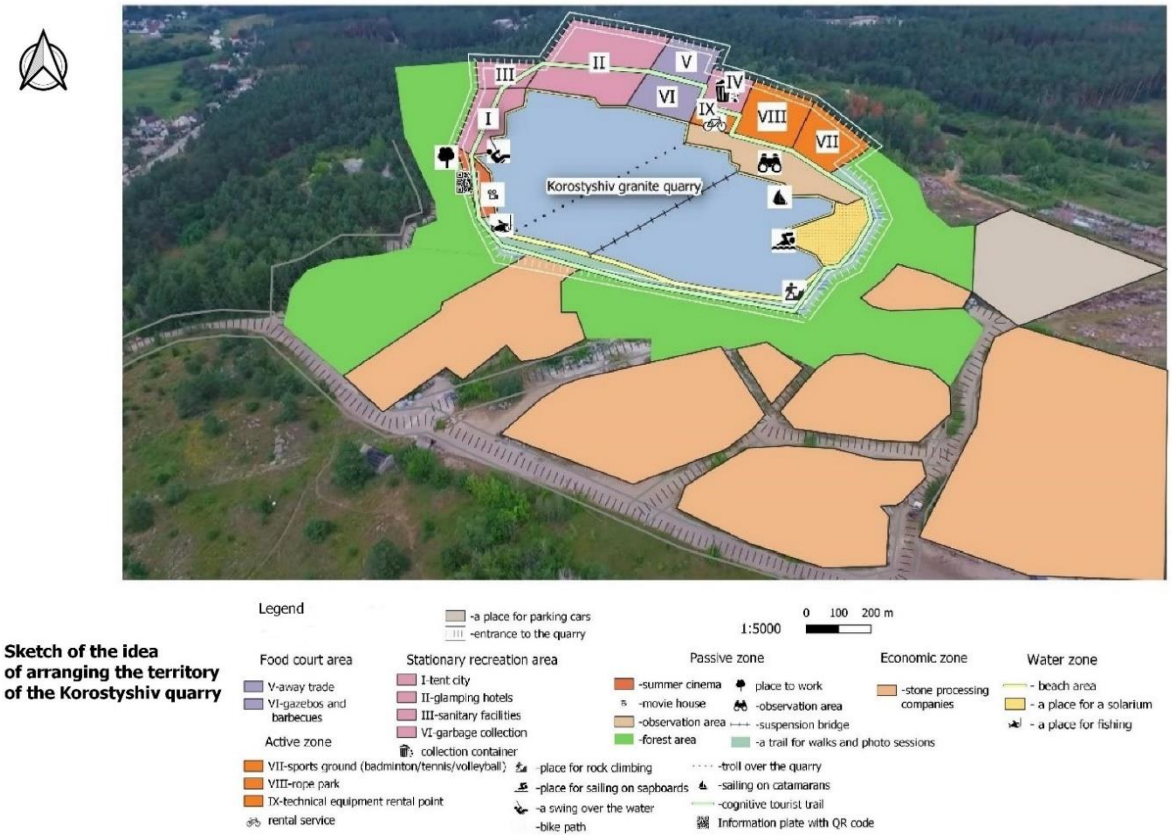


Fig. 3. Concept of the Korostyshiv granite quarry development

Source: developed by the authors using QGIS

In general, geotourism development in a former granite quarry can strengthen the environmental component of sustainable development by promoting ecosystem restoration, environmental education, sustainable infrastructure, local involvement, economic benefits, and environmental research and monitoring.

Conclusions. The study noted that the development of geological tourism is relevant for all categories of tourists, as it offers different ways to explore the territory and culture of its local residents. Thus, history and culture lovers can delve into the study of the relationship between the geological environment and its impact on people's lives. Nature lovers and outdoor enthusiasts can explore and appreciate natural attractions and resources through excursions and hiking. In order to improve recreation in the environment, a number of measures have been proposed that can increase the comfort of tourists stay. The granite quarry selected for the study is a popular place among both locals and weekend visitors. Therefore, it is worthwhile to properly organize the quantitative and qualitative parameters of their recreation, through the creation of parking spaces, hotel rooms, and various leisure facilities on the territory.

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FUNCTIONAL NUTRITION TO SUPPORT THE HEALTH OF THE POPULATION OF UKRAINE UNDER WARTIME CONDITIONS

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Abstract. *The population of Ukraine has been living in conditions of Russian aggression for more than a year. They are in a state of stress due to shelling, uncertainty of the future, risks of loss of life and property, worries for the lives of relatives who are in the ranks of the defense forces or found themselves in territories temporarily not controlled by Ukraine. Under these conditions, the quality of food, drinking water, and the environment deteriorate, with complex negative impacts on people's health. They need particular special nutrition with a full set of necessary essential nutrients, capable of providing physical and psychological endurance, preventing the occurrence and development of somatic, nervous and other types of various diseases. For this, health and functional food products and drinks are needed. They will include a scientifically based selection of physiologically functional ingredients with the necessary medical and biological indicators and directed therapeutic and preventive properties. The research analyses the positive effects of micronutrients that affect physiological processes in the human body during periods of stress and poststress. It is known that in such conditions the metabolism takes place more actively, the consumption of some vitamins and minerals increases, therefore the need for antioxidant vitamins and vitamin cofactors of the body's enzymatic systems increases. There are a number of factors that increase the impact of stress on the human body and, as a result, should be excluded. These include food toxins, alcohol, oxidants, and free radicals. One of the most promising ways to prevent stress and reduce its consequences is to include functional foods and beverages as part of the diet. Their composition should include these functional ingredients, the deficiency of which disrupts the body's adaptive capabilities.*

Introduction. Health is one of the most important priority life values that determine the quality of a person's life; it is a state of the body when it is capable of feeling the most comfortable in physical, mental, social and moral aspects.

The Charter of the World Health Organization states that health is a state of complete physical, mental and social well-being, and not merely the absence of disease or infirmity. Only healthy individuals can form a healthy society, and a healthy society, in turn, is bound to provide sustenance for individuals (Statute, 1946).

The war unleashed by the Russian Federation took the lives of many Ukrainian citizens, both military and civilian. The consequences of the war in Ukraine are assessed by the number of deaths, the scale of economic losses, the destruction of infrastructure and the number of forcibly displaced persons. In addition, war directly affects public health. The population of Ukraine is in a state of stress due to the uncertainty of the future, risks of loss of life and property, fear of shelling, worries for the lives of relatives who are in the ranks of the defense forces or found themselves in territories temporarily not controlled by Ukraine.

Citizens who have remained in the layer zone or temporarily occupied territories can suffer injuries, wounds, contusions. These people are constantly stressed by shelling, fear of losing relatives and housing. Under such conditions, there is a decrease in the quality of food, drinking water, deterioration of the environment, which negatively affects health at the current moment, and will also have delayed consequences (Roberts et al., 2019).

The body's adaptive reserves decrease; the morbidity associated with insufficient natural resistance to adverse environmental factors and the deterioration of living conditions increases. In the future, many Ukrainians could face mental exhaustion, psychological and mental problems, behavioral disorders, increased addiction and exacerbation of some illnesses (Spiegel et al., 2023).

The analysis of the situation experienced by Ukrainian society, which was carried out (Myronyuk et al., 2022), demonstrates that the armed conflict will have negative medical and demographic consequences, which will manifest themselves:

• the increase in the incidence of socially significant diseases, such as malignant neoplasm, tuberculosis, diseases of the circulatory system, diabetes, respiratory diseases, with an increase in the proportion of their detection in advanced stages or due to their complications;

• mental exhaustion of the population with an increase in the level of psychological and mental problems;

• an increase in the number of drug, alcohol and other addictions;

• the threat of an increase in the risk of the population contracting infectious and parasitic diseases, including tuberculosis, HIV/AIDS, acute seasonal viral infections, including vaccine-controlled and epidemic outbreaks of acute intestinal diseases, with an increase in the level of mortality, including premature, and disability of the population due to the lack of appropriate medical assistance;

• a high level of forced population migration to safe living areas and forced resettlement of people, including children, to the Russian Federation.

In the conditions of today, when the war forced many citizens of Ukraine to experience mental trauma, face depression or post-traumatic stress disorder, learn the difficult experience of moving to foreign cities and countries, it is especially important to ensure the triad of health: physical, mental and social. Considering the relationship between a person's state of health and the structure of his diet, proven by official medicine, it is possible to purposefully influence the improvement of the adaptation capabilities of the population of Ukraine by correcting the nutritional status and using modern food products of the new generation, adequate to the nutritional needs of the body in extreme conditions (Levy et al., 2022).

Nowadays, it is known that the health of a person who is under the influence of a complex of unfavorable environmental factors can be improved through the use of a special diet with a full range of necessary essential nutrients capable of ensuring physical and psychological endurance, counteracting the influence of negative exo- and endogenous factors, preventing emergence and development of somatic, nervous and other types of diseases (Rabbi et al., 2023). Healthy and functional foods and beverages provide such effects.

Physiologically functional food products and drinks require a guaranteed content of a certain functional ingredient in amounts from 10 to 50% of a person's daily need for it, therefore they are adequate to the nutritional needs of a person (Teklić et al., 2021). Consumption of such products allows you to adapt to the conditions of the external environment, prevent the appearance of diseases, accelerate recovery processes, and prevent premature aging.

Modification of the recipes of functional food products and drinks due to the transformation of the initial components, the introduction of functional fortifiers into the recipe has a positive effect on such physiological processes as increasing physical endurance, strengthening immunity, improving digestive functions and regulating appetite, normalizing metabolic processes, compensating for the deficiency of essential macro- and micronutrients (Granato et al., 2020).

The purpose of the work: based on the analysis of literary data and the results of personal theoretical and experimental research, determine directions for correcting the nutritional status of the population of Ukraine through regular consumption of functional products, adequate in terms of component composition to extreme conditions of life.

Materials and Methods. Based on a systematic approach, the bibliosemantic method and the method of structural-logical analysis were used during the conducted research. The research materials were data from scientific literature and personal practical experience in the development of technologies for functional food products with improved nutrient composition and a targeted impact on the health of consumers.

Results and Discussion.

Characterization of vitamins as functional ingredients that have a positive effect on the state of the human body in stressful and post-stress periods.

The key aspects in the creation of functional food products are the scientifically based selection of physiologically functional ingredients with the necessary sanitary-hygienic, medico-biological indicators, aimed at therapeutic and preventive properties as well as the development of new technological solutions that allow to significantly influence not only the organoleptic and physico-chemical indicators of raw materials and finished products, increasing their biological value, and also provide them with defined functional properties (Stetsenko et al., 2021).

Currently, special attention should be paid to the psycho-emotional state of our society. For over a year the majority of the population is in a state of stress or even distress that is maladaptive stress, which requires additional biochemical resources to overcome. If one's own resources are not enough, it is worth influencing this by consuming foods and drinks with a sufficient content of nutrients, which in a state of stress undergo increased costs. Since the content of nutrients in drinks is not significant, we will characterize the action of micronutrients that affect the state of the human body in stressful and post-stress periods.

In extreme situations, with changes in energy metabolism, increased physical exertion, and inhalation of polluted air in adverse environmental conditions, the formation of free radicals is happening, negatively affecting the body. The key links of the body's protective systems include: the antioxidant protection system, the enzyme detoxification system, and the state of the membrane apparatus of cells.

In order to improve the condition of the human body under such conditions, a sufficient amount of vitamins is needed, which participate in the metabolism, mainly regulating certain biochemical and physiological processes. First of all, they are necessary to ensure the mechanisms of enzymatic catalysis, normal metabolism, maintenance of homeostasis, biochemical support of all vital functions of the body. During stress, the metabolism is more active than in a normal state, the consumption of some vitamins and minerals increases, as a result of which the need for an increased supply of vitamins-cofactors for the most important enzyme systems of the body increases (Young et al., 2019). Table 1 provides a list of vitamins with anti-stress properties, as well as the mechanisms of their positive action.

Table 1.

Mechanism of positive action of vitamins with anti-stress properties

Vitamin A (retinol)	Antioxidant, protects brain cell membranes, which contain a large amount of fat and can be damaged by free radicals
Vitamin D (calciferol)	Strengthens immunity, improves the state of the nervous system, improves the assimilation of calcium, magnesium, and zinc
Vitamin E (tocopherol)	A powerful antioxidant that protects intracellular structures and membranes of brain cells from damage by free radicals
Vitamin C (ascorbic acid)	Antioxidant, participates in all types of metabolism, increases stress resistance, ensures the production of anti-stress hormones and interferon, and activates cells of the nervous system.
Vitamin B_1 (thiamine)	Participates in the processes of nervous regulation, contributes to the improvement of the work of the nervous system, improves cognitive and mental activity
Vitamin B_2 (riboflavin)	Supports and normalizes the functions of the central nervous system, and regulates the processes of excitation and inhibition in the nervous system, therefore it is especially necessary for people with significant mental and physical stress
Vitamin B_5 (pantothenic acid)	Helps cope with stressful situations, increases concentration, reduces depression and anxiety, activates mental activity, reduces fatigue
Vitamin B_6 (pyridoxine)	Anti-stress factor, necessary for the synthesis of neurotransmitters serotonin and dopamine, necessary for the functioning of the central and peripheral nervous system
Vitamin B_9 (folic acid)	Has a positive effect on depression and anxiety states, has an anti-stress effect
Vitamin (B_{12}) (cyanocobalamin)	Has a positive effect on the central nervous system, supports metabolism in nervous tissue, reduces irritability, improves memory and concentration
Vitamin PP (nicotinic acid)	Helps improve memory, protects the body from stress, participates in energy metabolism
Vitamin H (biotin)	Contributes to the normal functioning of nervous tissues

Essential nutrients for the anti-stress diet of the population of Ukraine

In addition to vitamins, an anti-stress diet should also include a group of vitamin-like compounds. L-carnitine participates in energy exchange and provides transmembrane transport of fatty acids in mitochondria. A deficiency of this nutrient leads to a significant decrease in the body's energy potential and increases the effects of stress (Virmani et al., 2022).

Coenzyme Q_{10} (ubiquinone) carries out energy exchange, and stimulates the improvement of heart muscle contractions. Important for consumption during times of stress, as it is one of the most effective antioxidants (Cirilli et al., 2021).

The group of mineral components most important in stressful conditions includes zinc and selenium. Zinc is a structural element of more than 300 enzymes that regulate the metabolism of proteins, fats, and carbohydrates, and is also involved in the expression of a number of genes. Zinc deficiency during stress leads to secondary immunodeficiency and contributes to liver cirrhosis and sexual dysfunction (Chasapis et al., 2020).

Selenium is an irreplaceable trace element necessary for the functioning of the body's antioxidant system, and is involved in the regulation of a number of hormones. Selenium deficiency contributes to the development of osteoarthritis (disease of bones and joints) and myocardiopathy.

Additions of succinic acid to the diet of the population will be appropriate. Succinic acid in the body has a multifaceted therapeutic effect. Its universal antihypoxic, hepatotropic and antistress effect has been proven (Saxena et al., 2017). The adaptogenic effect of succinic acid during heavy physical exertion has been established, there are data on the stimulating effect of succinic acid on protein synthesis, hemoglobin, glucose absorption and glycogen synthesis in the liver.

Antioxidant protection is provided by various components of food products (bioflavonoids, food indoles, and isothiocyanates). These compounds, not having energy and plastic value, control detoxification processes and protection of body systems from toxic effects. Their low content in the diet leads to a significant increase in the risk of developing chronic non-infectious diseases (Stetsenko et al., 2021).

Prospects for the use of herbal medicinal and spicy-aromatic raw materials for maintaining the health of the population of Ukraine

One of the most promising sources of natural biologically active substances is herbal medicinal and spicy-aromatic raw materials, which should be considered both as a physiologically active additive and as a multifunctional recipe component capable of significantly improving the organoleptic, food and consumer characteristics of new products and beverages. Raw materials can be used in the form of water and water-alcohol extracts, thickened and pasty concentrates, powders, CO_2 extracts, essential oils, etc. Complexes of compounds contained in plants act in a variety of ways, stimulating various body systems or compensating for their insufficient function (Varshney et al., 2021). This usually prevents the occurrence of allergic diseases and complications. In addition, medicinal plants have an antioxidant effect and the ability to remove toxic substances and metabolic products, and some compounds affect the enzyme activity of the body.

Medicinal and spicy-aromatic raw materials contain a wide range of biologically active substances in fairly significant quantities, capable of exerting a versatile influence on all functions and systems of the human body. For example, to increase the body's defenses against the influence of various harmful factors (small doses of radioactive radiation, stress, the destructive action of free radicals, physical and psycho-emotional overloads, non-specific infectious diseases, etc.), to have an antioxidant, general strengthening effect. The use of medicinal plants in the field of food technology requires careful control and compliance with the requirements for their quality and safety.

Factors that lead to increased consumption of essential nutrients

At the same time, in stressful conditions, a number of components that increase the consumption of essential nutrients should be excluded from the diet. Alcohol should certainly be classified as a toxic substance. Under conditions of stress, the enzymes alcohol dehydrogenase and aldehyde dehydrogenase, which oxidize ethyl alcohol, are spent on the utilization of endogenous alcohol, which is synthesized in increased quantities in connection with the transition of the body to work in emergency mode. Exogenous alcohol will be almost completely transformed into acetaldehyde and acetic acid. The acetic acid that is formed causes, in particular, metabolic acidosis - it lowers the pH of the blood and thus neutralizes the electrokinetic potential of erythrocytes, which leads to their clumping.

Destabilization of the colloid system of blood leads to deterioration of blood flow, increase in its viscosity, increase in hydraulic resistance in blood vessels, especially in capillaries. The presence of toxins in the blood reflexively leads to the narrowing of capillaries, which in turn sharply worsens the metabolism of xenobiotics present in body cells in excess in the post-stress period. Thus, the effects of stress only increase.

Similar consequences are also caused by smoking, which is associated with the formation in the alveoli of the lungs of a protective reaction of their narrowing to reduce the toxic concentration of tobacco products in the blood. The consequence of this is a decrease in the efficiency of the biotransformation of xenobiotics and the evacuation of the products of their biochemical rearrangement.

Increased consumption of fermented milk products with probiotics, containing live cultures of lacto- and bifidobacteria, as well as prebiotics, in the form of dietary fibers of vegetables and fruits, will significantly enhance the productive processes of metabolism with the transformation and removal of toxic substances arising as a result of experienced stresses.

Conclusions. A properly constructed diet during stressful situations caused by the full-scale invasion of the troops of the Russian Federation into Ukraine can be an effective tool for preventing the development and transition to maladaptive stress. In the case of maladaptive stress, the diet should be considered as one of the main tools for overcoming the effects of stress and bringing a person out of the post-stress state as quickly as possible.

The need for constant search and development of new effective means of protecting the health of the population of Ukraine requires the development and introduction into the production of special food products, the composition of which will be scientifically based and experimentally tested. The range of such products can be very diverse, as they are created on traditional food bases, and multifunctional fortifiers are natural biocomplexes of agricultural and medicinal raw materials with proven physiological effects.

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SECOND-HAND CLOTHES WASHED WITH DETERGENTS FOR CHILDREN'S CLOTHES: TOXICITY OF WATER-SOLUBLE RESIDUAL COMPOUNDS ACCORDING TO PHYTOTESTING AND HEALTH RISKS FOR CHILDREN

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Abstract. *The purpose of this study was to investigate the toxicity (according to the phytotest with garden cress) of water-soluble residual compounds from reusable clothes ("second hand"), provided that they were washed with detergents for children's underwear. Phytotesting with garden cress (Lepidium sativum L.) and statistical methods of processing the results were used in the study, the root length index and the phytotoxic effect of the solutions were calculated. Detergents for children's clothes, widely available in the retail network of Ukraine, were used for washing. It was established that the sensitive test indicators of garden cress to the water-soluble residual toxicants of the "second hand" clothing material are the length of the roots and the aerial part of the seedlings. Phytotoxic properties were noted for solutions obtained from the material without treatment and after washing with phosphonate-containing and phosphate-free products. The consequences of fabric treatment with a laundry conditioner after washing are ambiguous: the phytotoxic properties of the water-soluble residual compounds of phosphonate-containing powder were eliminated, but the phytotoxicity of the phosphate-free powder remained. Water-soluble residual compounds of household soap had a favorable effect on the growth of the roots of the test plant. Second-hand clothes washed with the specified detergents are potentially dangerous for the child's health, except for clothes washed with household soap, which eliminates the toxicity of the material and does not lead to the appearance of factors that are negative for health.*

Introduction. The declared value of the world trade in second-hand clothes is constantly increasing. The trade value of total exports rose from USD 0.75 billion (1990), to USD 1.53 billion (2001) and USD 4.2 billion (2018) (Lampel 2020). The low solvency of the citizens of Ukraine and the lack of provision of the population with basic wardrobe items determined the importance of second-hand clothing stores for people with low incomes (Kuchma 2010). According to unofficial statistics, 60-80% of Ukrainians buy clothes from second-hand stores (Bazik and Gayova 2019).

The reuse of clothes is one of the approaches of the concept of circular business models, which is widely used in the world (Mytsenko and Khadzhinov 2022; das Virgens et al. 2022) and allows a person and society as a whole to solve a number of environmental, economic and social problems (Filho et et al. 2019). Collected clothes can be: 1) reused as second hand; 2) rework (Kirichenko 2021). According to studies by Filho et al. (2019) textile reuse and recycling has environmental, economic and social benefits.

Along with this, new problems are emerging: environmental (accumulation of garbage in countries with a low level of socio-economic development), economic (decline of the textile industry) and social (deterioration of human health) (Kratik 2019; Kirichenko 2021). So, in reality, using used clothes does not solve environmental, economic and social problems.

In particular, there are risks to human health as a result of non-compliance with sanitary standards for processing clothes with formaldehyde (Mala 2017; Kratik 2019). High doses of formaldehyde can also be contained in new cotton items due to the peculiarities of the cotton fabric manufacturing technology (Herrero et al. 2022; Reitz et al. 2022). A safe and simple practice to remove formaldehyde from such items is to wash the garment before use (Herrero et al. 2022). Since children are the most sensitive to toxicants (Au 2002), special attention should be paid to children's clothing.

Both chemical and biological methods are used to assess environmental pollution, the toxicity of various compounds, and their impact on living organisms. One of the available and easy-to-perform biological methods is phytotesting (Smykun and Furman 2008; Torgashkova et al. 2018; Revathi and Sheena 2019; Calvo-Olvera et al. 2021; Bernegossi et al. 2022). Garden cress (*Lepidium sativum*) is one of the sensitive plant models in this test (Galli et al. 2019; Bożym 2020; Tkachuk and Okulovych, 2021; Tkachuk et al. 2022). Therefore, the purpose of this work was to study the toxicity (according to the phytotest with garden cress) of reusable clothes ("second hand") with different options for washing by detergents for children's clothes and to assess the risks to children's health when using such clothes.

Materials and methods. *Selection of "second hand" clothing samples and their preparation for research.*

Children's clothes made of 100% cotton (T-shirts) of white color was chosen for the study, which was purchased in the well-known chain of "second hand" stores in Chernihiv (Ukraine) in the amount of 3 pieces. From each T-shirt, 6 samples of material measuring 10 × 10 cm (18 samples in total) were cut. Of these, 3 samples (one from different T-shirts) were left untreated (option 2), and the other samples were washed by hand using various detergents, air-dried and ironed. Washing was carried out with the amount of detergent recommended by the manufacturer.

The following washing options of fabric "second hand" were used: option 3 – phosphonate-containing washing powder for children's clothes; option 4 - phosphonate-containing washing powder for children's clothes with subsequent treatment with conditioner for children's clothes; option 5 – phosphate-free washing powder for children's underwear; option 6 – phosphate-free washing powder for children's underwear with subsequent processing by conditioner for children's clothes; option 7 - household soap, 72%. Detergents widely available in the retail network of Ukraine were used. In order to prevent accusations of advertising or anti-advertising of laundry detergents, we do not list their trade names.

According to manufacturers, the composition of detergents is as follows:

• phosphonate-containing washing powder for children's clothes: 5-10% anionic surfactants, oxygen brighteners, zeolites; < 5% nonionic surfactants, cationic surfactants, phosphonates, soap, polycarboxylates; additionally: enzymes, optical brighteners, perfume composition.

• phosphate-free washing powder for children's underwear: > 30% sodium chloride; 15-30% sodium carbonate; 5-15% silicate; < 5% sodium percarbonate; soap; anionic surfactants; tetraacetylethylenediamine (TAED); perfumes.

• conditioner for children's clothes: < 5% cationic surfactants, < 5% nonionic surfactants, flavoring additive (hexyl cinnamal), preservative (benzisothiazolinone, methylisothiazolinone), aloe vera leaf juice.

• household soap (72 %): sodium salts of fatty acids of tropical vegetable oils and animal fats, water, glycerin, disodium ethylenediaminetetraacetate (disodium EDTA), antioxidant.

After drying in the fresh air and ironing, each sample was immersed in distilled water (100 ml) for 2 hours at a temperature of 24 ± 1 ºC to dissolve water-soluble residual compounds from the material in the water. The resulting solutions (aqueous extracts) were used in phytotoxicity studies.

Study of the toxicity of "second-hand" clothing samples by phytotesting with L. sativum.

Garden cress (*L. sativum*) produced in the Czech Republic (MoravoSeed), packaged by private enterprise "Scientific and production firm "Tiras", batch No. 69088-01, which, according to the information on the package, corresponds to State Standard of Ukraine 6006:2008 was used as a test plant. Garden cress seeds were placed on filter paper located at the bottom of self-made containers made of food plastic and moistened with the appropriate test solution (see the previous section). In the control, seeds were germinated on filter paper while watering with distilled water (option 1). The number of seeds per container is 10 pieces, the repetition of control and each experiment is threefold. Seed germination took place in the dark at a temperature of 24 ± 1 ºC. On the 3rd day, germination energy was determined, on the 5th day - germination and the length of the aerial part and roots.

Phytotoxic indices were calculated - root length index (RLI) and phytotoxic effect of solutions (PhTE) according to formulas (1) and (2), respectively.

$$\mathrm{RLI} = \frac{L_T(i) - L_C}{L_C}\ , \qquad (1)$$

where $L_T(i)$ and L_C are the average length of roots in the test (i) and in the control, respectively. Phytotoxicity was determined using the following scale (Bagur-González et al. 2011; Mtisi and Gwenzi 2019):

weak: $-0.25 \leq \mathrm{RLI} < 0$;

average: $-0.5 \leq \mathrm{RLI} < -0.25$;

high: $-0.75 \leq \mathrm{RLI} < -0.5$;

extreme: $-1 \leq \mathrm{RLI} < -0.75$.

$$\mathrm{PhTE} = \left(\frac{L_C - L_T(i)}{L_C}\right) \times 100, \qquad (2)$$

where $L_T(i)$ and L_C are the average length of roots in the test (i) and in the control, respectively (Baghdasaryan 2005).

Statistical analysis of experimental data.

The statistical module of the Microsoft Office Excel 2010 program was used for statistical processing of the obtained data. Descriptive statistics methods were used - calculation of the arithmetic mean value (M) and the standard error of the arithmetic mean value (m). The number of observations (n) for biometric indicators of seedlings was from 25 to 30 (depending on the number of seeds that germinated in each variant of the experiment). The significance of the differences between the control and the experiment was assessed by the Student's significance test (t). The statistical significance of differences in germination energy and seed germination (n = 3) was assessed using the χ^2 test using the Past 4.03 software (Hammer et al., 2001). A 95% probability of differences ($p \leq 0.05$) was considered statistically significant.

Results and discussion. Garden cress is a toxicant-sensitive plant that is used as a model test system in various toxicological studies (Galli et al. 2019; Bożym 2020; Tkachuk et al. 2022). Therefore, we used it to evaluate the toxicity of aqueous solutions obtained in the process of preparing material samples from "second-hand" children's clothing. The obtained results are presented below.

Test indicators of L. sativum

The results of the study of garden cress test indicators are presented in Table 1.

Table 1

Test indicators of *L. sativum*

Research option	The energy of germination, % (M ± m; n = 3)	Germination, % (M ± m; n = 3)	Length, mm	
			Roots (M ± m; n)	Above ground part (M ± m; n)
1	97.0 ± 3.0	97.0 ± 3.0	47.9 ± 3.1; 29	34.9 ± 1.8; 29
2	93.0 ± 3.0	97.0 ± 3.0	49.0 ± 3.9; 28	30.1 ± 1.4*; 28
3	97.0 ± 3.0	97.0 ± 3.0	26.6 ± 2.2*; 29	29.2 ± 1.4*; 29
4	97.0 ± 3.0	100	43.3 ± 3.3; 29	30.9 ± 1.3; 29
5	100	100	36.0 ± 2.8*; 30	29.7 ± 1.3*; 30
6	83.0 ± 3.0	97.0 ± 3.0	39.5 ± 4.2*; 25	35.4 ± 2.4; 25
7	97.0 ± 3.0	97.0 ± 3.0	62.4 ± 4.2*; 29	34.6 ± 1.8; 29

Note: * - differences from the control are significant at $p \leq 0.05$ (t_{st}=2.01-2.68-3.50); option 1 – the control (filter paper and distilled water); option 2 – the filter paper and aqueous extract of the fabric "second hand" without washing; option 3 – the filter paper and aqueous extract of the fabric "second hand" with washing with phosphonate-containing washing powder for children's clothes; option 4 – the filter paper and aqueous extract of the fabric "second hand" with washing with phosphonate-containing washing powder for children's clothes with subsequent treatment with conditioner for children's clothes; option 5 – the filter paper and aqueous extract of the fabric "second hand" with washing with phosphate-free washing powder for children's underwear; option 6 – the filter paper and aqueous extract of the fabric "second hand" with washing with phosphate-free washing powder for children's underwear with subsequent treatment with conditioner for children's clothes; option 7 – the filter paper and aqueous extract of the fabric "second hand" with washing with household soap (72%)

It was established that the tested solutions did not have a toxic effect on germination energy and seed germination (see Table 1). However, the length of the roots and the aerial part of the seedlings turned out to be sensitive indicators. Thus, it was established that the solution obtained during the polishing of the samples of option 2 (second-hand clothing material without washing) had a negative effect on the length of the above ground part: the indicator statistically significantly decreased compared to the control by 1.2 times, but the length of the roots was within the control limits (see Table 1).

The results of the study of phytotoxicity of solutions obtained after washing materials with synthetic detergents - phosphonate-containing powder for children's clothes (option 3) and phosphate-free powder for children's clothes (option 5) deserve attention. In both of these options, a significant decrease was recorded compared to the control in the length of the roots (by 1.8 times and 1.3 times, respectively) and the aerial part (by 1.2 times) of garden cress seedlings (see Table 1). At the same time, the roots of the test plants in variant 3 (phosphonate-containing powder) turned out to be darker than in the control variant. It is possible that the toxicity in options 3 and 5 is related to both the influence of the final amounts of formaldehyde and the constituent compounds of the detergents.

The result of fabric treatment with laundry conditioner turned out to be ambiguous. Thus, in the variant 4, the phytotoxic properties of the solution were not recorded, and in the variant 6, a statistically significant decrease was noted compared to the control in root length (by 1.2 times) (see Table 1). So, in the case of phosphonate-containing powder, additional rinsing of clothes after washing with conditioner for children's clothes eliminates the phytotoxic properties of its residual amounts, which cannot be said about phosphate-free powder.

The solution obtained from "second-hand" clothing material after washing it with household soap (variant 7) reliably stimulated the growth of roots - the rate was 1.3 times higher than in the control (see Table 1). So, in this case, phytotoxic properties were not recorded; the amount and composition of residual compounds of household soap proved to be favorable for the growth of the roots of the test plant.

Phytotoxic indices

Based on the results of the root length study, the phytotoxic indexes listed in Table 2 were calculated.

Table 2

Interpretation of the data obtained in the experiment

Research option	RLI	PhTE	Interpretation of phytotest results	Comments
1	Calculation is not expected	Calculation is not expected	No toxicity	No inhibition of growth
2	0.023	-0.023	No toxicity	No inhibition of growth
3	-0.445	0.445	Average toxicity	Average (40 %) growth inhibition
4	-0.096	0.096	Weak toxicity	Weak (10 %) inhibition of growth
5	-0.248	0.248	Weak toxicity	Weak (25 %) inhibition of growth
6	-0.175	-0.175	Weak toxicity	Weak (18 %) inhibition of growth
7	0.303	-0.303	No toxicity	No inhibition of growth

Note: option 1 – the control (filter paper and distilled water); option 2 – the filter paper and aqueous extract of the fabric "second hand" without washing; option 3 – the filter paper and aqueous extract of the fabric “second hand” with washing with phosphonate-containing washing powder for children’s clothes; option 4 – the filter paper and aqueous extract of the fabric “second hand” with washing with phosphonate-containing washing powder for children’s clothes with subsequent treatment with conditioner for children’s clothes; option 5 – the filter paper and aqueous extract of the fabric “second hand” with washing with phosphate-free washing powder for children’s underwear; option 6 – the filter paper and aqueous extract of the fabric “second hand” with washing with phosphate-free washing powder for children’s underwear with subsequent treatment with conditioner for children’s clothes; option 7 – the filter paper and aqueous extract of the fabric “second hand” with washing with household soap (72%)

According to the calculated indices, aqueous solutions 2 (fabric without washing) and 7 (fabric after washing with household soap) do not have toxic properties (see Table 2). An aqueous solution of second-hand clothing fabric after washing in a phosphonate-containing powder showed an average level of toxicity, and a weak level of toxicity in a phosphate-free powder. Phytotoxic indices of aqueous solutions from clothes after additional treatment with conditioner for children’s clothes characterize them as weakly toxic.

According to calculated indexes that take into account the length of garden cress roots, “second hand” clothes without washing are non-toxic, but the indicator of the length of the above-ground part shows slight phytotoxicity (see Table 1-2). Therefore, wearing such clothes without washing is dangerous because of the potential negative impact on health. The potential health risks associated with formaldehyde used to treat such items depend on the routes of exposure (such as inhalation or skin contact), the concentration of formaldehyde, and the duration of exposure. Inhaling formaldehyde can cause effects such as nausea, asthma exacerbations, and cellular changes that can lead to the development of tumors. Chronic inhalation exposure to formaldehyde can cause cancer (GAO-10-875 2010; Rovira et al. 2016).

However, formaldehyde in clothing is of greatest concern because allergic contact dermatitis occurs as a result of exposure to it on the skin. The formation of eczema, allergic contact dermatitis, affects the immune system and causes reactions characterized by rashes, blisters and peeling of dry skin, itching or burning. Another possible health effect from exposure to formaldehyde on the skin - irritant contact dermatitis - is also a form of eczema and has similar symptoms; however, the condition does not affect the immune system.

Avoiding clothing containing formaldehyde is usually effective in preventing allergic and irritant contact dermatitis and relieving symptoms, but this can be difficult to do because clothing labels do not list items that have been treated or contain formaldehyde. Washing clothes before wearing often reduces formaldehyde levels, but is not always successful. In some cases, avoiding or alleviating allergic contact dermatitis requires more drastic measures, such as taking medications with potentially serious side effects.

Finally, consumers may also be exposed to formaldehyde on their skin through the use of certain cosmetics, including skin care products, shampoos, and sunscreens that contain formaldehyde (GAO-10-875 2010). Second-hand clothes treated with formaldehyde, which has high bactericidal properties, can negatively affect the health of people - both consumers and workers of second hand clothing stores (Kratik 2019).

The obtained results indicate the necessity of washing second-hand clothes. At the same time, washing with synthetic detergents (both phosphonate-containing and phosphate-free) poses a threat to the health of children - residual compounds ensure medium and low toxicity of clothes. In particular, phosphonates, which are esters and salts of phosphonic acids and are being developed as an alternative to phosphates in laundry detergents, can cause a dermatological reaction (Dirty laundry… 2016).

The use of phosphonates in powders is a step on the way to reducing the content of phosphates in detergents, however, they are worse rinsed, and still lead to an increase in the content of phosphorus compounds in wastewater, and, therefore, to the deterioration of the ecological condition of water bodies where such wastewater enters. Among the compounds that can affect the health of children, the composition of the used phosphonate-containing product also includes: 1) zeolites, which have an increased content of silicates, which causes degreasing of the skin, as well as pollution of water bodies with aluminum; 2) optical bleaches (have a reflective effect and create the illusion of "shining" laundry, and do not affect the actual cleanliness of the laundry; they practically do not rinse off - their task is to remain on the fabric), which can cause contact dermatitis (Dirty laundry… 2016).

The composition of phosphonate-containing and phosphate-free products includes aromas that cause itching of the body, hands, eyes, contribute to the development of allergies and asthma. Also, both types of washing powders contain surface-active substances, the impact of which on health is manifested in impaired immunity, development of allergies, damage to the brain, liver, kidneys, and lungs (Dirty laundry… 2016).

There is evidence that surfactants can affect the human body for a long time due to the property of gradual accumulation in the brain, liver, heart, and subcutaneous tissue (Yuan et al. 2014). That is, they affect the human body as a whole, and not only at the skin level. The problem is also complicated by the inability of the vast majority of sewage treatment plants in our country to qualitatively remove surfactants and, as a result, their gradual accumulation in the environment (Frolova et al. 2019).

TAED has very low toxicity by all considered routes of exposure, practically does not irritate the skin and eyes, there is no evidence of sensitizing potential when in contact with the skin (Human & Environmental Risk Assessment... 2002).

It is possible to recommend, after washing in the investigated powders, additional treatment with a conditioner for children's clothes, which contains components of plant origin, which, according to the results, reduces the toxicity of the material, and, therefore, the risks of impact on health. However, the studied conditioner for children's clothes contains surfactants, as well as: 1) hexyl cinnamaldehyde, which is included in the group of compounds that cause skin irritation and are skin sensitizers (allergens) (Amyl and hexyl cinnamaldehyde... 2016); 2) benzisothiazolinone, which causes skin irritation and can cause a skin allergic reaction, causes serious eye damage (Benzisothiazolinone and its salts... 2019); 3) methylthiazolinone, which is a pesticide and is used to control slime-forming bacteria, fungi, algae in pulp and paper mills, water cooling systems, oilfield operations, industrial process water and air purification systems and is included in adhesives, coatings, fuels, processing fluids metals, resin emulsions, paints and various other special industrial products as a preservative (Methylisothiazolinone... 1998).

Methylthiazolinone is also used to control mold growth on wood products. In studies using laboratory animals, methylisothiazolinone was found to exhibit moderate acute toxicity by the oral and inhalation routes; has high acute toxicity when applied to the skin or eyes. In subchronic studies, the most significant toxicological effect was microscopic damage to the turbinates due to inhalation exposure. Developmental and chronic feeding/carcinogenicity studies in rats yielded no significant effects, and the US Environmental Protection Agency has classified methylisothiazolinone as a Group

D chemical not classified as carcinogenic to humans. The results of the mutagenicity study were questionable (Methylisothiazolinone... 1998).

Second-hand clothes washed with household soap will not have a negative impact on the child's health, because, according to the results of the study, the material does not show phytotoxicity. The composition of household soap includes EDTA. EDTA can contribute to aquatic toxicity at low concentrations, and its release into natural waters should be minimized where possible (Sillanpää 1997; Oviedo and Rodrígues 2003). Lanigan and Yamarik (2002), based on an analysis of publications, note that EDTA and its salts have been evaluated for their potential ability to cause chromosomal aberrations, semi-lethal processes, crossovers, direct mutations, replicative DNA synthesis, DNA strand breaks, dominant lethal processes, metabolic inhibition, sister exchange chromatids with mostly negative results (Lanigan and Yamarik 2002). So, in general, the best approach for removing the toxicity of second-hand material is washing with laundry soap.

Conclusion. Thus, the length of the roots and the above ground part of the seedlings turned out to be sensitive test indicators of garden cress. Phytotoxic properties were noted for solutions obtained from the material without treatment and after washing with phosphonate-containing and phosphate-free products. The consequences of fabric treatment with a laundry conditioner after washing are ambiguous: the phytotoxic properties of the phosphonate-containing powder were eliminated, but the phytotoxicity of the phosphate-free powder remained. The water-soluble residual compounds of the household soap had a beneficial effect on the growth of the roots of the test plant. The solutions obtained after processing the investigated samples of second-hand clothing material with detergents can be arranged in the following order of decreasing toxicity: washing powder for children's clothes (phosphonate-containing) > washing powder for children's clothes (phosphate-free) > washing powder for children's clothes (phosphate-free) + conditioner for children's clothes > washing powder for children's clothes (phosphonate) + conditioner for children's clothes > household soap. Second-hand clothes washed with the specified detergents are potentially dangerous for the child's health, except for clothes washed with household soap, which eliminates the toxicity of the material and does not lead to the appearance of factors that are negative for health.

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INTERNATIONAL TOURISM IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT: PUBLIC-DIPLOMATIC DIMENSION

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Abstract. *Research attention is focused on the public-diplomatic dimension of international tourism as a powerful factor in the sustainable development of Europe. Its important role in overcoming the consequences of Russian aggression against Ukraine in the conditions of a full-scale war in 2022-2023 and preventing the spread of military conflict in Europe is emphasized. It is emphasized that, having received the status of a candidate country for EU membership, defending the values of Euro-Atlantic civilization and global democracy in the confrontation with the Russian aggressor, Ukraine has prospects and must join the pan-European processes in the field of public diplomacy. In view of this, the spread of such measures as audio guides in Ukrainian in European tourist centers, the cultural segment of public diplomacy in the field of popularization of Ukrainian culture, green tourism within the framework of a pan-European relevant network with the inclusion of Ukrainian regions, in particular, the Carpathians and the Black Sea region, will serve as a task of European public diplomacy and contribute to the sustainable development of Europe, strengthening contacts with European countries that provide unprecedented humanitarian and military assistance to Ukrainians in the fight against the Russian aggressor. It is summarized that this is not fully answered by the Public Diplomacy Strategy of the Ministry of Foreign Affairs of Ukraine, which significantly limits the competences of the structures of the domestic tourism industry.*

Introduction. Public diplomacy plays an important role in international relations. One of its directions is tourism - a peaceful form of contact between peoples, which promotes intercultural communication and the authority of states as democratic. The development of the tourism industry is especially relevant for Ukraine and Europe as a whole in the context of Ukrainians' counteraction to full-scale Russian aggression, launched on February 24, 2022, not only because of promoting the reconstruction of the Ukrainian economy, strengthening relations of our state with friendly democratic countries that provide unprecedented support to Ukrainians in winning freedom and independence, but no less important is the potential of international tourism because of the need to prevent the spread of war in Europe.

The researchers state that, the impact of tourism as an instrument of public diplomacy and the assessment of the possibilities of its use in terms of ensuring the foreign policy interests of countries and regions remains a poorly studied topic (Parfinenko, 2016). We should add: the least studied is the public-diplomatic dimension of international tourism in the context of sustainable development under the conditions of globalization, the components of which are the processes of European integration. This caused the authors to turn to this problem.

Materials and Methods. The basis of the study was the processes of public and diplomatic activity in the segment of international tourism within the European space. The article is aimed at analyzing international tourism activities in the context of sustainable development. In addition to the used general scientific research methods, such as logic, analysis, synthesis, etc., the method of structural and functional analysis has become the leading one. Using this method we clarified the role of international tourism as a component of public diplomacy in the context of the tasks of sustainable development of Europe, including the situation with Ukraine in this context.

Results and Discussion. Public diplomacy, being an instrument of soft power that relies on cultural achievements and is aimed at creating a friendly and favorable international environment, helps the state to influence events and processes that are seemingly beyond its influence. Protection of certain social or legal standards by the state, increase of its moral authority, observance of the principles of the rule of law, creation of a harmonious domestic political system within the country, together with activity in the international format – all these factors affect state’s image and help to achieve its goals. As scientists emphasize, in the era of globalization, which is accompanied by the emergence and improvement of electronic means of mass communication, the emphasis on international interaction shifts in the direction of influencing a wide range of target audiences. Together with the expansion of the range of “actors” and the strengthening of the role of non-governmental entities that are “included” in public and diplomatic activities, this contributes to the consolidation of democratic institutions in countries and regions (Sukhorolska, 2015). Besides, which is equally important, it contributes to sustainable development, as it strengthens the foundations of peaceful relations between nations.

In the almost 60 years that have passed since the ideas expressed by the American scientists J. Nye and E. Gulion regarding public diplomacy as one of the tools of soft power (although the first actions of a public-diplomatic nature took place in the second half of the 1940s, and the term itself was used for the first time in 1878 (Misiuk et al., 2011)), public diplomacy was understood and is understood in different categories and dimensions (Western scientists J.Nye, E.Gulion, R.Armitage, J.Brown, K.Ross, U.Nills, V.Lippman, S.Anholt, W.Olins; Ukrainian scientists A.Makarenko, O.Kuchmiy, S.Hutsal, I.Matyash, V.Tsivaty, Ya.Turchyn, I.Sukhorolska, P.Sukhorolsky, K.Balabanov, M.Trofimenko, N.Zemzyulina, M.Zakharchenko, O.Vysotsky, etc.). Most scholars define public diplomacy as an international activity aimed at public representation of the interests of states or legitimate institutions (government agencies, non-state communities, organizations and individuals) in international relations (Ukrainian diplomatic encyclopedia, 2004). Complementing classical diplomatic activity with new tools and including in the diplomatic dialogue/ political scientist of the society of countries that communicate with each other, public diplomacy, according to V.Tsivaty, contributes to the promotion of a positive image of the state on the principles of human rights, tolerance, intercultural communication and culture of the world, necessary for general sustainable development and the search for ways of preventive and peaceful resolution of conflicts and wars (Tsyvaty, 2023).

At the same time, American scientists, depending on the subject of measures in public diplomacy, distinguish two main types of it: 1) activities carried out by the state, under its leadership or at public expense within the framework of the state's foreign policy to realize the national interest – public/public diplomacy; 2) activities carried out by various individuals and legal entities, civil society institutions independently of the state in the interests of the state, society or all mankind (civil / public diplomacy, civil diplomacy). Within both directions, the goal is to establish permanent contacts between civil society institutions of different countries, develop international networks and participate in their activities in conditions of weakening state control and creating an atmosphere of trust and equality. In the United States, in particular, according to the concept of citizen / civil diplomacy, every citizen has the right or even the duty to help the state implement foreign policy.

The subjects of such diplomacy can be students, teachers, scientists, athletes, business representatives, etc. – in this way, public interests are lobbied (Misiuk et al., 2011).

The main means of public diplomacy is communication with the target audience. Moreover, the nature of this communication in public diplomacy is specific. This is communication with the foreign public by state and non-state players in order to indirectly influence public opinion and political decision-making processes in the partner country, to prevent the emergence of a civilizational and cultural split between states and peoples. In the system of strategic communications, public diplomacy creates opportunities for interaction by defining the sphere of common interests and creating a space for dialogue at the international level in order to build and strengthen long-term friendly relations between the countries participating in the dialogue, taking into account the traditions and specifics of the development of these countries. The times when all world affairs were resolved only in a narrow circle and secretly are over. Today, thanks to the media, the Internet, social networks, etc., ordinary people in any country of the world can directly observe the most important events in international diplomatic life and influence political processes and political decision. Non-governmental organizations, private corporations, international organizations are becoming active subjects of public diplomacy. In order to effectively achieve its goals, the state actively interacts with representatives of the non-state diplomatic sector. Focusing on relevant strategies in the context of certain areas of public diplomatic activity, British researchers S. Anholt and V. Olins emphasize that a consistent, coordinated and continuous flow of useful, visible, world-class and relevant ideas, products and policies gradually increases the reputation of the country that produces them. One of the effective tools in this context is tourism (Anholt, 2011; Olins, 2005) - a social phenomenon and at the same time a complex dynamic system that includes objects, phenomena, conditions and processes of geographical, economic, organizational, legal, sociocultural, environmental, psychological content related to safe travel and tourist services.

The perception of tourism as a form of social and cultural activity in the sphere of public diplomacy became possible thanks to developments in which social institutions and social groups are considered as independent subjects of international relations (J.Rosenau, R.Keohane, J.Nye, C.Alger, M.Foucault etc).These works laid the foundation for the formation in the early 2000s the concept of non-state-oriented public diplomacy, consisting of many “actors” and networks that interact in a global environment. In this context, in addition to stating the loss of the state's absolute power monopoly in international political processes, the active role of actors "outside sovereignty" is recognized, and television, cinema, music, theater, sports, social networks, tourism, etc. are among the tools for strengthening foreign policy influence. Transparency of national borders, universalization of value orientations, dissemination of new information and communication technologies expand the range of non-state actors capable of communicating with the foreign public, increase the number of actors outside sovereignty, each of which affects the scale and pace of construction of "horizontal bridges", increasing the level of trust in a particular society. According to this approach, world tourist flows represent a global space of socio-cultural interrelations with corresponding economic and foreign policy influences, within which the tourism activity of countries is one of the practices of spreading the value orientations of peoples. Thanks to this, the world becomes interdependent, and mass tourist flows create a special space of social networks, social ties and interactions, the basis for appropriate political decisions and determination of geopolitical influences is formed.

In 1975, in the final act of the conference on security and cooperation in Europe, known as the Helsinki Final Pact of 1975, tourism was defined as a means of promoting international contacts and developing trust between peoples. In 1980, the Manila Declaration of the World Tourism Organization (hereinafter - WTO) declared tourism a factor in peace, moral and intellectual basis for international understanding and cooperation. According to the WTO data, the number of international tourist arrivals during 1950-2015 increased from 25.3 million persons to almost 1.2 billion. Cash receipts from the tourism sector are calculated by trillions of US dollars. In 2017, for example, international tourism mastered 12% of world GDP (Gross Domestic Product), and revenues from tourism, in general, exceeded 1340 billion US dollars. In this context, 2018 was a record year with its 1.7 trillion US dollars. At the same time, the first places in the world in terms of the number of foreign tourists are taken by European countries, in particular, France and Spain. The impressive globality of international tourism is manifested in the steadily growing number of international tourist arrivals, the widespread spatial expansion of tourism, and the formation of world centers of tourist attraction. More than 900 million tourist trips are made per year. Every 15th person in the world is somehow connected with the tourism industry (Parfinenko, 2016; Prokopenko, 2020; Sychova, 2019; Onyshchuk, 2021).

International tourism is at the forefront of global trends. As an activity, it implies the obligatory involvement in the production process of factors of different state affiliation, requires the creation of a unified informational, legal and cultural field. In terms of sustainable development, as pointed out by the WTO, in a global dimension, international tourism contributes to environmental sustainability (guarantees compatibility with tourism development by maintaining basic ecological processes, biological diversity and biological resources), socio-cultural sustainability (ensures development compatible with the culture, identity and life values of the local population), economic sustainability (contributes to the economic efficiency of tourism development and the situation in which the chosen method of resource management ensures the possibility of their use by future generations) (Parfinenko, 2016; Sychova, 2019).

As for Europe, it should be emphasized that during 2009-2022, as the researcher Tsivatiy points out, a new institutional model of public diplomacy of the European Union emerged. In accordance with various variants of its sectoral focus, it allows to ensure comprehensive international cooperation, realizing the EU's potential in various fields - education, science, security and protection of citizens, culture, medicine, sports, ecology and human rights, etc. Public and diplomatic influence on public opinion is exercised to promote the interests of the EU, in particular through interaction with individual citizens, groups, institutions and media in the public European space (Tsyvaty, 2023). This is especially important now, when Ukraine, having obtained the status of a candidate country for EU membership, is fighting for its independence in the confrontation with the Russian aggressor and defending the values of democracy, becoming a shield for European countries. From the point of view of the need to prevent the spread of hostilities on them and promote sustainability in this part of the world, the slogan "Tourism is a passport of peace" is not only questioned but also perceived primarily in the context of intensifying the processes of European integration. The development of international tourism, of course, is one of its effective tools.

In the context of the European sustainability competence framework and the European Green Deal as a catalyst for promoting environmental sustainable development of society, the European Commission has identified certain tasks. According to these tasks, in the field of implementation of sustainable development values, the formation of the following competencies should be promoted:

the value of sustainable development, support for justice, promotion of nature. In the sphere of covering the complexity of the process of sustainable development – respectively, systemic thinking, creative thinking, the formation of problem tasks. In the field of forecasting the future of sustainable development – sustainable literacy training, adaptation process, analytical thinking. In the field of activity on the formation of sustainable development – respectively, political management of the process of forming sustainable development, collective actions of society, personal initiative of each member of society (Green Competences, 2022). Taking into account the above given information, it should be summarized: most of these competencies are formed through international tourism, and the most favorable conditions are created by public-diplomatic interaction within the European space.

Logically, everything that has been mentioned above leads to the fact that Ukrainian tourist destinations of any direction should become links of the relevant pan-European destinations, merge into them, integrating not only from the point of view of proximity in terms of physical space, but also from the point of view of European socio-culturality. Cross-cultural relations in the context of international tourist activity, green tourism and historical and cultural segments as components of this activity, in addition to economic efficiency, contribute to public and diplomatic communications of European countries in general and deeper integration of Ukraine into the European space, being a powerful factor of peaceful relations within its framework, therefore - a factor of sustainable development.

Having accepted refugees from Ukraine, providing the country with humanitarian and military aid, friendly European countries prove by their actions that Ukraine is an integral part of Europe. In view of this, the spread of such measures as implementation of audio guides in the Ukrainian in tourist centers, popularization of Ukrainian culture in the context of pan-European public diplomacy (not only in the context of the purely relevant activities of Ukraine), green tourism within the framework of a pan-European relevant network with inclusion in it Ukrainian regions (in particular, the Carpathians, Black Sea recreation areas, etc.), will contribute to the unification of Europe, strengthening the base of its sustainable development and important public and diplomatic functions. However, because of the importance of such tasks, the process of institutionalizing public diplomacy in Ukraine was started rather late. In 2015–2020 the Department of Public Diplomacy of the Ministry of Foreign Affairs of Ukraine (hereinafter the MFA) was established; Ukrainian Institute; international marketing campaign "Ukraine now", media project "Ukraïner" and other projects. In 2021, the "Strategy of Public Diplomacy of the Ministry of Foreign Affairs of Ukraine for 2021-2025" was published. There public diplomacy is defined as a system of measures through which the state communicates with the public of other states and influences the formation of public opinion of the population of other countries to promote its national interests and realize foreign policy goals. The functions of public diplomacy, respectively, are the establishment of a dialogue "state-to-person" with the consideration of the diversity of national and global audiences, the promotion of interpersonal contacts "person-to-person". The principles of public-diplomatic activity of the MFA of Ukraine are project management, innovation, cultural expansion, people-centricity, sustainability, and strategic goals and objectives, obviously, are the growth of the economy vanity and the best understanding of Ukraine among foreign audiences; to stand by its European and Euro-Atlantic choice; active and successful defence of Ukraine against hybrid threats, disinformation and fakes from the side of the russian federation; active promotion of Ukrainian sovereign identity in the world (Public Diplomacy, 2021).

Taking into account the limited resources, the strategy of "niche" public diplomacy has been determined to be optimal for Ukraine, in the context of which the advantage or niche that the country can fill due to a favorable geographical location, expertise in a certain field or a unique product has the potential to become a useful and creative solution for the world . Such advantages for Ukraine, as determined by its Ministry of Foreign Affairs, are the agricultural potential of Ukraine, the domestic IT sector, as well as the creative potential and experience in countering hybrid threats. For effective communication, paying attention to the target audience, it is recommended to select appropriate tools and formats. Among those defined in this list, the following correspond to the tourism industry, in particular: communication campaigns and projects; ads and advertising campaigns (advertorials); cooperation with media and online platforms with a wide international audience; cultural and scientific exchange of students, scientists, intellectuals and artists; press tours, visits of journalists to Ukraine; participation in world events and leading international exhibitions, fairs, salons, film and art festivals, exhibitions, sports competitions, etc.; cooperation with foreign mass media, journalists, bloggers and opinion leaders; work of cultural centers; publication of books, brochures, catalogs; souvenirs with the identity of Ukraine, etc. However, the defined subjects of public diplomacy are the apparatus of the MFA, foreign diplomatic institutions, and the Ukrainian Institute. Non-state subjects of public diplomacy can also participate in the implementation of the Strategy with the aim of forming a holistic positive image of Ukraine in the world (Public Diplomacy, 2021).

In terms of the functioning of the domestic tourism industry, this completely subordinates its structures to state bodies and narrows the field for public-diplomatic activity in the field of international tourism, therefore, slows down the inclusion of Ukraine in the European processes of sustainable development, although now, on the battlefields and in the rear, Ukrainians courageously defend the values of western democratic world.

Conclusions. The public-diplomatic dimension of international tourist activity is an important factor in promoting the sustainable development of Europe. During 2009–2022, a set of measures of the European Union was implemented in this direction. Having received the status of a candidate country for EU membership, defending the values of Euro-Atlantic civilization and global democracy in the confrontation with the russian aggressor, Ukraine has prospects and must join these pan-European processes. However, this is not fully answered by the Public Diplomacy Strategy of the Ministry of Foreign Affairs of Ukraine, which significantly limits the relevant competencies of the structures of the domestic tourism industry.

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TRANSGLUTAMINASE IN FOOD ADULTERATION AND PERSPECTIVES OF SUSTAINABLE DEVELOPMENT

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Abstract. *Transglutaminase (TGase) is an enzyme which creates isopeptide bonds between side chains of amino acids glutamine and lysine of various proteins, thus forming crosslinks and joining protein molecules together. It is widely used in food industry. In particular, it improves the texture and appearance of e.g. meat products, increases the product weight and extends the shelf life. TGase is also used for replacement of preservatives, emulsifiers, stabilizers, flavors, dyes and sweeteners. Usage of TGases from various sources is regulated by governing bodies and is currently allowed in European countries and in Ukraine. However, utilization of TGases in manufacturing chain is generally not disclosed on the product labels. For instance, food companies prefer to not disclose e.g. that the ham block has been manufactured out of small pieces of meat leftovers using TGase. They charge buyers as if that was the solid section of real meat. Moreover, ordinary consumers generally have little ideas on the processing technology of the food products they buy. Most of the product label information is written in a complicated way using abbreviations. By avoiding decoding and proper explanations, manufacturers try to mislead consumers and avoid responsibility. Furthermore, manufacturers constantly apply tricks to replace food ingredients and use various additives. This may lead to aggravating global problem of food adulteration and falsification. The goal of this paper was to draw attention of various circles of health professionals, regulatory officials and wide public to possible involvement of TGases in our food products.*

Introduction. The famous phrase “We are what we eat” is thought to be first coined by the ancient Greek philosopher and physician Hippocrates. He believed that food plays an important role in human life because it was the source of energy and nutrients (Drees and Barthel, 2022). It is hard to disagree with such statement. However, the current situation on the food market may be not that clear. These days food contains less useful and natural ingredients and more artificial additives due to the constant profit apetites of manufacturers. This is referred to as food product adulteration. Transglutaminase, also known as “meat glue”, has become one of the most valuable instrument for food manufacturers. The natural role of TGases is formation of biological polymers, which are necessary for the body to create barriers and stable structures. Due to the ability of the TGases to form bond between proteins, it can literally glue together meat, seafood, fish and dairy products (Calcaterra et al., 2020). The usage of TGase for industrial applications was fist initiated in Japanese food industry back in 1959 by the company «Ajinomoto» under the trade name Activa. Buckwheat noodles and crab meat were the first products created via TGase. These days the usage of TGases became a lucrative business for the food companies, as products glued together from different pieces or from food industry wastes look just like naturally prepared and sold at a higher price. Currently, this enzyme is widely used and we can often see food products manufactured via its usage on the shelfs of our supermarkets. However, we generally do not realize the involvement of TGases in the processing chain of the product. Moreover, most manufacturers do not indicate the presence of TGase in the detailed chemical composition of their products since this information is not obligatory due to current official requirements.

For instance, widely used and popular in Ukraine "crab sticks" are in fact produced out of leftovers of fish products and have nothing to do with crabs. Moreover, transglutaminase is used in so called "molecular cuisine" restaurants with non-traditional dishes. Combination of soy isolate with transglutaminase improves the passage of probiotics and prebiotics through the stomach to the lower intestines (Yew et al., 2011). It is widely believed, at least by food companies, that transglutaminase is completely safe for the consumers. However, given the catalytic properties of the enzyme and its ability to form isopeptide bonds between proteins, it is possible that TGases in food products can affect health and well being of the consumers even in marginal quantities. Consequently, we become increasingly dependent on consumption of low quality food ingredients as they become a substantial part of our diet under false believe that they were the high quality products.

We set up a project to estimate how widespread the TGase usage is in the Ukrainian food industry and whether manufacturers always inform consumers about the presence of TGases in their products.

TGase is used not only in food processing chain. It is utilized e.g. in drug development and to increase synergistic activity and bioavailability of probiotics. The TGases used in food industry are mostly obtained from plants and microorganisms of the family *Streptomyces spp* (Vasić et al., 2023). The bacterial enzyme is calcium-independent and it is widely used in food industry. Another example of TGase is coagulation factor XIII (fibrin-stabilizing factor). It is activated by thrombin and makes crosslinks between polymer fibers of fibrin, leading to stabilization of blood clot. This TGase is normally extracted from blood of cows, chickens and pigs.

The main advantages which food producers get by using the TGase enzyme from the point of view of the producers of this supplement (https://cpt.in.ua/ua/catalog/transglyutaminaza/) are the following:

- improved consistency of food products;
- increased juiciness and elasticity of products;
- raise in the output of final products;
- ensure stable quality;
- reduction in moisture loss especially during storage;
- minimal quantities of enzyme required for processing chain due to high enzymatic activity of the additive.

The most used in food industry variant of transglutaminase these days is microbial transglutaminase (mTGase) obtained from the bacteria *Streptoverticillium moboarense*. It is considered safer than the TGases from other sources. It has higher binding properties than TGases from blood plasma and other alternative sources. This feature has positive effect on the functional biocatalytic properties of the enzyme, and enables to efficiently modify proteins in food products at the molecular level. As a result, usage of mTGase has a positive impact on important physicochemical properties of food proteins (hydrophobicity, gelation, etc.). Therefore, it is used in food industry to reduces a large number of other ingredients in recipes, such as carrageenans, gums, phosphates, emulsifiers, etc. (Yew et al., 2011).

Application of transglutaminase in various branches of food industry in Ukraine

Meat industry. TGase is used to process meat derived ingredients from various sources, including muscles, cartilages, blood serum, intestines, tissues from various organs, etc. These mixtures can be combined with vegetable proteins, milk, muscular (myoglobin) proteins, or collagen protein. As it was stated above, transglutaminase is a biocatalyst that ensures formation of the protein bonds due to cross-links between amino acids, namely lysine and glutamine, and therefore can form solid blocks of meat products which resemble the natural meat. It is widely used in production of e.g. ham and sausages. The techniques which utilize TGases can be so advanced that the meat industry is able to produce a solid piece of meat which is difficult to distinguish from the real meat. Technically, the TGases contribute to formation of a protein mesh structure between the cells of which moisture and fat are retained. For this, a certain concentration of the protein is required. It is estimated that for efficient protein-protein crosslinking the total concentration of proteins in the processed row materials should be at least 12% in the mixture. The nature of the protein generally does not have substantial influence on the ability of TGase to form crosslinks. Often TGase is used for gluing small pieces of meat into one bigger block to give it a shape of a natural solid piece of meat, as shown in Fig. 1. In this figure a ham bought from a supermarket in Ukraine was sliced and left in the refrigerator overnight. During this time, the pieces of meat developed areas of different colors. We assumed that this ham block was produced by gluing smaller pieces of low quality meat by using transglutaminase. The label of that ham package did not contain any indication of using TGases for in the processing chain of the product. Fig. 2 shows typical product obtained via crosslinking activity of TGases, namely “crab sticks”. The label on the product did not contain any indication on the usage of TGases in processing chain and neither it clearly indicated source of the ingredients used in manufacturing the product. However, the simple comparison of the size of the “crab sticks” with real crabs which we could have seen in nature does not support the idea that these “crab sticks” could theoretically be produced out of solid crab pieces. Moreover, the price of the product does not support the idea that the final product was produced using crab derived ingredients.

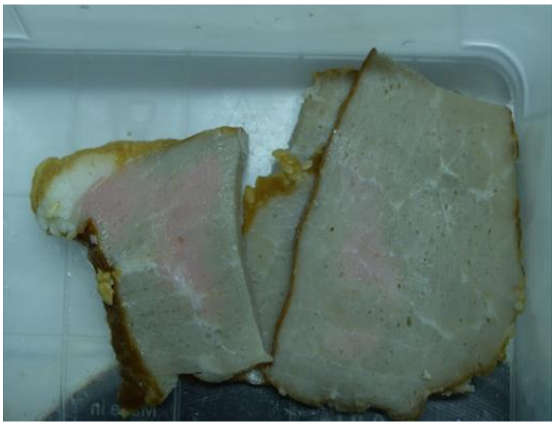

Fig. 1. This ham block was most probably manufactured from small pieces of meat from various source glued together by transglutaminase.

Fig. 2. This product, so called "crab sticks", was most probably produced from fish wastes via transglutaminase.

Dairy industry. Milk proteins have been the subject of extensive research and are considered one of the most extensively studied protein complexes found in food. They exhibit a diverse range of functionalities and play important roles in various aspects of food science and technology. Individual milk proteins, such as caseins and whey proteins, have unique properties that contribute to their functional capabilities in food formulations. Transglutaminase is often used in manufacturing of dairy products to improve texture, increase stability and enhance functionality. It can help create a firmer and smoother texture in dairy products like cheese, yogurt and ice cream. It can also be used to bind different components together, such as in the production of processed cheese or restructured dairy products. It was shown that modification of milk proteins by transglutaminase leads to their partial cross-linking and formation of high molecular weight polymers in the range of 55–200 kDa. Enzymatic modification of milk proteins increases the ethanol stability of both raw milk and pasteurized milk but not thermal stability of the milk (Tarapatskyy M, 2019). Overall, the use of transglutaminase in dairy products offers several advantages. Here are some of the benefits:

1) Improved texture: transglutaminase can enhance the texture and mouthfeel of dairy products by cross-linking proteins. It helps to form a network of proteins, resulting in a smoother and more cohesive texture. This is especially useful in products like cheese, yogurt, and ice cream.

2) Increased stability: transglutaminase improves the stability of dairy products by creating stronger bonds between proteins. This helps to maintain product integrity and prevent separation or syneresis. It can improve the heat stability of dairy proteins, making them more resistant to thermal processing.

3) Extended shelf life: the use of transglutaminase can enhance the shelf life of dairy products. It can improve the firmness and reduce the moisture content of products, which inhibits the growth of spoilage microorganisms and extends product freshness.

4) Enhanced functional properties: transglutaminase can improve the functional properties of dairy proteins. It can increase the water-holding capacity, emulsifying properties, and gelation abilities of proteins. This is particularly beneficial in processed dairy products like cheese or yogurts, where these properties are important for product quality and stability.

5) Reduced fat and sodium content: transglutaminase enables the production of dairy products with reduced fat and sodium content. By utilizing transglutaminase, it is possible to create low-fat or reduced-fat dairy products without compromising texture and sensory attributes.

It is however important to note that the use of transglutaminase in dairy products should adhere to regulatory guidelines and labeling requirements to ensure consumer safety and transparency. Moreover, the use of transglutaminase in dairy products should be clearly indicated on the label, especially for individuals with gluten sensitivity or celiac disease, as some forms of transglutaminase are derived from wheat.

Storage of vegetables and fruits. Whey protein modified by TGase in combination with pectin and other ingredients was used in research to create protein film, which could be used for vegetables and fruits to improve their freshness and extend their shelf life (Marquez et al., 2017). One of the most important functions of edible coating is to protect fruits from moisture loss and improve their capability for storage. Moreover, this can help to decrease losses associated with transportation, distribution, and long-term storage on trade shelves. Edible films have been used since 1980. Only 10 vegetable and fruit companies provided such services. Nowadays the use of edible films spreads quickly with ever increasing annual sales exceeding 100,000,000 $ (Tiamiyu et al., 2023).

Baking industry. In baking, transglutaminase can be used to enhance the elasticity and strength of dough. It can improve the dough's handling properties, allowing it to be stretched and shaped more easily. TGase is also useful to retain moisture without loss of mass fraction. The beneficial properties of TGase are extensively exploited in baking industry in the production of bread, pizza dough, and other yeast-based products, as well as in manufacturing of pasta and noodles. The use of TGase brings substantial advantages also to products baked out of frozen dough (Kim et al., 2008). TGase can also be used to create layered or laminated dough. By bonding together layers of dough, it can help create flaky and tender pastries, such as croissants and puff pastry. Another application of transglutaminase in the baking industry is in the production of gluten-free products. Since gluten is responsible for the structure and elasticity in traditional baked goods, gluten-free products often lack these qualities. In gluten-free baking, the absence of gluten can also result in a dense and crumbly texture. Transglutaminase can help to improve the texture and structure of gluten-free dough, especially those which are based on non-gluten species of flour such as rice, buckwheat and corn, making it more similar to traditional baked goods (Diowksz and Sadowska, 2021). TGase is also intensively exploited in development of new varieties of protein rich and allergen free bread such as soy bread (Hutasoit, 2012). Overall, use of TGases can lead to improved texture and a more enjoyable eating experience for individuals on a gluten-free diet. It is worth noting that the use of transglutaminase in the baking industry is subject to various types of regulations and guidelines in various countries. It is important for bakers to follow the recommended usage levels and ensure that they comply with any labeling requirements related to the use of transglutaminase in their products.

Public awareness. Generally, ordinary consumers are mostly unaware that they consume products containing TGases. We set out to investigate how widespread TGases are in the Ukrainian food industry and whether manufacturers always inform consumers about the presence of TGases presence in their products.

It is important to note, that by solely organoleptic studies, which involve standard methods of evaluating the product quality using the senses, it is difficult to establish the presence of TGases in cheese, milk, yogurt, etc. As to the safety of the products manufactured via use of TGase, the most investigators conclude that TGases have no unwanted side effects. However, increasingly more information is emerging about the occurrence of diseases caused by excessive consumption of recently emerged products. Thus, serological markers of microbial and tissue TGases have been detected. They can bind gliadin with the formation of antibodies to TGase, which is known as being involved in celiac disease (Torsten and Aaron, 2018; Agardh, 2020).

It is the microbial transglutaminase that is still most often used in the food industry as it was in the early days of its usage (De Jong and Koppelman, 2002; Lerner and Benzvi, 2021). It was reported that mTGase can potentially suppress the body's defense mechanisms and mimic other types of human transglutaminase, which might cause chronic human diseases. It was assumed that food additives such as transglutaminase extensively used in the food products is one of the major environmental factors for induction of autoimmune diseases. Thus, TGases can increase intestinal permeability through the opened tight junctions, resulting in entry of foreign immunogenic antigens and activation of the autoimmune cascade. Similar evidences were reported to increase the intestinal permeability TGases (Amirdivani, 2018). It was stated that TGases might represent a new environmental inducer of celiac disease (Aaron and Torsten, 2019). Moreover, TGases can be immunogenic in celiac patients and thus can trigger abnormal immune responses. That leads to the load increase on the intestinal lumen of the immune system (Matthias et al., 2016). The etiology of these diseases is related to epidermal transglutaminase, which acts as a trigger for epithelium damage. Based on the above adverse effects, regulatory and food safety authorities should review the status of transglutaminase. Food must be labeled and carefully evaluated for toxicity and health safety. Currently, there is no clear information on product labels which type of TGase was used for food manufacturing. Moreover, in Ukraine most of information on product labels is written in a complicated and incomprehensible manner for ordinary consumers. This is one way for the manufacturers avoid responsibility. According to regulations in many EU countries, food manufacturers are obliged to provide a detailed information about composition of their products, so that consumers can make the reasonable informed decisions to consume the products or avoid them. Therefore, the EU consumers are generally protected from potential unscrupulous actions of market operators. One form of "meat glue" was banned in Europe, namely the combination of thrombin and fibrinogen, both of which are obtained from the serum of animals (European Parliament, 2010). The binding properties of this additive however is different from mechanism of TGase, as it works via polymerization of fibrin molecules after thrombin activates fibrinogen and transfers it to fibrin. In addition, European Parliament stated that Commission Directive itself recognized that the use of "meat glue" (from thrombin and fibrinogen in this case) as a food additive could mislead the consumer as to the state of the final food, taking into account that the purpose of this additive was to bind individual pieces of meat to obtain a single meat product (European Parliament, 2009). Therefore, the risk of misleading consumers is obvious (Deweid et al., 2019). It is of note that the sole purpose of the use of TGase in meat processing industry does not differ from the use of the banned "meat glue" based on thrombin and fibrinogen.

64 years have passed since the isolation of TGase. During this period, a massive of different information was found about positive and negative consequences of its usage for human health. It is now clear that TGases are able to cross-link proteins and other macromolecules, changing their structure, composition, antigenicity, physical and chemical characteristics. There is also data supporting cautious approach towards wide usage of TGases, as they can manifest themselves as the causes of allergic reactions, poisoning, malabsorption syndrome, problems with the pancreas, etc.

It is still preliminary to draw a firm conclusion about positive or negative effects of transglutaminase as a food additive. Careful and thorough investigation of the role and consequences of the use of TGases in technological food chains is still largely required in European countries and in Ukraine.

Conclusion: Without any doubt, the use of transglutaminase in the food industry brings many advantages. It improves organoleptic indicators, increases effectiveness of food production, promotes creation of the new products and increases profitability of food producers. It is still allowed in Ukraine and other European countries as a replacement of preservatives, emulsifiers, stabilizers, flavors, dyes and sweeteners. On the other hand, there is increasing amount of data supporting involvement of TGases in pathogenesis of many diseases. To this, it is still not clear whether the technological approach to create higher value products out of low quality ingredients is ethically acceptable and feasible in terms of requirements for sustainable development. Moreover, a thorough public discussion is still needed to figure out if this could be regarded as a counterfeit product when the new technology allows to glue together pieces of meat wastes to make it look like a natural piece of meat and sold at a higher price. However, it is clear that ordinary consumers should have chances to be informed about what they buy and consume.

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EUROPEAN STUDIES FOR SUSTAINABLE DEVELOPMENT

SUSTAINABLE ENVIRONMENTAL LEARNING IN THE EFL CLASSROOM

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Abstract. *This paper identifies major current trends in teaching environmental issues in the EFL classroom and presents a suitable methodology for facilitating sustainable development instruction at higher educational institutions with the participation of university teachers of English as a foreign language. Based on the experience of EFL instructors of the National University of Food Technologies, Ukraine, it analyses the most effective methods and teaching strategies as they emerge from both disciplinary and interdisciplinary curricula. A variety of practically-oriented tools, such as questionaries, discussions, individual and group projects investigating the human impact on the environment, develop problem-solving and collaboration skills of learners; foster critical and systems thinking; motivate to act responsibly in regard to the environment. To this end, students learn how to use and analyze scientific information available in a digital environment. Particular consideration is given to an integrative approach which broadens educational opportunities through the collaboration of experts from different fields, including English faculty. It is emphasized that individual and collective experiences in various learning contexts help university students develop their understanding of ecosystems and foster their civic engagement in response to environmental problems. The paper also discusses English faculty's contributions to environmental studies in academic settings in Ukraine and discusses the challenges which they face in the education process.*

Introduction. Ukrainian educators have been constantly introducing changes to curricula, methods and strategies of training students in line with the European environmental policies and recommendations. Sharing the European Union's goals for sustainable development, Ukrainian universities aim at preparing young professionals to profound environmental, economic and social changes by creating the system of interconnected learning with emphasis on the environmental part (Council Recommendation, 2022). On the way to a greener Europe, universities assume leadership in building a close network of professionals, representing learners, businesses, local communities, government and nonprofit organizations. This approach was adopted by the Ukrainian NGO European Studies' Platform for Sustainable Development (EuroStudies Platform) which had been created by leading Ukrainian scholars to facilitate communication between educators who teach sustainability in different fields, particularly, in economics, environmental protection and social/public health. The Platform serves as a legal and information vehicle for all-national Association of Ukrainian professors and researchers in European Studies on sustainability. It provides methodical support to young and experienced professionals, enables interaction with policy makers and civic servants, advances interdisciplinary research through its scientific publications and regular events (conferences, meetings, seminars, workshops etc.).

The English department's faculty of the National University of Food Technologies address the EU recommendations by promoting pro-sustainable practices, developing life-long competencies ensuring not only personal well-being, but also meaningful contributions to the society "in a time of rapid and profound change" (Council Recommendation, 2018). In this respect, the importance of sustainable pedagogy is undeniable. It is defined as "learning at the point of need" Woolis (2018). Facilitating deep learning at the individual and systems levels, the sustainable approach to education makes it possible to connect rigorous academic content with practice. The sustainability-based communities create an entirely new working environment in which students have access to resources, support, peer learning, and collaboration anywhere and anytime. Employing "methods and approaches that are collaborative, experiential, practically oriented … and support interdisciplinary and cross-curricular activities", English faculty can prepare students for participation in international projects requiring English proficiency and specific skills to respond to global challenges (Council Recommendation, 2022).

Materials and methods. This paper aims at identifying the current trends in teaching environmental issues in EFL classrooms and presenting a suitable methodology to facilitate sustainable development instruction at higher educational institutions with the participation of university teachers of English as a foreign language. Content analysis of academic sources from various knowledge domains was conducted for a single discipline and in the interdisciplinary context. We use a descriptive approach to familiarize a broader community of scholars with methodological tools employed in teaching environmental content in the EFL courses. Our analysis of literature on integrative learning provides a context for understanding the role that English faculty play in the process of multidisciplinary collaboration. By bringing together research results from different disciplines, we present new perspectives on the development of students' environmental awareness by English faculty in Ukraine.

Since any educational technology requires a close examination before its implementation, collecting information about the latest approaches to environmental studies worldwide and following successful educational projects have considerable relevance to English faculty.

Results and discussion. Based on the contributors' own teaching experiences at the National University of Food Technologies (NUFT), Ukraine and academic research, the article features the topic-led methodologies as they emerge from both disciplinary and interdisciplinary curricula.

Training in the English as a foreign language (EFL) classroom for sustainable development enables students to collect relevant information about the environment in English, to communicate orally and in writing about the planet's urgent problems, and to participate in international projects. Moreover, knowledge of foreign languages provides unique educational experiences not available in a single-discipline format, at a single university, or even in a single country. Nowadays such experiences are gained in Ukraine through collaborative learning facilitated by the Internet.

At the beginning of a course, English faculty can carry out the assessment of students' knowledge acquired at school. A pre-course survey or open-ended questionary serves this purpose. A range of questions regarding global warming, biodiversity conservation, renewable energy sources, and eco-friendly consumption can be selected to learn about students' environmental attitudes, their interests and concerns. The results might serve as a guidance for further educational activities (Tolppanen & Aksela, 2018).

Our teaching experience at the National University of Food Technologies in Ukraine shows that in the first year of their studies, students demonstrate basic ecological literacy sufficient to serve as a focal point for further learning. Freshmen at the intermediate level of English can maintain a conversation about natural and human-caused disasters, climate change, endangered species preservation, and recycling.

Eliciting prior knowledge through surveying, discussing, and doing vocabulary exercises is a reliable tool for identifying the previously learned terminology and introducing a new one: *greenhouse effect, global warming, deforestation, energy consumption, fossil fuels, carbon cycle/footprint/emissions, ozone layer, population growth, natural habitat, engendered species,* etc.

At any stage of classwork, relating the learning material to students' personal life brings positive results, especially when students are engaged in communicative activities. For example, a list of carbon-reducing actions (e.g., *unplugging non-working devices, line-drying clothes, reducing shower time, carpooling*) which students practice and learn about, can be compiled as an outcome of in-class discussions. Ukrainian students come from different socio-economic backgrounds. By sharing information about carbon-reducing actions, students from low-income families can help their better-off peers become more eco-friendly and consume conscientiously. Moreover, due to the differences in their upbringing, students raise various important points that are worth exploring. For instance, city residents often voice concerns about higher temperatures and air pollution, while country dwellers are preoccupied with soil erosion, flooding, electricity shortages, and the impact of climate change on agricultural production (Fischer et al., 2005; Ayanlade & Jegede, 2016). Students' experiential knowledge about climate change can be collected and later disseminated on suitable occasions, such as Earth Day, a Climate Awareness Week, or an Environmental Marathon.

Another way to personalize learning is to discuss climate changes affecting outdoor recreation activities. In particular, Ukrainian students often mention changing seasonal patterns, such as less snow for skiing in winter; atypically high temperatures in summer discouraging from being outside, and devastating floods. Relying on their experiences, learners make their own judgements about the future and realize the necessity of climate action.

Explanatory readings and exercises based on them are suitable for both in-class and home work. Practitioners offer engaging activities that stimulate students' interest and make scientific concepts more understandable. For example, after reading a text on carbon emissions, four small groups of students do a jigsaw puzzle. Each group completes a worksheet on one of four industries: electricity, construction, food, and transportation. Then, an "expert" from each group explains how carbon emissions happen in a particular industry (Goralnik et al., 2019, p. 32). It is crucial to focus on climate change as an energy system issue (Jorgenson et al., 2019) as well as to dispel the misconception that "electricity is somehow "clean" and is not related to global warming (Cordero et al., 2008, p. 869).

Discussions, papers, individual and group projects investigating the human impact on the environment stimulate creativity, problem-solving and decision-making. In a small-group setting, students can discuss the following "policies":

No meat is served at the university canteen.

Have your own cup, food container, and cutlery at the university canteen.

The university canteen does not sell bottled or canned beverages anymore.

An example of creating a future-world vision–to employ backcasting–is given by Mulder (2000). Students are asked to respond to the following questions:

What will the world look like, in about fifty years?

What will the increased number of people need?

What do we need to do nowadays and in the future to contribute to fulfilling those needs?

How can the necessary changes in culture, structure and technology be made? (p. 187).

Such tasks develop an anticipatory or future-thinking competence (Wiek & Kay, 2015) that has recently been advanced in climate change education.

Current news reports delivered by students are a helpful means of building their awareness of environmental problems at local, national, and international levels. The media present conflicting views on climate change which themselves are a good starting point for discussion and further learning.

Writing tasks, in particular, essays and term papers, are intended to stimulate learners' reflective thinking about readings, lectures, podcasts, documentaries etc. as well as engage them cognitively and emotionally (Howell, 2021). It is equally important to create an opportunity for exploring eco-friendly personal choices in quantitative terms. For example, students can calculate their carbon footprints with the help of online calculators. One of them at footprint.wwf.org.uk shows a personal carbon footprint in comparison to the world average and the UK average. In fact, reducing carbon footprint has become a part of universities' environmental strategy worldwide (Valls-Val & Bovea, 2021).

The use of data analysis tools adds an explorative dimension to studying, raises students' concern about the environment, and motivates them to take action on climate change. On the other hand, it helps students understand scientific methods, develops their analytical skill and academic mindsets (Boose, 2014) as well as cultivates social change within universities (Filho et al., 2023). Online resources aggregating various pieces of scientific information (images, numerical data, maps, texts, etc.) facilitate evidence-based learning in the EFL classroom. This type of work should not be neglected because the ability to collect and interpret data is central to the contemporary educational standards (Veron et al., 2016, p. 48).

At the National University of Food Technologies sustainable environmental learning is also employed through co-teaching with experts, represented by scientists and faculty members from other departments. They have the ability and resources to contribute to improving the quality of education. With their assistance, the most complicated environmental issues can be successfully presented to students. Moreover, co-teaching can create a shift from surface learning to deep learning when analysis, synthesis and evaluation are employed (Kelly et al., 2015, p. 51).

Linking different knowledge systems in the educational process requires particular formats. An integrative approach is a tool through which modern educators create various contexts for students to acquire and apply environmental knowledge, to connect to local and global places, as well as to develop a greater understanding of ecosystems (Lowell, 2008). Usually, authentic content from other disciplines is included in a particular course. However, a piecemeal inclusion of scientific concepts might prevent learners from reaching desirable outcomes. Even when environmental knowledge is grounded in multiple areas of the university curriculum, it can still be difficult for students to acquire it. Another way to extend environmental knowledge is invite non-academic stakeholders to give academic lectures, presentations, and reports to students not majoring in science.

To achieve learners' greater understanding of controversial issues (e.g., climate change), coordinating knowledge acquisition across disciplines is considered to be an effective course of action. Such coordination is possible with the help of a paid coordinator (Pharo et al., 2012). For instance, the transacademic interface manager of the School of Sustainability at Arizona State University assists instructors with training teams, establishes relationships with stakeholders, and provides basic project management services (Wiek & Kay, 2015).

Integrative environmental instruction overpasses the traditional modes of learning since a "curriculum embracing education for sustainability requires a broader approach than just discipline knowledge" (Filho et al., 2016, p. 127). For exploring complex real-life problems whose solutions are outside the boundaries of a single discipline, integrative collaborative projects have been implemented in higher education. In their search for an appropriate sustainable framework, university teachers often resort to project-based learning (PBL) or problem-based and project-based learning (PPBL) (Savery, 2006; Chace, 2014; McGibbon & Van Belle, 2015; Filho et al., 2016; Guo et al., 2020). As interdisciplinary coursework, PBL requires curricular transformation in accordance with the tasks of sustainable social, technological, and environmental development. PBL employs active-learning approaches based on both individual and group work supported by expert guidance from instructors or relevant stakeholders.

Individual projects are assigned to students to encourage them to work independently, explore their intellectual and professional potential, and relate to real-life challenges on a personal level by trying different roles (e.g., a researcher, an innovator, a community leader, a civic servant, etc.). In fact, "Project-Based Learning tends to be a group activity with a timeline, milestones and other formative evaluation steps" (McGibbon & Van Belle, 2015, p. 83). It is a learner-centered approach that includes conducting research, applying knowledge and skills to a defined problem, and finding a viable solution in close collaboration with experts in the field (Savery, 2006; Ortiz & Huber-Heim, 2017).

Taking into account the complex nature of environmental issues (Baker et al., 2020) teachers of EFL face a number of challenges, mainly, because the topic of ecology lies outside of their expertise. They might lack confidence in teaching it and, in particular, in answering students' questions (Tolppanen & Aksela, 2018, p. 376). The situation is complicated by the lack of resources supporting interdisciplinary learning (Filho et al., 2016, p. 128). Instead of implementing time-consuming activities, such as interdisciplinary projects, papers, and debates, English instructors might prefer to focus on doing less demanding content-integrating tasks, such as vocabulary building, reading, and answering text-based questions.

Owing to their heavy workloads, university teachers do not have enough time to follow the latest scientific advances and familiarize themselves with the available resources on climate change (Veron et al., 2016, p. 47). Consequently, they might propagate popular views dominant in the media, not caring enough about the scientific accuracy of information. As Gardiner (2004) admits, "the public and political debates surrounding climate change is often simplistic, misleading, and awash with conceptual confusion" (p. 595).

Among the other barriers to a comprehensible and accurate coverage of the topic are a small number of hours allotted to an English course, the lack of time for finding and adapting authentic materials for classes, the need to respond to internal and external pressures, such as educational programs accreditation, the lack of institutional support for environmental learning, and students' language proficiency incompatible with deep content learning.

Despite all the challenges mentioned above, EFL instructors include into their courses environmental content which is supposed to be comprehensively represented across university subjects and disciplines to foster broader understanding of global issues, facilitate students' active civic engagement and provide viable solutions to complex problems. This means that universities need to introduce some organizational changes to educational process reflecting the interdisciplinary nature of the environmental issues under study in curricula and academic research programs (Filho et al., 2023), which is currently not the case neither in a majority of foreign educational establishments nor in Ukrainian ones (Khalaim & Urenje, 2021). A 2020 environmental assessment of Ukrainian education showed that environmental knowledge lacked depth, it was inconsistently structured and distributed throughout different educational levels which were not sufficiently connected (Kharchenko et al., 2020).

To provide sustainable outcomes, some scholars support the idea of training educators in environmental science and sustainability (Fahey et al., 2014; Rosenberg Danery et al., 2015), and call for universities' support for developing knowledge co-production and decision making (Baker et al., 2020) based on "formal and extra-curricular resources for sustainability" (Filho et al., 2016, p. 127).

In Ukraine, the educational standards for English proficiency at higher educational institutions have been risen to ensure that, by 2023, students who enter bachelor's programs know English language at least at the B1 level, the intermediate level in the Common European Framework of Reference developed by the Council of Europe. Since Ukrainian freshmen possess different levels of language proficiency, additional efforts to adapt teaching methods and the content of courses to students' needs are to be made by English faculty. Although the number of students taking specialty courses and defending their bachelor's and master's theses in English has been constantly growing at Ukrainian universities, students still have difficulties in expressing themselves in English and mastering professional discourse, which might impede effective international collaboration.

English faculty–who regularly use communication-based methods for improving students' discourse competencies–can participate in co-teaching and contribute to enhancing the quality of integrated learning by facilitating communication activities. They can share their knowledge of methodology and lessons' design, as well as carry out, in their classes, a number of tasks related to specialized projects with native speakers' participation. English faculty can assist in writing project-related documentation, communicating with international participants, producing information materials for the public, providing translation, and moderating meetings. Such collaboration can be beneficial for both the environmental science faculty and the English faculty, especially when it is properly balanced with their various teaching, research, and administrative duties.

Students at science departments are often overloaded with theoretical content. Solving numerical exercises does not provide them with a good understanding of environmental and engineering problems. Consequently, engineering students have a comparatively weak ability to articulate technical knowledge (Ortega-Sánchez et al., 2018, p. 737). To boost students' communication skills, it is essential to address the need in learning creativity, cognitive flexibility, and adaptability (Gill, 2011, p. 14). For this reason, science faculty resort to methods conventionally employed for developing speaking and presentation skills in English language courses.

Communication-based activities extend the boundaries of theoretical instruction and develop students' ability to express themselves in a foreign language. For example, at the University of Granada, Spain, professional communication is channeled through weekly talks, discussions, and a social network forum. Students in both the bachelor program in civil engineering and the master program in environmental hydraulics improve their communicative and critical thinking skills by giving weekly talks on current engineering news in English. Various aspects of their presentations are evaluated, including the technical content, the non-verbal language, and the audio-visual support (Ortega-Sánchez et al., 2018).

A number of the methods described above have been regularly employed by educators in arts, humanities, and social sciences (McDuff, 2012). The collaboration with colleagues from other departments or with external specialists can help engineering faculty to teach more creatively and streamline communication in the field.

Conclusion. Sustainable environmental learning in the EFL classroom has to be incorporated into a wider educational context provided by faculty members from other academic departments.

The implementation of integrative ecological instruction on all educational levels is a powerful means of developing students' eco-friendly habits, preparing them for environment protection actions in a well-informed and collaborative manner. In the course of students' learning, communicative approaches are of great importance, especially when active learning is guided by practical needs.

The integrative approach aims at higher-level performance which not only provides students with scientific knowledge, but also equips them with a skillset necessary for dealing with environmental issues in the future. Currently, English faculty's role in integrative learning is not sufficiently articulated and is to be explored further.

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THE ENVIRONMENTAL COMPONENT OF THE CONCEPT OF SUSTAINABLE DEVELOPMENT IN THE ACTIVITIES OF INSTITUTIONS OF HIGHER EDUCATION IN UKRAINE

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Abstract. *The article highlights the impact of teaching special educational disciplines on the formation of environmental awareness among students of Ukrainian universities and the importance of this process in the implementation of the goals and objectives of sustainable development of Ukraine. The purpose of the article is to determine the role of the ecological component of sustainable development in the teaching of educational disciplines in institutions of higher education of Ukraine. The scientific novelty lies in the fact that for the first time, based on the analysis of the content of the syllabi of individual academic disciplines taught in Ukrainian universities, the impact of such teaching on the formation of environmental awareness of students of humanitarian and technical specialties and their readiness to implement the tasks of sustainable development of Ukraine has been determined. The research confirmed the connection between teaching environmental disciplines for students and the formation of a sustainable idea about the global problems of humanity. At the same time, most of them have lack of comprehensive idea of the prospects of sustainable development, the content of its components and the specifics of the formation of connections between them. It was determined that the ecological component of the concept of sustainable development is embodied in the teaching of a number of academic disciplines in universities of Ukraine. The majority of students express concern about the facts of environmental pollution and realize their connection with global problems of humanity, worrying about their own safety. In general, the instructors managed to form students' ideas about the global problems of humanity and the prospects for overcoming them, and the level of environmental awareness of the respondents turned out to be relatively high. In this regard, perhaps it would be worthwhile to introduce the teaching discipline "Fundamentals of sustainable development" for students of all majors, replacing it with environmental disciplines.*

Introduction. The concept of sustainable development appeared as a result of the synthesis of economic, social and environmental components. According to the main provisions of the concept of sustainable development, it should ensure the integrity of biological and physical natural systems, and the main attention is paid to preserving the ability of ecosystems to adapt to changes, among which the spread of urbanization is highlighted. In addition, there are concepts of sustainable development, the content of which is often dictated by ideas about the economic interests and needs of each individual country. In such concepts, the provisions of the concept of sustainable development are often distorted in favor of certain political forces or powerful financial and industrial groups. In this case, the term "sustainable development" is mainly associated with the steady growth of economic indicators, the development of certain regions of the country, its settlement structure, and measures to preserve the environment lead to unsystematic actions, a certain improvement of the sanitary living and working conditions of citizens.

It is important for Ukraine that the reconstruction of settlements, production facilities, and transportation routes destroyed during the Russian-Ukrainian war should take place in line with the concept of sustainable development, focused on the ability of future generations to meet their needs. It is known, for example, that the desire to ensure the energy security of the state contributed to the increase in the volume of well drilling focused on the production of shale gas, and the need to increase jobs – to the allocation of land plots for production needs without coordination with local self-government bodies. In this regard, there are risks associated with the fact that the maximization of profits will be achieved, including at the expense of a frivolous attitude to environmental pollution.

In such conditions, the role of institutions of higher education in the formation of a caring attitude towards the environment can be reduced to the formalization of the training of specialists of the relevant profile. To test this hypothesis, a survey was conducted of students for whom disciplines related to nature protection are professional or auxiliary. The comparative analysis made it possible to determine the impact of teaching on the attitude of student youth to environmental protection with the determination of priorities of economic activity, protection of nature and care for future generations. In addition, a comparative analysis of the content of the syllabuses of educational disciplines made it possible to single out the problems to which their authors pay the most attention. The combination of scientific abstraction, sociological, cultural and psychological methods made it possible to find out the place of educational courses related to nature protection in the formation of environmental consciousness of students, as well as the influence of the readiness of the young generation to implement innovative measures in line with the concept of sustainable development.

Historiography. Some aspects of the defined research topic are presented in the papers V. Trehobchuk (Trehobchuk, 2002), E. Libanova (Libanova, 2014), V. Shevchuk (Shevchuk, 2007; Shevchuk, 2010) etc. The authors mainly focused on the analysis of the connection between nature management and environmental security. However, the process of forming the ecological consciousness of the youth of Ukraine still needs careful research and assessment of the prospects for its further modernization.

Aim. The purpose of the study is to determine the role of the ecological component of sustainable development in the teaching of academic disciplines in institutions of higher education of Ukraine.

Methodology. The principles of comprehensiveness and historicism are applied in the work**.** The research uses methods of comparative analysis, as well as scientific abstraction, sociological, cultural and psychological methods.

Results and Discussion. The analysis of the content of the study load of students of Ukrainian institutions of higher education allows us to state that most of the disciplines related to environmental protection are taught during the training in the specialty 101 – Ecology. Institutions of higher education organize the teaching of the academic disciplines "Ecology", "General Ecology", "Biodiversity and Environmental Protection", "Ecology of Urban Systems", "Landscape Ecology", "Protected Affairs", "Techno-Ecology", etc. However, the analysis of the direction of the educational process shows that in some cases the teachers do not set themselves the goal not only to convey to students the main provisions of the concept of sustainable development, but also to influence the formation of environmental awareness.

Thus, the content of the relevant syllabi shows that at the University of Prykarpattia named after Vasyl Stefanyk, the faculty teaches the academic disciplines “Biodiversity Protection” (the goal is the formation of students’ knowledge and skills in the field of conservation and rational use of biodiversity), “Nature Protection and Conservation Affairs” (the purpose of teaching the course: formation of students’ system of knowledge and skills in the field of environmental protection), at the National University of Civil Defense of Ukraine at the Faculty of Technogenic and Environmental Safety – “Organization and Management in Environmental Protection Activities”. The purpose of teaching the last discipline is the professional orientation of ecologists in the field of development and practical use of modern tools of environmental regulation and policy in the conditions of a transition to a market economy, preparation of students to independently solve professional tasks on the basis of holistic ideas about methods of managing environmental activities to ensure stable development of social and ecological systems of the state. The purpose of teaching the course “Biodiversity” at the Lviv National University named after Ivan Franko is the need to expand students’ biogeographical knowledge of biodiversity, to acquaint students with the biodiversity conservation system that exists in Ukraine and the world, as well as the sustainable use of its components.

The discipline “Landscape Ecology” is taught at the National University of Natural Economy and Nature Management. The purpose of teaching is to acquire theoretical knowledge and acquire relevant practical skills regarding the general concepts of the role of landscape ecology in the study of natural reality, assessment and forecasting of the state of geosystems, and in solving practical problems of rational nature management. To acquaint students with the principles of spatial and systemic differentiation of the geographic envelope, the peculiarities of its functioning and dynamics.

At the Bilotserkiv National Agrarian University, the educational discipline “Nature Reserve” is taught, the purpose of which is to provide future specialists with a complex of knowledge on the theoretical and practical basis of nature protection, organization, planning and implementation of nature protection activities, the formation of students in systemic ecological thinking and the skills of making optimal management decisions in the field of nature reserve, the effectiveness of nature protection activities and the balanced management of forestry, hunting and horticulture.

Instead, the purpose of studying the academic discipline “Bioecology”, which is taught at the Vinnytsia National Agrarian University, is the formation of future specialists in the appropriate practical skills and practice of applying knowledge of biology and ecology in everyday life, assessing their role for the sustainable (balanced) development of humanity, science and technology, the formation of students’ ecological outlook, knowledge about the interaction of living organisms, their populations and groups with each other and with the environment, the peculiarities of the functioning of ecosystems of different hierarchical levels under the influence of natural and anthropogenic factors, as well as the ecological foundations of balanced nature management.

The State University of Trade and Economics and Kyiv National University of Economics named after Vadym Hetman pay the most attention to the problems of sustainable development when teaching academic subjects. In general, these universities are characterized by a comprehensive approach to the formation of students’ environmental awareness and their readiness to implement the concept of sustainable development while preserving the balance of its elements.

In a number of Ukrainian universities, the teaching of the study discipline “Fundamentals of Ecology” is organized. The purpose of such teaching is determined, for example, to acquire the knowledge needed in the design of radio-electronic equipment, the selection of ultra-high frequency devices and antennas, the study of electrodynamics and the propagation of radio waves (Separate structural unit “Kryvyi Rih Professional College of the National Aviation University”). In addition, in a number of universities, the discipline “Fundamentals of Ecology” belongs to the elective category. This also applies to some faculties where training is carried out by specialty 101 – Ecology.

In such conditions, when teaching academic disciplines, lecturers are mainly focused on the formation of students not so much environmental awareness, but practical skills related to the profession they are trying to master. Environmental problems are not given priority. Therefore, there are potential risks that students may develop a consumerist attitude towards nature and a lack of ideas about the components of sustainable development. At the same time, it is noticeable that for students of natural sciences, the emphasis in teaching is on the ecological component of sustainable development, and for economics students – on the economic component. Such an approach often leads to the formation of a one-sided view of sustainable development, and therefore does not contribute to the formation of a comprehensive understanding of its features and is not aimed at the formation of environmental awareness.

In the context of this study, for example, the lack of focus on the formation of ideas about the close connection of economic development with natural limitations is cause for concern. Often, such an approach is transformed into a belief in the expediency of ensuring the interests and needs of people living now, not for the benefit of posterity. The threat of meeting one’s own needs at the expense of future generations is especially important in the context of overcoming the devastating consequences of the Russian-Ukrainian war. If such consequences will be overcome on the basis of modern corporate interests of large financial and industrial groups with the indifferent attitude of the majority of citizens, then conditions may be formed in the future that will significantly complicate the sustainable development of the state.

The statement about the existence of difficulties in the formation of environmental consciousness in institutions of higher education of Ukraine is mostly confirmed by the results of a questionnaire survey of students conducted on the basis of the Cherkasy National University named after Bohdan Khmelnytskyi. Of interest are the results of a survey of students of technical and humanitarian specialties, where special disciplines related to the ecological component of the concept of sustainable development are not taught, and of the Educational and Scientific Institute of Natural and Agrarian Sciences, for which the teaching of such educational disciplines is organized.

It should be noted that about 90 % of students of technical specialties (T) and 96 % of students of humanitarian specialties (H) are concerned about problems related to the protection of the natural environment (Figure 1). At the same time, 45 % of students of technical specialties did not participate in activities related to nature protection. Such an indicator among humanitarians is 41 % (Figure 2). Students’ attitude to environmental pollution was most influenced by information about global problems of humanity (T – 56 %; H – 61 %) and warnings about their own health (T – 22 %, H – 13 %). Instead, ideas about the stable development of the state are important for only 4 % of students of technical specialties and for 11 % of humanitarians (Figure 5). Most of the students of both specialties would make remarks to relatives or close people if they harmed nature in one way or another (Figure 3). At the same time, significantly fewer respondents would make such a remark to strangers (Figure 4). The main caution in this case was the fear of the possible use of violence by those who would need to make a remark. At the same time, a relatively large part of the respondents expressed their readiness to independently eliminate the damage to nature, if those who did it did not listen to the relevant remark. Most of the interviewees noted that they often come across facts when, during the discussion of certain problems in social networks, other communication participants do not realize the negative consequences of their actions in relation to nature. In the comments, you could also often find the statement that cleaning in parks and squares does not change much, since most Ukrainian citizens are not aware of environmental pollution.

Technical specialties **Humanitarian specialties** **Educational and Scientific Institute of Natural and Agrarian Sciences**

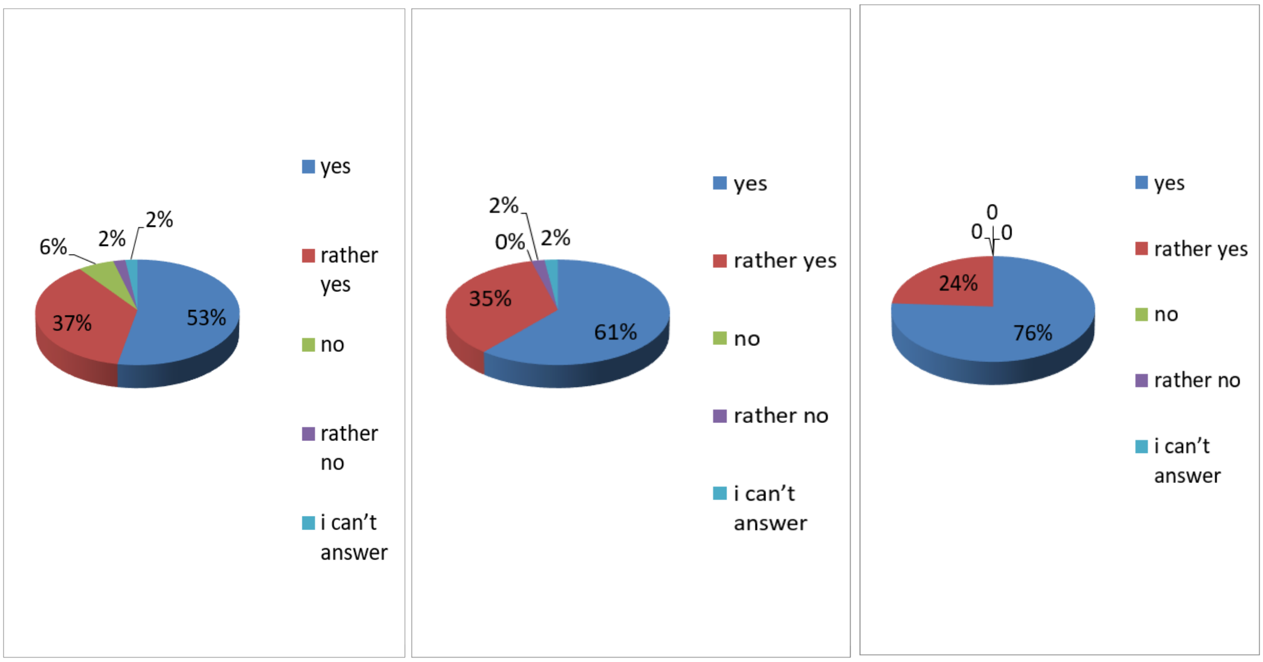

Fig 1. Are you concerned about environmental issues?

Technical specialties **Humanitarian specialties** **Educational and Scientific Institute of Natural and Agrarian Sciences**

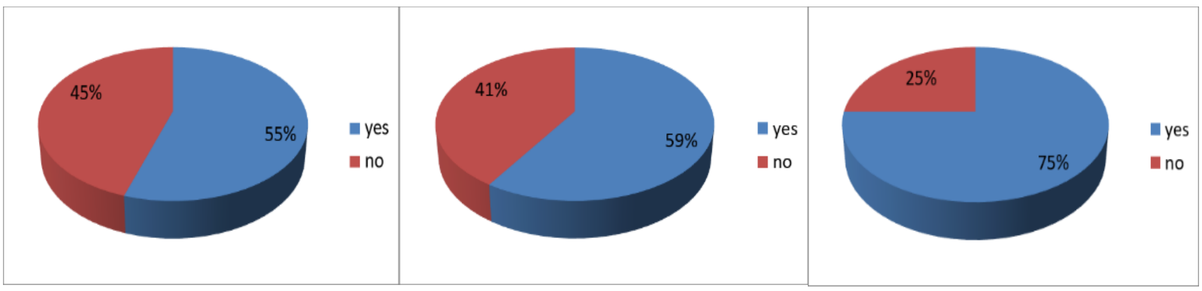

Fig 2. Have you personally participated in activities related to environmental protection?

Technical specialties | Humanitarian specialties | Educational and Scientific Institute of Natural and Agrarian Sciences

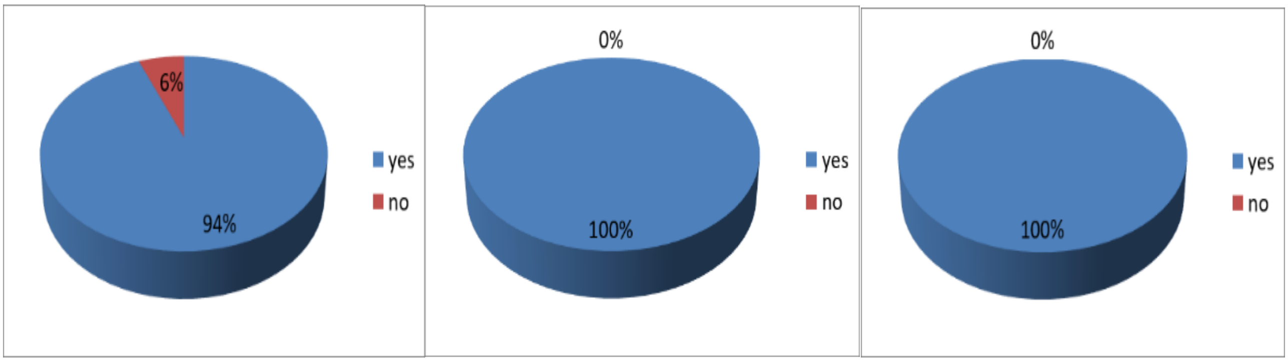

Fig 3. If someone you know was involved in environmental pollution, would you make a remark to him/her?

Technical specialties | Humanitarian specialties | Educational and Scientific Institute of Natural and Agrarian Sciences

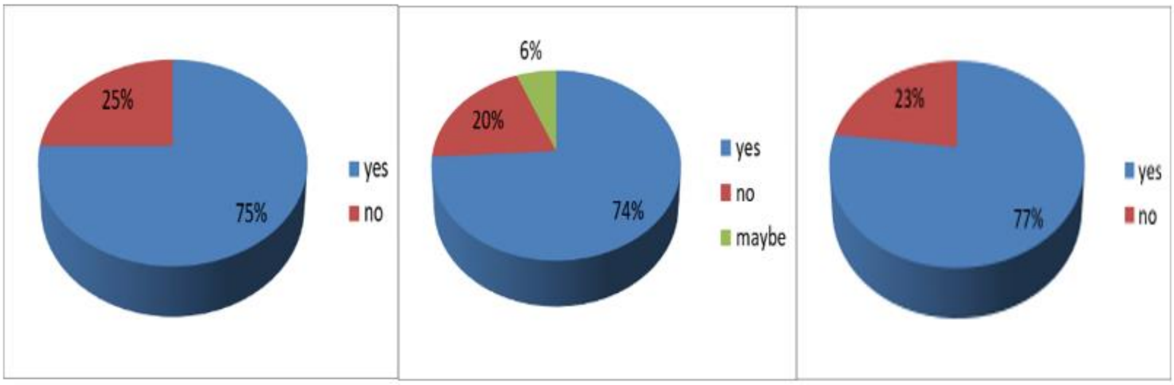

Fig 4. If a bystander was involved in polluting the environment, would you make a remark to him/her?

Technical specialties | Humanitarian specialties | Educational and Scientific Institute of Natural and Agrarian Sciences

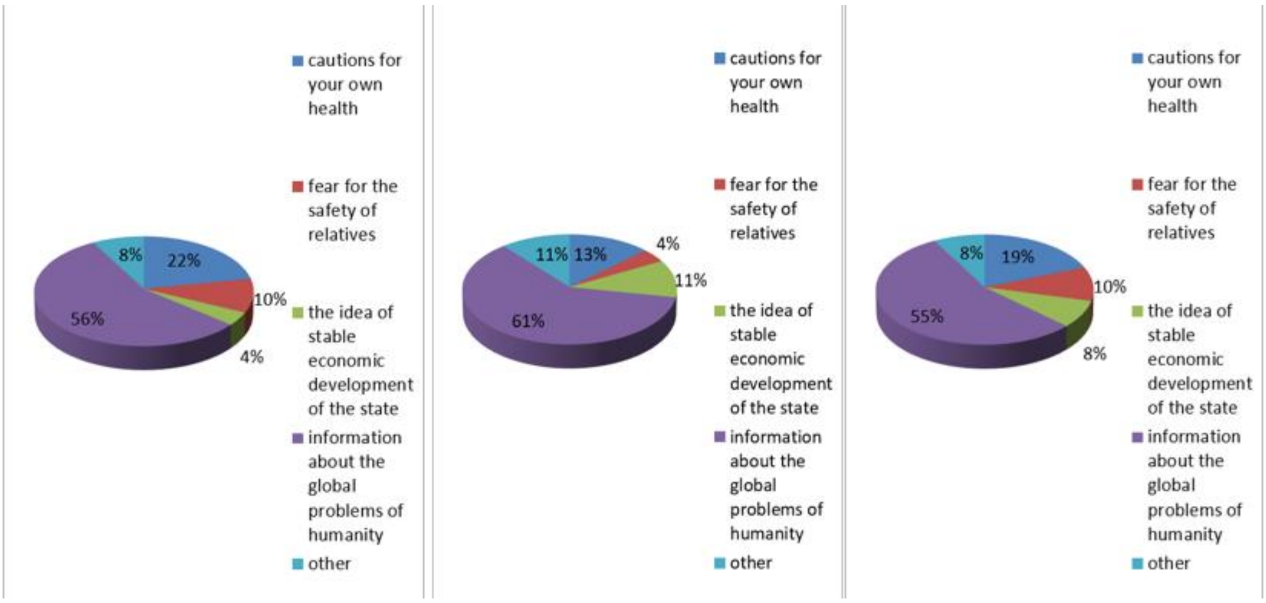

Fig. 5. What had the greatest impact on your attitude to environmental pollution?

Conclusions. The ecological component of the concept of sustainable development is embodied in the teaching of a number of academic disciplines in Ukrainian universities. In some of them, such disciplines are optional. Their priority as compulsory disciplines is more characteristic of economics and natural sciences**.** The results of the survey allow us to note the tendency that the majority of students express concern about the facts of environmental pollution and are aware of their connection with global problems of humanity, worrying about their own safety. The answers and comments of the students of the Educational and Scientific Institute of Natural and Agrarian Sciences testify to their somewhat greater awareness of the current problems of sustainable development. However, the lack of a comprehensive understanding of the prospects of sustainable development is noticeable, as most students associate it mainly with its ecological component. Thus, lecturers generally managed to form students' ideas about the global problems of mankind and the prospects for overcoming them, and the level of environmental awareness of the respondents turned out to be relatively high. But most of them lack a comprehensive idea of the prospects of sustainable development. In connection with this, perhaps it would be worthwhile to introduce for students of all specialties the teaching of the educational discipline "Fundamentals of sustainable development" with the replacement of its ecologically oriented disciplines.

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NEW TECHNOLOGIES FOR THE SUSTAINABLE DEVELOPMENT

DEVELOPMENT OF THE METHOD OF OBTAINING GRAIN FLAKES USING UV-IRRADIATION

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Abstract. *The method of obtaining flakes of increased biological value from grain crops has been developed. This method includes preparation of grain for processing, which involves cleaning grain from impurities, sorting, airing, separation of ferromagnetic impurities, washing and disinfection, peeling, hydrothermal treatment at a temperature of 12 - 16° C. Hydrothermal treatment takes place in three cycles, each of which involves intensive moistening of the grain for 4 hours followed by dehydration for 4-6 hours with a total duration of 26 - 30 hours. After the first cycle, the grain is treated with ultraviolet radiation with constant stirring. The thickness of the grain layer is 15 - 20 cm. The wavelength of ultraviolet radiation 250 - 300 nm; radiation intensity is 200 - 260 W/m^2. The distance from the grain placement plane to the radiation source is 25 - 30 cm, process duration 55 - 60 sec. The next stage is flattening of raw materials, drying of the flakes at a temperature of 45 - 65° C to a moisture of 12 - 14%, airing, packing.*

The main physico-chemical and organoleptic indicators of quality of wheat flakes of increased biological value are investigated. The nutritional value of the product is determined. It was investigated that the microbiological seedability of wheat flakes does not exceed the permissible values. Storage for 6 months does not significantly impair quality.

The developed method of processing cereals for producing flakes allows to obtain a product with high biological value, namely, an increased content of water-soluble and fat-soluble vitamins, in particular, the content of vitamin E is 8.5 mg%, B_1 - 1.12 mg%, B_2 - 1.15 mg%; content of food fibers, which are natural food sorbents - 2.5%.

Introduction. One of the leading branches of the agro-industrial complex of Ukraine is the grain processing industry, the urgent issue of which is the improvement of existing and the development of new methods for the preparation of grain materials for the production of food products, in particular, increased biological value.

Currently, there are a large number of ways for processing cereals, which are characterized by certain advantages and disadvantages. It is worth noting that methods that would contribute to the maximum preservation and accumulation of biologically active grain compounds are quite small.

One of the promising ways of improving the quality of raw materials is the use of physical methods of exposure, in particular UV-irradiation. Ultraviolet radiation treatment is used in pre-sowing treatment of grain and seeds of agricultural crops in order to reduce the influence of phytopathogenic microflora, stimulate the processes of seed life, create environmental prerequisites for plant protection during the growing season.

In the process of processing with ultraviolet radiation, the absorption of photons by matter occurs. Energy conversion in biological objects occurs in stages: absorption of a photon by a molecule and transfer of energy to another molecule. One form of conversion of absorbed energy of optical radiation is photobiological action - change of biological state of structures of living organism. Thus, when treated with ultraviolet radiation, intracellular metabolic processes are activated both in the grain and in the seedling. Short-term treatment with wave ultraviolet radiation increases the indicators of the physiological fullness of grain, such as energy and the ability to germinate, germ viability by 10 - 15%, which leads to activation of synthesis of biologically active compounds - vitamins, vitamin-like substances, etc. In addition, ultraviolet radiation treatment contributes to a significant decrease in the level of external and internal phytopathogenic microflora, provides disinfection of grain, increases consumer qualities and shelf life of cereal processing products.

UV-irradiation of grain for 5 - 6 hours using a wavelength of 254 nm can serve as an ecological friendly and safe method of sterilization, relative to the microbiological purity of raw materials (Hidaka et al., 2006).

A number of authors who investigated the effect of UV-irradiation of wheat grain on its sowing qualities using mercury-quartz lamps or other emitters note the activation of the antioxidant system of grain under the action of physical influence, as well as an increase in the ability to germinate (Araújo, et al., 2016; Wang et al., 2012).

Scientists have studied that UV-irradiation with doses of 120 J/м^2 of rapeseed seeds increases the germination energy by 15%, compared to control samples; increased hydration of raw materials was also noted (Semenov, et al., 2021). It is noted that treatment with ultraviolet radiation for 5-60 minutes of seeds of peanuts and mung beans contributes to the improvement of growth parameters (Siddiqui A. et al., 2011).

UV radiation treatment is proposed by scientists as an ecological technology for changing the characteristics of wheat flour. It is noted that irradiation of wheat flour with UV-C radiation (254 nm) of different radiation power and exposure time affects the change in physical and chemical properties (water-binding capacity, content of amylose, reducing sugar, sulfhydryl (SH), disulfide (SS) groups (Kumar A. et al., 2020).

It has been investigated that UV treatment of raw materials causes the accumulation of phytochemicals, including ascorbic acid, carotenoids, glucosinolates and phenolic compounds (Darré M. et al., 2020). Among UV-C ranges, light at 253.7 nm is recognized as an effective and safe technology for food disinfection (Monteiro M.L.G. et al., 2022) it is the most effective against microorganisms, since at this wavelength the highest absorption of light by microbial nucleic acids occurs (Koutchma T., 2019).

In the literature there is no data on the possibility of producing flakes based on biologically activated wheat grain using UV-irradiation of grain.

Materials and Methods. The purpose of our work was the scientific and practical substantiation of the method of producing flakes of increased nutritional value based on grain crops, which involves the use of UV-irradiation of grain in the process of its biological activation.

To achieve the goal, it was set to solve the following tasks:

- to develop and scientifically substantiate a method for producing flakes of increased biological value;
- to investigate the influence of the processing mode on the content of vitamins in the grain;
- research the main quality indicators of wheat flakes;
- to investigate indicators of microbiological stability of flakes;
- determine the nutritional value of wheat flakes.

During experimental studies, wheat grains, varieties Odeska 267, harvests 2021 were used; produced samples of flakes. The moisture of the test samples was determined by drying to a constant mass at a temperature of 105°C. Protein content was determined by Bradford, starch by polarimetric method. Fat was determined by exhaustive extraction with chemically pure hexane. Vitamin E is determined colorimetrically; B_1, B_2 – fluorometrically; fiber – by acid hydrolysis. Vitamin C was determined by titrometric method. The method is based on the extraction of vitamin C from the test sample with a solution of acid (hydrochloric, metaphosphoric or a mixture of acetic and metaphosphoric), followed by titration visually or potentiometrically with a solution of 2,6-dichlorophenolindophenolate sodium.

The wavelength of ultraviolet radiation characterizes the active factor. Three regions can be distinguished from the biological activity of ultraviolet radiation: UV-A (380 - 315 nm) - it has relatively little biological activity; UV-B (315-280 nm) - has a stronger effect on biological objects; UV-C (280 - 100 nm) - harmful effect on humans and plants (Bjorn L.O., 2015). Therefore, the ultraviolet wavelength 320 - 290 nm is selected for processing the grain mass in the proposed method, such an effect provides the desired effect.

Treatment with ultraviolet radiation of native dry grain with a moisture of 10 - 14%, in which biological processes are not active, is not advisable to increase its biological value, in particular, the content of vitamins and vitamin-like substances. In the grain, which is hydrothermal treatment at low temperature conditions, enzymatic processes are activated, which stimulate the synthesis of biologically active substances, ultraviolet radiation treatment significantly intensifies these processes. Therefore, for the efficiency of ultraviolet radiation treatment, the grain is pre-intensively moistened to the moisture of the 18 - 24%.

Microbiological indicators of the mixture of flakes were determined in finished samples, the moisture of which was 11 - 12%. To this end, the test samples were seeded superficially on agarized nutrient media: meat-peptone agar (detection of mesophilic aerobic and facultative anaerobic microorganisms - MAFAnM), wort-agar (yeast and fungi). Plates with crops were incubated for 2 - 3 days at a temperature of 37°C to set the total amount of m/o (MAFAnM). Cultures on plates with wort-agar medium for detection of fungi and yeast were incubated at a temperature of 28°C for 5 - 7 days.

Object and subject of research. The object of research is a method of obtaining flakes of health-improving purpose from wheat grain. The subject of the study is the content of vitamins in wheat grain prepared according to the proposed method; nutritional value and microbiological indicators of flakes.

Results and Discussion. We have proposed a method of obtaining flakes of increased biological value from wheat grain. The initial stage includes grain preparation for processing, which involves cleaning the grain from impurities, sorting, airing, separation of ferromagnetic impurities, washing and disinfection. Next, the grain husking process is carried out. The next stage is hydrothermal treatment of the prepared raw materials at a temperature of 12 - 16ºC in three cycles, each of which involves intensive moistening of the grain for 4 hours with subsequent dehydration for 4 - 6 hours followed by dehumidification with a total duration of 18 - 30 hours. Due to the activation of the enzyme complex, biological changes occur in the grain structure, it begins to germinate, is in the so-called "awakened state", the grain is biologically activated.

After the first cycle, the grain is treated with ultraviolet radiation with constant stirring, grain layer thickness 15 - 20 cm, ultraviolet radiation wavelength 250 - 300 nm; radiation intensity 200 -

260 W/м^2, distance from grain placement plane to the radiation source 25 - 30 cm, process duration 55 - 60 sec.; flattening, drying flakes at a temperature of 40 - 45° C to a moisture of 12 - 14%, airing, packing.

The intended process of grain peeling provides for the use of this method for film crops - oats, barley, rye, millet, buckwheat, etc.

The effect of biological activation, which is combined with UV irradiation, on the content of vitamins in wheat grain, was investigated, Table 1.

Table 1.

Effect of treatment regimen on vitamin content in wheat grain

№	Grain moisture, after hydrothermal treatment, %	Distance from grain to irradiation source, cm	Vitamin content in wheat grain, (mg%) after hydrothermal treatment and ultraviolet radiation treatment				Conclusions
			C	B_1	B_2	E	
1	12.2±0.4 Control (native grain)	20	2.52± 0.14	0.22± 0.01	0.12± 0.02	0.32± 0.03	A small increase in vitamins, compared to the initial amount.
2	18.3±0.1	25	4.25± 0.03	0.70± 0.01	0.65± 0.01	9.85± 0.01	The content of vitamins in the grain after processing increased 1.5 - 3 times, vitamin E - 30 times compared to the initial amount.
3	20.5±0.3	28	6.20± 0.04	0.93± 0.01	1.01± 0.02	11.5± 0.04	The content of water-soluble vitamins in the grain after hydrothermal treatment increased by 2 - 4 times, vitamin E - 35 times compared to the initial amount.
4	24.3±0.2	30	6.00± 0.03	1.12± 0.01	1.15± 0.01	12.30 ±0.02	The content of water-soluble vitamins in the grain after hydrothermal treatment increased by 2 - 4 times, vitamin E - by 38 times compared to the initial amount.
5	30.6±0.5	35	4.00± 0.06	0.80± 0.03	0.85± 0.01	10.20 ±0.06	Decrease in vitamin content

Thus, the proposed method of processing cereal crops on a flake allows to increase the biological value of the grain, in particular the content of vitamins, and, accordingly, the consumer qualities of flakes from it.

It has been experimentally established that ultraviolet irradiation of grain, which underwent preliminary intensive moistening for 4 hours and dehydration for 4 - 6 hours, stimulates physiological indicators, in particular energy and germination ability, viability of the embryo, intensifies the processes of synthesis of vitamins and vitamin-like substances in the grain. It has been found that irradiation of the grain for longer than 60 seconds is undesirable due to excessive overheating of the grain, which negatively affects the biological activation process. Thus, with ultraviolet irradiation 70 - 80 seconds indicators of physiological value of grain are reduced by 15 -20%, with the effect of ultraviolet irradiation 80 - 100 seconds - by 25 - 30%. It has been investigated that the optimal duration of the ultraviolet radiation treatment process is 55 - 60 seconds.

The optimal distance from the grain placement plane to the infrared radiation source is 25-30 cm, (Table 1). At the same time, the wavelength of ultraviolet radiation is 250-300 nm; radiation intensity – 200 - 260 W/m^2. Under such influence, the desired effect of increasing the physiological fullness of the grain is achieved, as well as intensification of the synthesis of vitamins and vitamin-like compounds; that is, higher power is impractical, energy consumption increases.

Experimentally, it was found that for uniform treatment with ultraviolet irradiation with constant mixing of the entire grain mass, the thickness of the grain layer should not exceed 15 - 20 cm.

Under laboratory conditions, an experimental batch of flakes of increased biological value from wheat grain was produced according to the developed method.

The main physical and technological indicators of wheat flakes quality are determined (Table 2).

Table 2

Physical and technological quality indicators of wheat flakes

№	Indicator	Wheat flakes
1	Moisture, %	11.5±0.3
2	Volumetric mass, g/cm^3	441.5±0.3
3	Average particle size, mm	6.3±0.1
4	Angle of natural inclination, deg	65.5±0.2
5	Sliding angle on metal, deg	18.5±0.3
6	Actual density, g/cm^3	462.3±0.2
7	Cohesiveness	1.4±0.1

Wheat flakes have a permissible moisture value. The average particle size of the flakes depends on the grain size and is within the range acceptable for grain-based foods. Values of volumetric mass and actual density indicate the high quality of this grain product. Optimal values of cohesiveness of wheat flakes characterize their ability to move freely during unloading from containers and during transportation.

The organoleptic indicators of the quality of wheat flakes of increased biological value were investigated, Table 3.

Table 3

Organoleptic indicators of wheat flakes

Indicator	Received data
Appearance of flakes	Oval-shaped flattened grains up to 1.2 mm thick
Color	Creamy white
Taste and smell	Inherent in wheat cereals without an extraneous taste and smell and signs of musty and mold
Consistency after cooking	The grains are completely swollen, well boiled, and stick together a little
Taste and smell after cooking	Inherent in wheat grain processing products without an extraneous taste and smell

It has been experimentally established that cereal flakes of increased biological value have acceptable organoleptic indicators, which makes it possible to predict consumers' demand for these products.

The nutritional value of wheat flakes obtained according to the developed method was studied (Table 4).

Table 4.

Characteristics of the nutritional value of wheat flakes

Product sample	Energetic substances,%			Dietary fiber,%	Vitamin content, mg%			Energy value, kcal
	Proteins	Fat	Carbo-hydrates		E	B_1	B_2	
Wheat flakes	12.8 ±0.3	1.5 ±0.1	68,5 ±0.3	2.52 ±0.06	8.54 ±0.02	1.12 ±0.01	1.15 ± 0.03	338

The developed method of processing cereals for production of flakes allows to obtain a product with high biological value, namely, increased content of water-soluble and fat-soluble vitamins and vitamin-like compounds, minerals, dietary fibers, in terms of the content of the main energy-generating substances, wheat flakes are not inferior to traditional grain products.

We investigated the microbiological resistance indicators of wheat grain flakes prepared according to the developed method. Fresh dried flakes were used for determination, as well as those stored for 6 months, Table 5.

Table 5.

Microbiological indicators of wheat flakes produced according to the developed method

Microbiological indicators	Cereal flakes, normative value	Wheat flakes after drying	Wheat flakes after storage for 6 months
MAFAnM, KFU/g, no more	$5 \cdot 10^4$	$1 \cdot 10^2$	$5 \cdot 10^2$
Molds fungi, KFU/g, not more	$1 \cdot 10^3$	Not found	Not found
Pathogenic microorganisms, including bacteria of the genus *Salmonella*, in 25 g	Not allowed	Not found	Not found
Bacteria of the group of *E. coli (coliforms*), in 0.1 g	Not allowed	Not found	Not found
Sulfite-reducing clostridia, in 0.01 g	Not allowed	Not found	Not found

As a result of the conducted studies, it was found that the microbiological seedability of flakes made on the basis of biologically activated wheat grain does not exceed the permissible values. Storage for 6 months does not significantly impair the quality, such grain products are safe from the point of view of microbiological purity.

Conclusions. Wheat flakes produced on the basis of grain prepared by the developed method are a product of health-improving purpose. Biologically activated cereals and, in particular, wheat, are valuable raw materials for the production of innovative food products for functional, health and therapeutic and preventive purposes. The developed method of processing cereals for producing flakes allows to obtain a product with high biological value, namely, an increased content of water-soluble and fat-soluble vitamins, in particular, the content of vitamin E is 8.5 mg%, B_1 - 1.12 mg%, B_2 - 1.15 mg%; content of food fibers, which are natural food sorbents - 2.5%. In terms of the content of basic energogenic substances, wheat flakes are not inferior to traditional grain products.

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USE OF INNOVATIVE CULTURES OF MICROORGANISMS IN THE TECHNOLOGY OF FERMENTED BEVERAGES

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Abstract. *The article presents the results of theoretical and experimental research on the expediency of using dry leavens and yeast cultures in bread kvass technology, which are used in various branches of the food industry and at the household level. The characteristics of yeast and lactic acid bacteria used in the technologies of fermented beverages are given. The possibility of using dry sourdoughs Acidolact VIVO, Yogurt VIVO, Kvass VIVO, Bifivit VIVO, Streptosan VIVO to ensure the intensification of the production process of bread kvass has been determined. The characteristics of sourdough starters, the content of microorganism cultures in them, the prospects of using them for fermenting sourdough wort are given.*

Comparative characteristics of the use of pure yeast culture Saccharomyses cerevisiae MP-10 with dry starters are given. This can be important in industrial technology. The dynamics of changes in dry matter and titrated acidity during the fermentation of fermented wort with certain starter cultures were studied. Fermentation took place using a pure yeast culture Saccharomyses cerevisiae MP-10 at temperatures of 30 and 36 ^{0}C. The influence of temperature on the physiological activity of yeast during combined alcoholic and lactic acid fermentation under different technological regimes was investigated. The organoleptic parameters of bread kvass using sourdough starters were determined. Based on the results of research into the wort fermentation process and organoleptic evaluation of the finished product, recommendations for the industrial production of bread kvass were provided. Manufacturers of kvass bread using dry starters are recommended to use a pure culture of yeast Saccharomyses cerevisiae MP-10. It has been proven that the use of this yeast culture in combination with dry starters allows to intensify the technological process, in particular at elevated temperatures, to improve the organoleptic qualities of finished products.

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Introduction. An important direction of the development of the beverage industry in the world is the increase in the production of food products with a low sugar content and intended for the prevention of various diseases and used in environmentally unfavorable conditions (Giri et al., 2023). Numerous studies in the field of nutrition physiology show that the most rational form of such products are soft drinks (Basinskiene et al., 2020, Jordana, 2000).

According to the current standard, soft drinks include: juice drinks, drinks based on spicy and aromatic raw materials, drinks based on flavors, drinks based on grain raw materials, drinks based on mineral waters, special purpose drinks, artificially mineralized waters and fermented drinks (fermented drinks). There is a steady trend in the world to increase the production of soft drinks and expand their assortment. However, their biological value, balanced composition, as well as adaptability to the needs of the human body need to be improved. These issues have been resolved in the countries of Western Europe and Japan, where the composition of drinks has been brought into line with scientifically based norms of consumption of biologically active substances (Dulka et al., 2019).

The range of non-alcoholic beverages in the developed countries of the world is quite wide: from drinks like cola to natural fruit and vegetable juices. It should be noted that their basis is mainly concentrated juices, essences, mineral waters, and artificial compositions. Fermented soft drinks are insufficiently produced. This indicates a certain one-sidedness of their production in the world. The situation is somewhat better in the countries of Eastern Europe due to the production of beverages based on bread raw materials. In particular, bread kvass, a traditional drink for this region.

Non-alcoholic fermented drinks are a food product of plant origin. Their organoleptic and physicochemical properties are formed as a result of the vital activity of cultures of microorganisms substances (Branyik et al., 2012).

Until the beginning of the 20th century, fermented rye kvass was used as a fermentation agent because it contained microorganisms. Such leavens were a mixture of different types of yeast and acid-forming bacteria. When introduced into the nutrient medium, they caused its fermentation. But this method is unacceptable in industrial use, because from the point of view of technological and microbiological aspects, consistently high organoleptic and regulatory physico-chemical indicators of the finished product are not provided. Therefore, in the production of fermented beverages, it is desirable to use only pure cultures of microorganisms, regardless of whether it is a monoculture or an association of cultures of microorganisms (Sõukand et al., 2015, Marsh et al., 2014).

For the fermentation of kvass wort, different breeds of kvass yeast are used. You can also use pressed or dry baker's yeast. The use of pure cultures of yeast races R-87, K-87, KM-94 is considered the most effective in the production of bread kvass. They allow to simplify the technology, to achieve high indicators of kvass (Dulka, 2019).

Yeasts are simpler unicellular organisms belonging to the class *Saccharomyces*. They cause alcoholic fermentation of wort carbohydrates, which occurs under the influence of yeast cell enzymes. The role of yeast in kvass technology is decisive, since the quality of the finished product depends on it. Mainly its taste-aromatic properties. When choosing a yeast strain for the fermentation of fermented wort, it is necessary to take into account their technological properties: high fermentation activity, resistance to autolysis, the ability to form a dense sediment after fermentation, the ability to give the product excellent taste and aroma qualities (Vitriak, 2002).

The most common is the use of dry or pressed baker's yeast. Their use ensures acceptable fermentation of wort, but at the same time the organoleptic indicators of kvass and its stability are low (Dulka, 2019, Semenov et al., 2019).

When using wine yeast, the rate of fermentation slows down significantly, as their enzymatic system is adapted to the fermentation of fruit must.

Breeds of brewer's yeast have acceptable fermentation activity and are closest in characteristics to kvass yeast, but are adapted to a higher dry matter content in the original wort (Rana et al., 2020).

Kvass yeasts are facultative anaerobes and ferment glucose, sucrose, maltose and raffinose to a lesser extent, and partially ferment dextrins, which allowed them to be classified as representatives of *Saccharomyses cerevisiae*, not *Saccharomyses minor*, as previously believed. They do not assimilate lactose, arabinose, xylene, mannitol. Their cells, after cultivation on kvass wort for 24 hours, have dimensions of 6.3...7.5×5...7 μm. The temperature optimum for yeast development is

25...30 ^{0}C (Dulka, 2019, García et al., 2019).

When preparing kvass using only yeast cultures, there is no accumulation of lactic acid. This happens due to the absence of lactic acid fermentation. Therefore, the necessary conditions of kvass are achieved by blending the fermented wort with organic acids (Dulka, 2019). The use of cultures of lactic acid bacteria in the process of wort fermentation is more appropriate in comparison with artificial acidification. In addition, such combined fermentation prevents the formation of extraneous microflora in the fermentation process and significantly reduces the risk of infection of the finished product (Taco et al., 2021).

Lactic acid bacteria mainly belong to the genus *Streptoccocus* and are spherical or oval in shape. Or to the genus *Lactobacillus*, which are immobile non-spore-forming short rods. All of them are gram-positive microorganisms (Hati et al., 2019).

The most famous lactic acid bacteria used in bread kvass technology are β-bacteria of races 11 and 13, which belong to the genus *Lactobacillus*. In the wort, these bacteria look like rods connected in pairs or in short chains. After cultivation for 24 hours, the cells of these bacteria have a length of 1.2...2.0 μm and a width of 0.5...0.6 μm. They are anaerobes, mesophiles, and belong to bacteria of the heteroenzymatic type of carbohydrate decomposition. During fermentation, acetic acid and carbon dioxide are first formed, and lactic acid accumulates at the end. As a result of fermentation of sour wort, bacteria produce lactic, oxalic, acetic, malic and other acids, as well as ethyl alcohol and carbon dioxide. These microorganisms ferment maltose, maltotriose, and sucrose well. The temperature optimum for vital activity is 30...35 ^{0}C (García et al., 2019).

The most promising technologies of fermented beverages are those whose technology involves the use of several cultures of microorganisms belonging to different taxonomic groups, including yeast and lactic acid bacteria.

Fermentation of kvass wort has its own characteristics. This is due to the biochemical composition of the raw materials, the features of the joint development of yeast and lactic acid bacteria, and the incompleteness of the process. As a result of fermentation, fermented wort is biotransformed into a finished drink with original taste and aroma properties (Vitriak, 2002).

Lactic acid bacteria differ from yeast in their high demands on the composition of the nutrient medium. They need a complete composition of amino acids and vitamins of group B. Therefore, protein hydrolysates or yeast extracts, vitamins are necessary for their development. That is, substances formed in the process of yeast autolysis. However, the metabolism of lactic acid bacteria leads to an increase in the acidity of the environment, which negatively affects the vital activity of yeast cells and can cause a slowdown in their fermentation activity.

The joint development of yeast and lactic acid bacteria is based on the mutual exchange of nutrients, different requirements for the composition of the wort and the speed of reproduction. As a result of joint cultivation, the direction of their characteristic fermentation changes. In the first half of the combined fermentation process, as a result of the life activity of lactic acid bacteria, lactic acid accumulates and the acidity of the environment increases (up to pH 5.0...5.5), favorable conditions for the life activity of yeast are created. In the second half of the fermentation process, the further increase in acidity inhibits the vital activity of yeast cells and they begin to die. The products of autolysis of yeast become a nutrient medium for lactic acid bacteria, which, when the process is carried out for a long time, leads to the termination of the vital activity of yeast (Dulka et al., 2019).

In order to balance the development of yeast and lactic acid bacteria at the wort fermentation stage, production cultures must be prepared separately and under optimal conditions. At the same time, it is necessary to control the acidity of lactic acid wort and the concentration of yeast cells in the wort. Therefore, introduction of production cultures of yeast and lactic acid bacteria should be carried out separately, depending on their physiological state (Jordana, 2000).

For enterprises of small and medium capacity (up to 1,000 dal per day), the use of a clean culture department in the production structure is impractical, as it requires significant material and labor resources. Therefore, such enterprises use dry or pressed baker's yeast for the fermentation of kvass wort. To give the drink the necessary acidity, acidification of the finished product is used by adding lactic or citric acid (Gran et al., 2003).

Currently, the consumer market of various leavens for the preparation of fermented drinks at home is represented quite widely. The sourdough market includes sourdoughs for obtaining fermented milk products, including yogurts, sour cream, kefir, and various types of cheeses. The composition of these leavens is diverse and is represented by yeast and bacteria. These microorganisms have different physiology and form different qualitative composition of the finished product and its organoleptic and physicochemical indicators.

Thus, the research and selection of dry cultures of yeast and lactic acid bacteria for the production of bread kvass is relevant.

The purpose of the work is the research and selection of dry leavens, which are used for the preparation of fermented milk products and have a wide range of cultures of microorganisms, for the preparation of bread kvass. Sourdough research will be conducted in combination with *Saccharomyses cerevisiae* MP-10 yeast culture, which is a traditional yeast race for kvass preparation (Dulka, 2019).

Materials and methods. The researches used: dry commercial leavens and pure MP-10 yeast culture according to passport data, drinking water from the centralized water supply of the city of Kyiv according to DSanPiN 2.2.4-171-10, white sugar according to DSTU 4623-2006, kvass wort concentrate in accordance with current regulatory documentation.

During the research, methods generally accepted in the beer-non-alcoholic industry of the food industry were used.

Samples were prepared for research using starter cultures:

1 - VIVO Acidolact - "Narine" sourdough starter;

2 - VIVO Yogurt - sourdough starter for yogurt;

3 – Kvass VIVO – starter for kvass (control);

4 - Bifivit VIVO - sourdough starter for children's sour milk nutrition;

5 – Streptosan VIVO – sourdough starter for Streptosan sour milk drink.

Working suspensions of *Saccharomyces cerevisiae* MP-10 yeast at the rate of 8% of the wort volume were added to samples 1, 2, 4, 5. Sample 3 was used as a control, yeast was not added.

The initial indicators of fermented wort for all samples were: dry matter content – 3.3%; acidity - 1.15 cm^3 of NaOH solution conc. 10 mol/dm^3 per 100 cm^3.

The wort was fermented at temperatures of 30 and 36 ^0C for 24 hours. Fermentation was terminated when the dry matter content of the wort decreased by 0.8...1.0% and the acidity increased by 2.0...2.5 cm^3 of NaOH solution with a concentration of 1.0 mol/dm^3 per 100 cm^3.

The physiological state of yeast cultures and their concentration were determined by microscopy using a Horyaev camera. A solution of methylene blue was used to determine the number of dead cells.

Experiments were performed in identical conditions, in three to five repetitions. The given research results are the mean value of the obtained results.

Results and discussion. The choice of dry sourdoughs was due to their wide use in various branches of the food industry and in everyday life, taking into account the fact that they were not used in the production of bread kvass.

The characteristics of the studied preparations of dry starters by species composition are given in Table 1 (VIVO, 2023).

Table 1

Characteristics of dry sourdough starters

Sample №	**Name sourdough**	**Specific composition of the sourdough**	**Characteristics of sourdough**
1.	Acidolact VIVO	*Lactobacillus acidophilus Streptococcus salivarius subsp. termophilus; Lactococcus lactis subsp. diacetulactis.*	It is recommended for use after antibiotics or chemotherapeutic drugs, as a support for the body's microflora. The bacteria that make up the sourdough are resistant to most types of antibiotics and are able to inhibit the development of pathogenic microorganisms. It has a complex anti-inflammatory effect, neutralizes toxins and side effects of food products, activates the body's cleansing processes.
2.	Yogurt VIVO	*Streptococcus salivarius subsp. termophilus; Lactobacillus delbrueckii subsp. bulgarricus; Lactobacillus acidophilus; Lactococcus lactis subsp. lactis; Lactococcus lactis subsp. diacetylactis; Lactococcus lactis subsp. cremoris.*	Recommended for people of all ages. Consumption of the product satisfies the body's need for amino acids, calcium salts, vitamins, etc. Useful for people with increased physical or psychological stress. Normalizes digestion, promotes the removal of harmful substances from the body, strengthens immunity. Contains a significant amount of lactic acid, which suppresses the development of pathogenic bacteria in the body
3.	Kvass VIVO	*Lactobacillus acidophilus; Streptococcus salivarius subsp. termophilus;* microflora of kefir fungi; dried baker's yeast.	The product normalizes digestion, promotes the removal of harmful substances from the body, has the ability to heal wounds, restore the microbiocenosis in the intestine, fight gastritis and colitis, and promote the rejuvenation of the body.
4.	Bifivit VIVO	*Acetobacter aceti; Bifidobacterium bifidum; Bifidobacterium longum; Bifidobacterium adolesctntis; Lactococcus lactis ssp.*	The product is highly effective in the prevention and treatment of diseases of the gastrointestinal tract, effective in staphylococcal infection, allergies, respiratory diseases, impaired immunity and

		cremoris; *Lactococcus lactis ssp. diacetylactis;* *Propionibacterium freudenreichii.*	metabolism. Restores healthy intestinal microflora in case of dysbacteriosis.
5.	Streptosan VIVO	*Streptococcus salivarius subsp. termophilus;* *Enterococcus faecium.*	Sourdough cultures are part of the microflora of Caucasian fermented milk products such as matsoni and suluguni. The product has the ability to resist the pathogens of intestinal infections and putrefactive bacteria, normalizes metabolism, the work of the cardiovascular system, and prevents premature aging of the body.

Indicators of dry starters Acidolact VIVO, Yogurt VIVO - sourdough starter for yogurt, Kvass VIVO, Bifivit VIVO, Streptosan VIVO and the possibility of their use in the technology of bread kvass are given.

The dynamics of changes in the concentration of dry substances of kvass wort during fermentation with the tested starter samples at a fermentation temperature of 30 ^{0}C are shown in Figure 1.

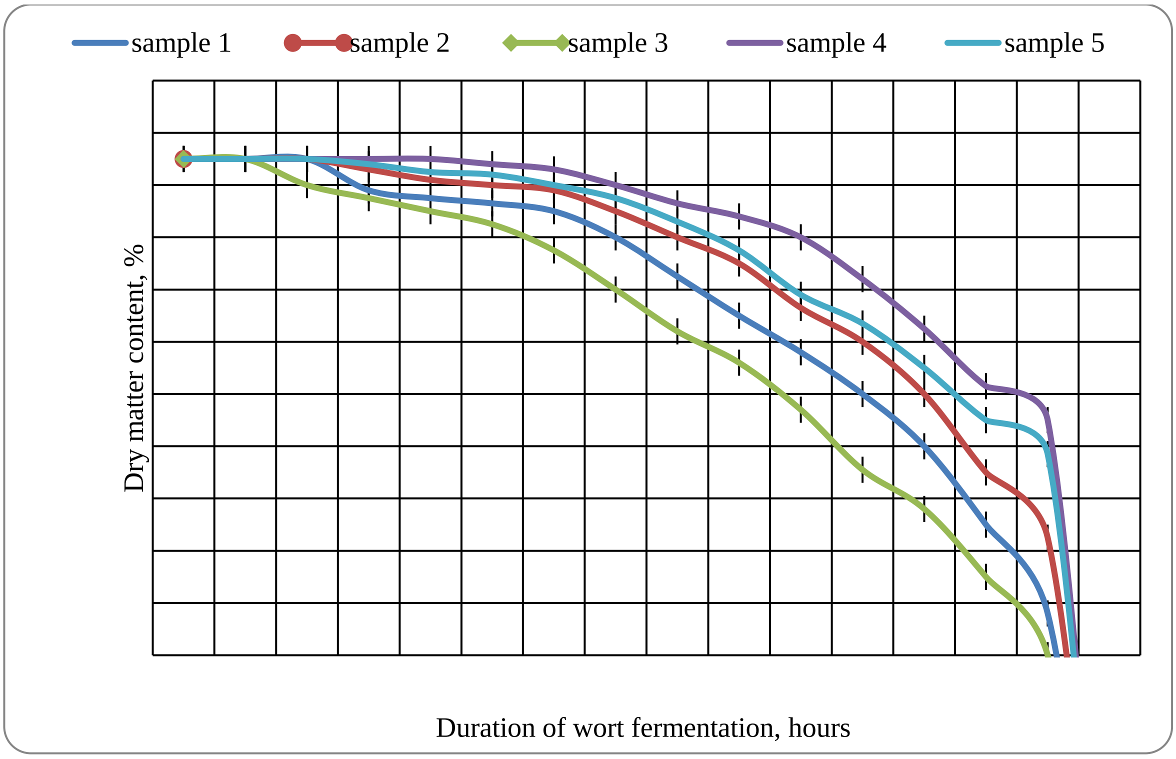

Fig. 1. Dynamics of wort dry matter at a fermentation temperature of 30 ^{0}C

It was established that in the first 2.0...2.5 hours of fermentation, the reduction of dry matter content practically did not occur in samples 1, 2. For samples 4 and 5, this duration was about 3...4

hours. This indicates the necessary duration of yeast adaptation to environmental conditions. During the fermentation of sample 3, the lag phase was of insignificant duration. Presumably, this is explained by their greater adaptability to the environment, since the drug is intended for the preparation of bread kvass. Fermentation of the wort in this sample lasted 16 hours. The duration of fermentation of samples 1, 2, 5 and 4 was 17.5; 19; 20 and 22 hours, respectively.

Thus, it was determined that sample 3 can be considered the most acceptable according to the given indicators.

The dynamics of the titrated acidity of the wort at a temperature of 30 ^{0}C is shown in Fig. 2.

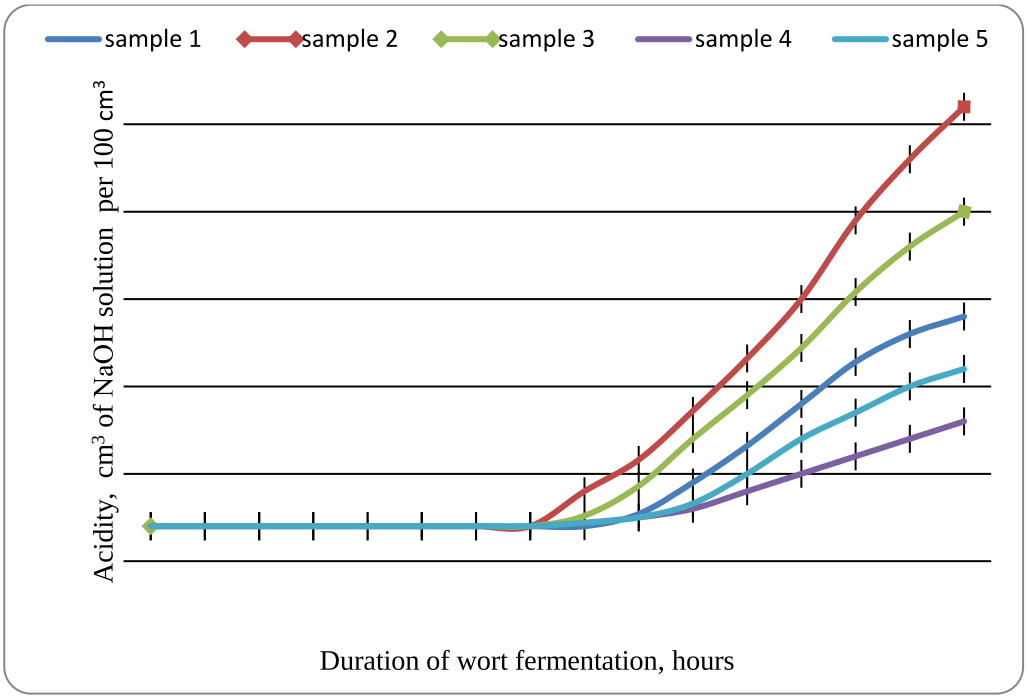

Fig. 2. Dynamics of the titrated acidity of the wort at a fermentation temperature of 30 ^{0}C

A low rate of acid formation at 30 ^{0}C was noted for all samples. However, in samples 1 and 3, the acidity increased more intensively during 21 and 17 hours, respectively. This can be explained by the presence in their composition of strains of lactic acid bacteria that are able to ferment carbohydrates at low temperatures. The lag in the increase in acidity of sample 4 is explained by the absence of glucose-fermenting bacteria in the sourdough.

Therefore, the moderate fermentation of fermented wort at 30 ^{0}C occurs most intensively in samples 1, 2, 3 during 17...21 hours. At this time, there is a decrease in the initial concentration of dry substances by 0.8...1.0% and an increase in acidity to 2 cm^3 of NaOH solution per 100 cm^3 of kvass.

It can be assumed that for sufficient acid formation in a shorter time, a temperature higher than 30 ^{0}C is favorable. Therefore, the next fermentation of the wort was carried out at a temperature of 36 ^{0}C.

The change in the content of dry substances and titrated acidity at the fermentation temperature of the wort of 36 ^{0}C is shown in Fig. 3 and 4.

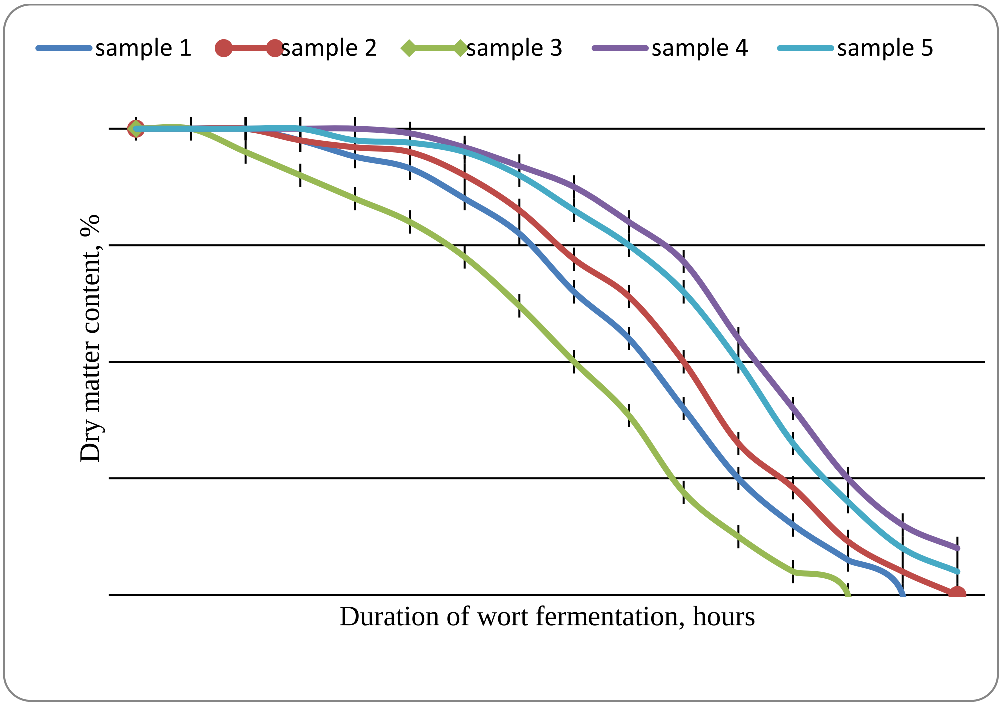

Fig. 3. Dynamics of changes in dry substances at a temperature of 36 ^{0}C

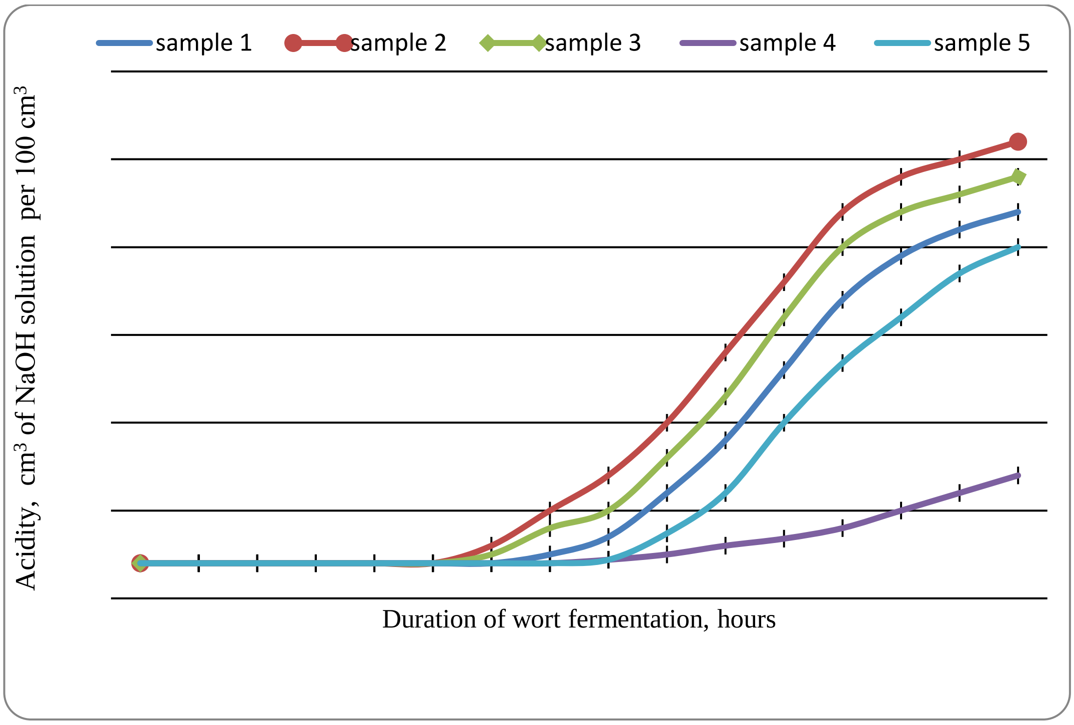

Fig. 4. Dynamics of changes in titrated acidity at a temperature of 36 ^{0}C

It was established that at a fermentation temperature of 36 ^{0}C, the fermented wort reached the normative indicators of a decrease in the content of dry substances in a shorter period of time than at a fermentation at a temperature of 30 ^{0}C. The most intensive fermentation took place in samples 3 (14 h), 1 (16 h) and 2 (18 h), which is explained by the presence in them of the thermotolerant yeast culture *Saccharomyses cerevisiae* MP-10.

Sample 4 (1.7 cm^3 of NaOH solution with a concentration of 1 mol/dm^3 per 100 cm^3) had the lowest value of the acidity indicator at 36 ^{0}C, which is explained by the absence of sugar-fermenting lactic acid bacteria in its composition. Samples 2 (14.5 h), 3 (15 h) and 1 (16 h) best provided the necessary acidity.

Thus, the phase of yeast adaptation to the environment at a higher temperature was short-lived, the fermentation process was shortened by almost 3 hours. The increase in titrated acidity was also more intense when the fermentation temperature increased.

The obtained research results were compared. It was established that the yeast *Saccharomyses cerevisiae* MP-10 is capable of fermenting sourdough wort in the presence of cultures of lactic acid bacteria that are not typical for brewing kvass. Fermentation takes place both at the usual temperature for alcoholic fermentation of 30 ^{0}C and at a higher temperature of 36 ^{0}C. It should be noted that for most samples, raising the temperature to 36 ^{0}C allowed to shorten the fermentation process by 3...5 hours. in comparison with fermentation of wort at a temperature of 30 ^{0}C.

The following series of studies was conducted to study the influence of the fermentation temperature regime of sour wort on the accumulation of yeast cells during combined alcoholic and lactic acid fermentation.

It is known that the duration of fermentation is influenced by the concentration of seed microorganisms, their physiological state and fermentation temperature.

In order to find out the influence of lactic acid bacteria on the viability of yeast cells, their physiological state was studied with the determination of the number of dead cells.

Sterile kvass wort with a concentration of 3.3% of dry substances was fermented at temperatures of 30 and 36 ^{0}C for 18...24 hours. The initial concentration of yeast in the wort was 4.7 million cells per cm³ of wort.

The content of yeast cells in fermented wort within 18...24 hours. at temperatures of 30 and 36 ^{0}C are shown in fig. 5...7.

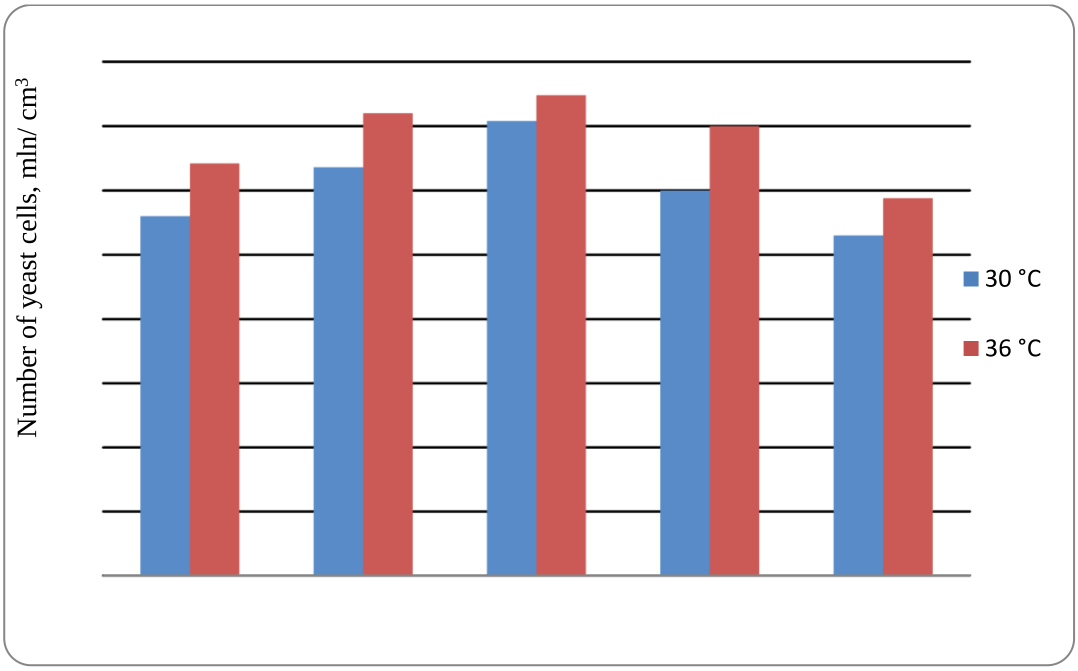

Fig. 5. The effect of temperature on the growth of yeast cells for a fermentation duration of 18 hours.

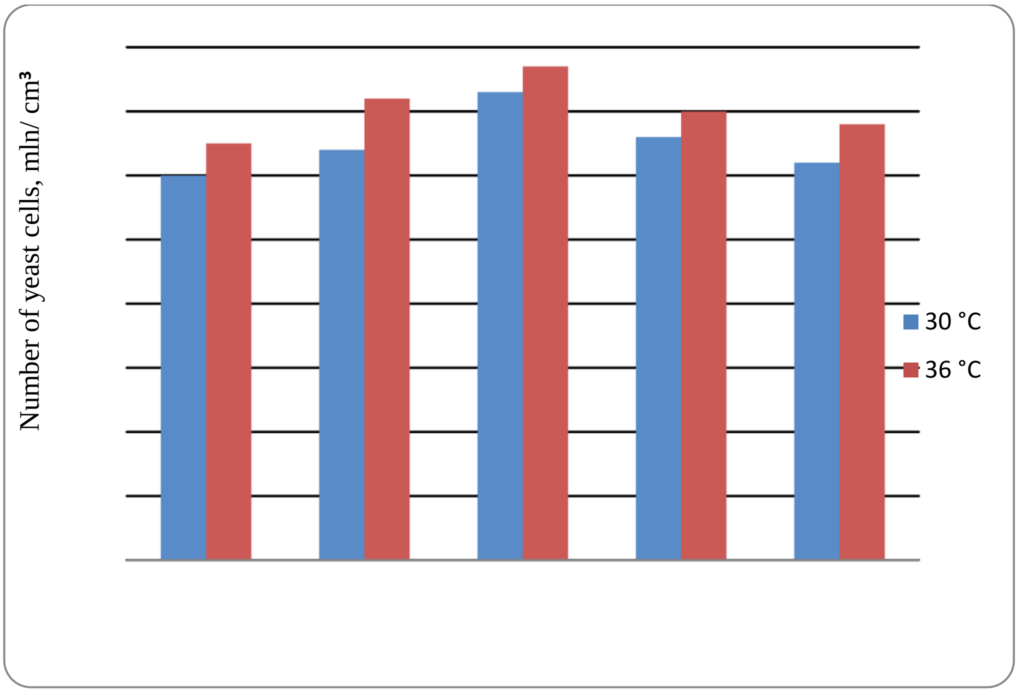

Fig. 6. The effect of temperature on the growth of yeast cells for a fermentation duration of 20 hours.

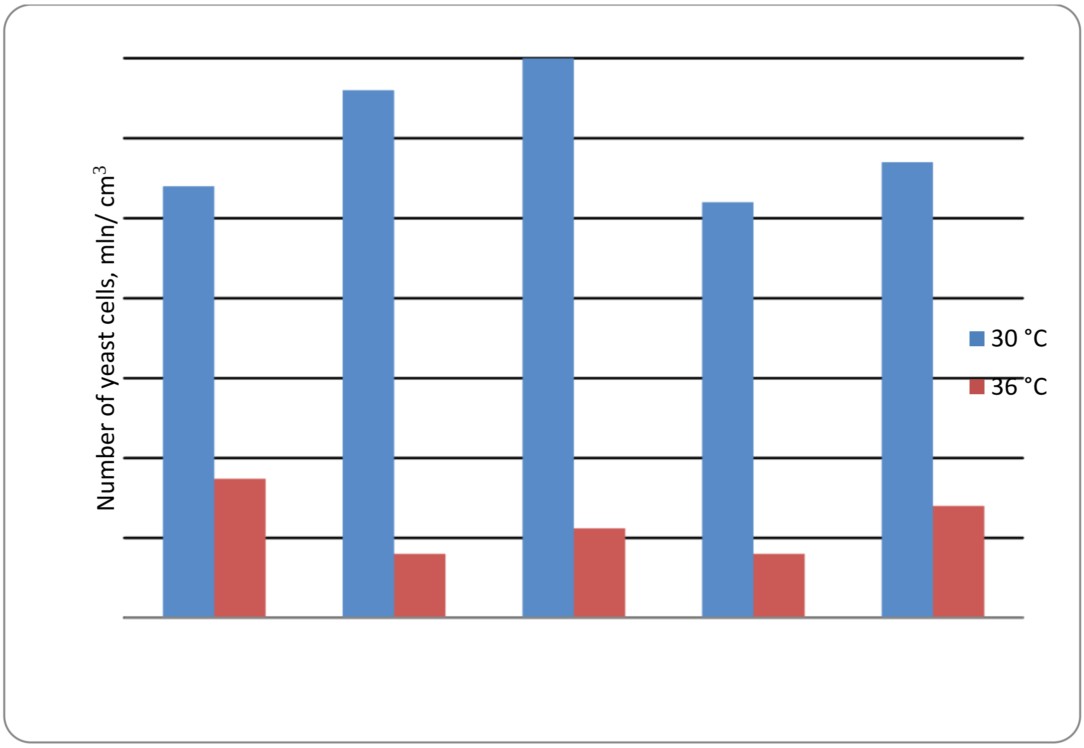

Fig. 7. The effect of temperature on the growth of yeast cells for a fermentation duration of 24 hours.

It was established that the yeast *Saccharomyses cerevisiae* MP-10 in all studied samples had high fermentation activity in the environment with lactic acid bacteria. When the duration of fermentation of wort is 18 hours at different temperatures, an increase in the number of yeast cells was observed throughout the process. The most intensive accumulation of yeast cells (exponential growth phase) was observed at a temperature of 30 ^{0}C. At the same time, up to 40 million cells per cm^3 accumulated in the environment. At the same time, the number of dead cells was less than 2%.

An increase in temperature to 36 $^{0°}$C (Fig. 7) led to a shortening of the exponential phase. After the stationary phase, cell growth decreased by 10...12% after 20 hours of fermentation. At this temperature, thermolabile lactobacilli are activated, the environment is depleted, and acidity increases. Therefore, an increase in the number of dead yeast cells up to 20% was observed, which subsequently led to a deterioration of the organoleptic indicators of the finished product due to yeast autolysis.

Therefore, for the fermentation of kvass wort with researched starters, including the use of yeast *Saccharomyses cerevisiae* MP-10, it is possible to recommend a temperature within the range of 30...36 ^{0}C. This contributes to the active process of alcoholic fermentation, growth and reproduction of yeast up to 20...25%, improvement of the organoleptic properties of kvass. However, the temperature of 36 ^{0}C is the limit and the duration of fermentation should not be more than 18 hours. Based on the obtained results, it was determined that dry preparations of lactic acid bacteria cultures can be used in kvass technology, since the nature of wort fermentation and the increase in acidity did not have significant differences.

The organoleptic characteristics of kvass of the studied samples are given in table. 2.

Table 2

Organoleptic characteristics of kvass for the studied samples

Indicator	Sample №				
	1	2	3	4	5
Appearance	Dark brown color, without turbidity (7.0)	Dark brown color, without turbidity (6.0)	Dark brown color, without turbidity (6.6)	Brown color, cloudy (5.7)	Dark brown color, no cloudiness (4.9)
Flavor	Strong aroma of rye bread, clean, characteristic of bread kvass (5.0)	Pure aroma of rye bread, characteristic of bread kvass (5.0)	the aroma is characteristic of bread kvass, clean (5,0)	aroma of rye bread, characteristic of bread kvass (4.8)	the aroma is uncharacteristic, the extraneous smell of burnt rye bread (3.7)
Taste	Harmonious, strong taste of rye bread, sweet and sour, Refreshing (6.9)	Refreshing, harmonious taste, without extraneous aftertaste (6.0)	The characteristic taste of kvass is strongly expressed, sweet and sour (6.5)	Refreshing taste, without extraneous aftertaste (5,5)	Sour, empty taste, bitterness is felt, not characteristic of kvass (3.6)
General assessment, points	18.9	17.0	18.1	16.0	12.2

According to the results of the organoleptic evaluation of the studied samples, it was established that the appearance and color of the drinks were traditional. They had a characteristic dark brown color, were opaque, and did not contain foreign inclusions. It should be noted that sample 4 had a less saturated color, the aroma of burnt bread and bitterness in the aftertaste. The aroma of some samples was insufficiently pronounced or empty. Most of the samples had a mild, harmonious sweet-sour taste characteristic of bread kvass.

Kvass samples 1 and 3 received the highest score, which indicates the expediency of their use in kvass technology.

Conclusions: 1. The possibility of using dry sourdoughs Acidolact VIVO, Yogurt VIVO, Kvass VIVO, Bifivit VIVO, Streptosan VIVO in the technology of bread sourdough is substantiated.

2. The influence of temperature on the physiological activity of *Saccharomyses cerevisiae* MP-10 yeast during the combined alcoholic and lactic acid fermentation of fermented wort using the studied dry starters was determined.

3. Shortening the fermentation process and obtaining high quality indicators of the finished product is ensured by increasing the fermentation temperature to 36 ^{0}C and using the culture of *Saccharomyses cerevisiae* MP-10.

3. The organoleptic indicators of kvass obtained using dry leavens in combination with the use of pure yeast culture *Saccharomyses cerevisiae* MP-10 indicate the feasibility of its use in bread kvass technology.

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APPLICATION OF AN IMPROVED TECHNIQUE FOR MEASURING THE MASS FRACTION OF ALCOHOL-CONTAINING RAW MATERIALS IN COSMETIC PRODUCTS

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Abstract. *An improved technique for measuring the mass fraction of ethyl alcohol in water-alcohol solutions using gas-liquid chromatography with a vapour-phase sampler has been proposed. The principle of the method consists in the transfer of volatile components, including ethyl alcohol, from the solution to the vapor phase, its introduction into the chromatograph, the separation of the mixture on a capillary column, followed by the registration of the signal on the flame ionization detector.*

The prepared sample, the working solutions of the mixtures and the mixture for checking the retention time are heated in a stoppered vial. This allows you to balance the content of volatile components present in the liquid and in the vapor phase. Part of the equilibrium sample of the steam is introduced into the gas chromatograph column.

The static vapor phase sampler provides the possibility of introducing 3 ml of the vapor phase (volatile substances) of the sample directly to the analytical column, increasing the sensitivity of the technique and extending the resolution of the column.

The mass fraction of ethyl alcohol is calculated by the external standard method according to the ratio of the areas of the chromatographic peaks of ethyl alcohol from the mass fraction of ethyl alcohol in solution.

This technique makes it possible to test cosmetic products for the content of ethyl alcohol in water-alcohol and gel solutions, as well as to confirm the quality and safety of alcohol-containing raw materials in accordance with the requirements of the Technical Regulations for cosmetic products.

Introduction. Ethyl alcohol is widely used as an industrial raw material in the perfumery and cosmetics industry. According to the International Cosmetic Ingredient Dictionary and Handbook, ethanol acts as an defoamer, a perfume, an binder, an antimicrobial component and an ingredient that reduces the viscosity of cosmetic products.

During the outbreak of COVID-19, an emergency occurred the demand for basic hygiene products that caused them critical deficit and numerous falsifications (inconsistencies in quality). Alcohol-based hand rubs (ABHRs) formulated with technical-grade ethanol were temporarily permitted in Canada and the U.S beginning April 2020 to meet the current demand due to COVID-19. ABHRs formulated with technical-grade ethanol are low risk for general use. Overall, the highest risks were associated with methanol (for its toxicity), ethyl acetate (skin defattening), and acetaldehyde (carcinogenic and teratogenic). For these reasons, Health Canada and the United States Food and Drug Administration have issued recalls on products containing some of these contaminants. More vigilant policing by regulatory agencies and general product users are required to ensure compliance, safety, and efficacy of these new products (Tse et al., 2021).

Typically, ethanol used for hand sanitizer must adhere to specific monographs (e.g. Food Chemicals Codex; FCC and the United States Pharmacopeia; USP), and are regulated by governmental agencies (e.g. Health Canada; HC, and the United States Food and Drug Administration; US-FDA). To ensure that process contaminants are minimized, ABHRs are normally formulated using raw materials conforming with USP or FCC guidelines. The USP monograph combines colorimetric tests and analytical chromatography to determine purity of the ethanol. Common contaminants naturally coproduced during grain fermentation include, methanol, acetates, aldehydes, butanols, amyl alcohols, propanols, and pentanols (Onuki et al., 2016).

The FDA discovered serious safety concerns with some hand sanitizers during testing. This includes some hand sanitizers that: are contaminated with potentially toxic types of alcohol, do not contain enough active ingredient (ethyl alcohol or isopropyl alcohol), have labels containing false, misleading, or unproven claims (FDA, 2023).

There are many types of alcohol. Only ethyl alcohol and isopropyl alcohol (also known as 2-propanol) are acceptable alcohols in hand sanitizer. Other types of alcohol, including methanol and 1-propanol, are not acceptable in hand sanitizer because they can be toxic to humans. Recent FDA safety testing discovered some hand sanitizers contaminated with these potentially toxic types of alcohol.

The alcohol content is the most important parameter that must be controlled in the manufacture of disinfectants. Optimum germicidal activity occurs at concentrations between 60–95% of either ethanol, isopropanol or n-propanol. Moreover it has been found that the disinfectant for hands with an alcohol concentration below 60% (vol/vol) is ineffective and may even put the user at greater risk of infection (WHO, 2009). Alcohol concentrations of 60% to 95% (vol/vol) kill 3.4 to 5.8 log 10 CFU in 30 seconds, with higher concentrations having better antibacterial activity. However, concentrations of greater than 95% are less potent because water is essential for protein denaturation (Trampuz et al., 2004).

There are many types of alcohol. Only ethyl alcohol and isopropyl alcohol (also known as 2-propanol) are acceptable alcohols in hand sanitizer. Other types of alcohol, including methanol and 1-propanol, are not acceptable in hand sanitizer because they can be toxic to humans. Recent FDA safety testing discovered some hand sanitizers contaminated with these potentially toxic types of alcohol.

In the conditions of high competitiveness of commercial spirits both in the domestic and foreign sales markets, in today's conditions, the determining indicators of its quality are the concentration of ethanol and the content of microcomponents (aldehydes, esters, fusel oils, namely isopropyl alcohol and methanol) in the finished products. The composition of alcohol-containing raw materials and products is difficult to analyze, and for this reason scientists usually choose gas chromatography methods. Thanks to a wide selection of extraction methods and detectors, qualitative and quantitative analysis of many chemical compounds with different functional groups can be provided (Kostic et al., 2021; Sirhan et al., 2019; Wiśniewska et al., 2014).

A more advanced method is headspace gas chromatography, the principle of which is the preliminary extraction of volatile components from a liquid or solid sample (formation of a vapor phase) and their subsequent introduction into the gas chromatograph system. This makes it possible to increase the sensitivity of determining volatile components in the sample and significantly expands the capabilities of the gas chromatographic system. In research (Panasenko et al., 2018) two methods suggested in the State Pharmacopoeia of Ukraine for determination of methanol and propanol-2 contents in liquid medicines were used, specifically: head-space gas-chromatography and classic gas chromatography with common injection technique. However, it has bee shown that classic gas chromatography is not able to give information about amounts of propanol-2 in substances, while head-space chromatography has determined concentration of this compound in all examined tinctures.

Ethyl alcohol for the perfumery and cosmetic industry of EU countries and most other countries of the world is denatured and exempt from excise duty (Denatured Alcohol), which is defined by the EEC Council Directive 92/83. Denatured alcohol is included as an ingredient in the European database of cosmetics and their ingredients COSMILE Europe. According to the International Nomenclature of Cosmetic Ingredients (INCI), ethyl alcohol is designated as Alcohol Denat and under this name it can be found in the list of cosmetic ingredients. Since 2004, alcohol denatured for the perfumery and cosmetics industry in Ukraine was subject to excise tax, which made the products made from it non-competitive. Alcohol-containing raw materials for perfumery and cosmetic products were imported or produced in Ukraine of dubious quality and origin. Consumption of ethyl alcohol in the industry fell from 200,000 decalitres a year to almost zero. The output of alcohol-containing perfumery and cosmetic products was decreased sharply.

The joint efforts of interested organizations and enterprises (State Enterprise «UKRSPYRT», Ltd. «SUPERMASH», the Ukrainian Association of Perfumery and Cosmetics, Ministry of Agrarian Policy and Food of Ukraine and other) for more than 12 years have led to the adoption of a number of laws that allow unblocking the production and circulation of denatured alcohol in Ukraine:

- it has been allowed to dispense denatured alcohol for the production of perfumery and cosmetic products (Article 229 of the Tax Code of Ukraine) since 2019,
- a list of denaturing additives for alcohol denaturation has been defined (Decree of the Cabinet of Ministers of Ukraine of 14.08.2019 No. 722), including for perfumery and cosmetic products,
- it is allowed to record denatured ethyl alcohol and products from it with mass flow meters in kilograms (Article 230 of the Tax Code of Ukraine).

Determination of the volume fraction of ethyl alcohol is carried out in accordance with DSTU 7457:2013 "Water-alcohol solutions. Methods of determining the content of ethyl alcohol" using glass hydrometers for alcohol or pycnometers, that is, the methods are based on the dependence of the density of the water-alcohol solution on the content of ethyl alcohol. Earlier studies (Kyziun et al., 2005) showed a significant effect of the presence of denaturing additives on the density of water-alcohol solutions and, accordingly, on the readings of alcohol meters when determining the volume fraction of ethyl alcohol. The measurement of the volume of ethyl alcohol according to the current regulatory documents is possible only during the measurement of the batch of alcohol that is sent for denaturation. After the denaturation process is completed, i.e. after adding denaturing additives and mixing the prepared batch of denatured alcohol, accounting for ethyl alcohol denatured according to the current methods, with accuracy in accordance with the current regulatory documentation, is impossible, for example, during the release of a part of the manufactured batch. The gas-liquid chromatography method has an undeniable advantage over other methods. Therefore, the improving of a technique for measuring the mass fraction of ethyl alcohol in water and water-alcohol solutions is relevant.

The aim of the research is to improve the technique for measuring the mass fractions of ethyl alcohol and microcomponents (aldehydes, esters, methanol, fusel oils, including propanols and butanols) in aqueous and aqueous-alcoholic solutions using gas chromatography with a vapor phase sampler.

Materials and Methods. The conducted scientific and research work was carried out in accordance with the priority direction of activity of the Scientific and Methodical Laboratory of Chromatographic Research, namely the improvement of measurement methods according to the direction of the laboratory's activity, the field of accreditation and production tasks. The proposed methodology for determining the mass fraction of alcohols was improved on the basis of the methodology according to the DFU (State Pharmacopoeia of Ukraine, 2014).

The research was carried out on an HP 6890 Plus gas chromatograph with a flame ionization detector, equipped with an automatic device for introducing a static vapor phase HP 7694 Headspace Sampler manufactured by Agilent Technologies Inc. (USA); using a capillary analytical column HP-624 (part No. 19091V-413, length 30 m, inner diameter 0.32 mm, film thickness of the stationary phase 1.8 μm) manufactured by Agilent Technologies Inc. (USA). When measuring the mass fraction of ethanol in water-alcohol mixtures, propanol is used as an internal standard. If it is necessary to determine other alcohols, fusel oils or denaturing additives, then propanol is not used as an internal standard, and calculations are made according to the calibration characteristic, where each point of the calibration characteristic is the arithmetic mean of two observation results. The calculation of the grading characteristic, which describes the dependence of the area of the chromatographic peak on the mass concentration, is performed by the method of least squares.

Research objects: hand sanitizers. The research was carried out at the request of the applicants for the compliance of the samples with labelling and detection of falsification by the State Enterprise "UKRMETRTESTSTANDART".

Results and Discussion. The principle of this technique consists in the transfer of volatile components, including ethyl alcohol, from the solution to the vapor phase, its introduction into the chromatograph, the separation of the mixture on a capillary column with subsequent registration of the signal on the flame ionization detector. The grading characteristic was set according to 5 mass concentration values of ethyl alcohol. Each point of the calibration characteristic is the arithmetic mean of two observation results. The calculation of the grading characteristic, which describes the dependence of the area of the chromatographic peak on the mass concentration, is performed by the least square method. The grading characteristic is considered satisfactory if the correlation coefficient satisfies the condition $r \geq 0.99$. If the value of the correlation coefficient is $r<0.99$, then the calibration characteristic is considered unsatisfactory, the cause is found and eliminated, after which the procedure for constructing the calibration characteristic is repeated.

To prepare a perfume-cosmetic product for testing a sample of an aqueous or aqueous-alcohol solution of 1.0±0.01 g is taken into a measuring flask with a stopper with a capacity of 100 cm^3. After that, 40 cm^3 of distilled water is added to the flask. The flask is closed with a stopper, sample is stirred until complete dissolution and kept in a thermostat at a temperature of (20.0±0.1)°C for 20 minutes. Next, the sample is brought to the mark with distilled water, stoppered, and mixed thoroughly. 0.5 cm^3 of the diluted solution of the test substance is introduced into the prepared glass vial with a capacity of 20 cm^3 and the vial is stoppered. Similarly, a parallel sample is prepared. Measurements are carried out on an automatic static vapor phase introduction device HP 7694 Headspace Sampler in the following sequence (table 1):

- blank solution;
- a mixture solution for checking retention time (Mixture F);
- five grading solutions (Mixture A, Mixture B, Mixture C, Mixture D, Mixture E) (fig. 1).

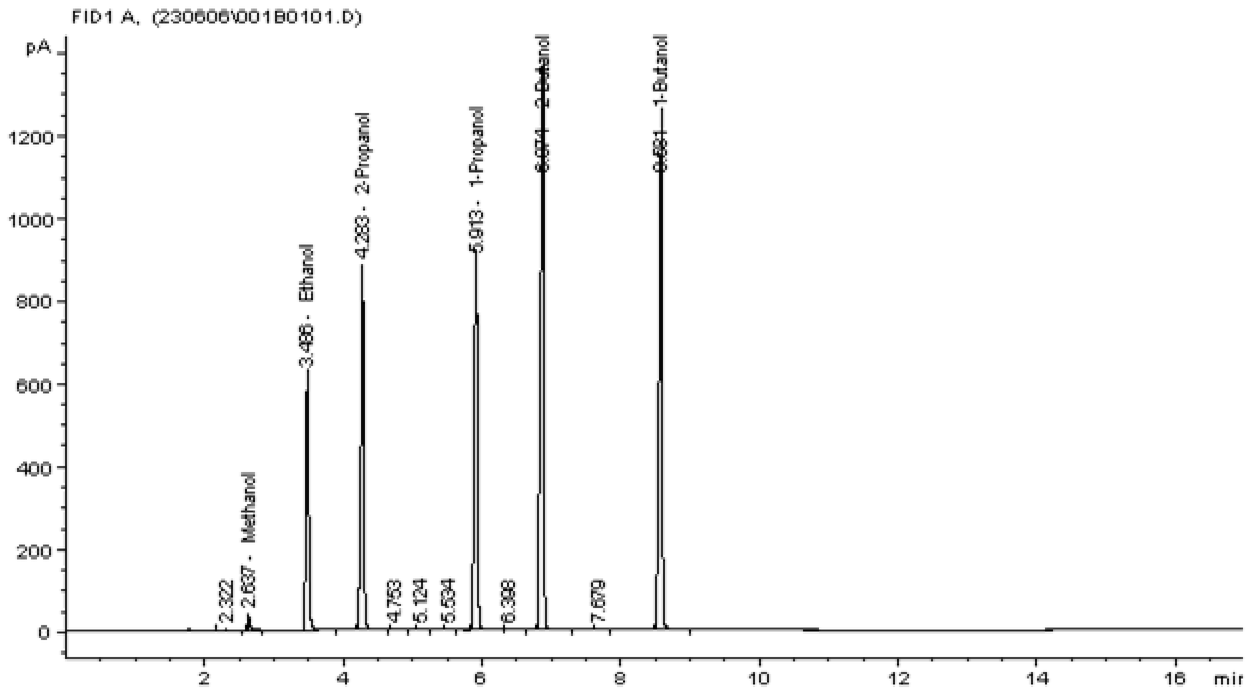

Fig. 1 Chromatogram of a standard sample of StMix alcohols (methanol, ethanol, 2-propanol, 1-propanol, 2-butanol, 1-butanol)

The sequence of placement of the grading solutions is from lower mass concentration to higher.

Table 1

Concentration of working solutions of mixtures of ethyl alcohol

Mass concentration, g/dm^3	Blank solution	Mixture A	Mixture B	Mixture C	Mixture D	Mixture E	Mixture F
	0,0	0,40	0,50	0,60	0,70	0,8	0,65
Mass of ethyl alcohol, g		0,4000 ±0,004	0,5000 ±0,005	0,6000 ±0,006	1,4000 ±0,014	0,8000 ±0,008	0,6500 ±0,007
Volume of the flask, dm^3	0,1	0,1	0,1	0,1	0,2	0,1	0,1

The blank solution was obtained from the same distilled water that was used in the preparation of standard solutions. The shelf life of solutions is 3 months, provided they are stored in a refrigerator at a temperature from +4 to +10°C.

Calculation of the mass concentration of ethyl alcohol in the solution of the prepared sample is performed according to the calibration curve. The calibration curve is set for 5 mass concentration values of ethyl alcohol. Each point of the grading characteristic is the arithmetic mean of two observation results. The calculation of the grading characteristic, which describes the dependence of the area of the chromatographic peak on the mass concentration, is made using the method of least squares. Chromatography is performed on the prepared sequence. Identification of the ethyl alcohol peak on the chromatogram is carried out by the content time according to the table stored in the chromatographic system.

Ethyl alcohol and other volatile organic compounds are determined in a diluted solution of the test product using gas chromatography with a flame ionization detector. The prepared sample, the working solutions of the mixtures and the mixture for testing the retention time are heated in a stoppered vial. This allows to balance the content of volatile components present in the liquid and in the vapor phase. Part of the equilibrium sample of the steam is introduced into the gas chromatograph column.

The mass fraction of ethyl alcohol is calculated by the external standard method, according to the ratio of the areas of the chromatographic peaks of ethyl alcohol from the mass fraction of ethyl alcohol in solution.

Research has established the need to analyse a control sample (Mix D) in duplicate after every 10th sample and at the end of each sequence to verify calibration. The arithmetic mean of these two repetitions should be within ±10% of the value of the mass fraction of ethyl alcohol certified according to the preparation procedure. If this condition is not met, all measurements after the last acceptable control sample must be repeated.

It has been proven that all samples of the product must be measured in duplicate. The measurement results of two copies should be within ±10% of the average value of the measurement results of this sample. If this condition is not met, then the measurement must be repeated (for two samples of the product), and the results of the two new measurements must be within ±10% of the average value of the results of this sample. During the research, samples adulterated with propanol and containing toxic methanol, acetone, and methyl ethyl ketone were found in hand sanitizers (fig. 2 and fig. 3).

Figure 2 shows a chromatogram of a hand sanitizer sample in which an increased amount of toxic substances, the content of which is not indicated on the label, was found, namely, methanol-0.5 % and acetone-0.1 %.

Methanol or methyl alcohol, also known as wood alcohol, is used to make rocket fuel and antifreeze and is very toxic, since its decomposition produces toxic substances: formaldehyde, formic and lactic acids, which disrupt processes important for the normal functioning of the body. Methanol poisoning can occur after inhaling its vapors, as well as after absorbing them through the pores of the skin or when ingested. Without expertise, it is quite difficult to distinguish methanol from ethyl alcohol by appearance, smell and taste. The direct use of methanol in cosmetics is prohibited, and its impurities in life-threatening concentrations can be present in technical ethyl alcohol, denatured alcohol and its surrogates (Lanigan, 2001). According to the Technical Regulation on cosmetic products of Ukraine, it is permissible to use methanol to denature ethyl and isopropyl alcohol in an amount not exceeding 5% of the content of these alcohols.

Acetone and methyl ethyl ketone (MEK) are potentially toxic to the body through inhalation, ingestion or skin contact. People who are occupationally exposed generally complain of symptoms such as headaches, confusion, dizziness, irritation (in throat, nose and eyes) and loss of consciousness. The exposure limits are 2 mg/L and 50 mg/L for MEK and acetone respectively (Southon et al., 2020).

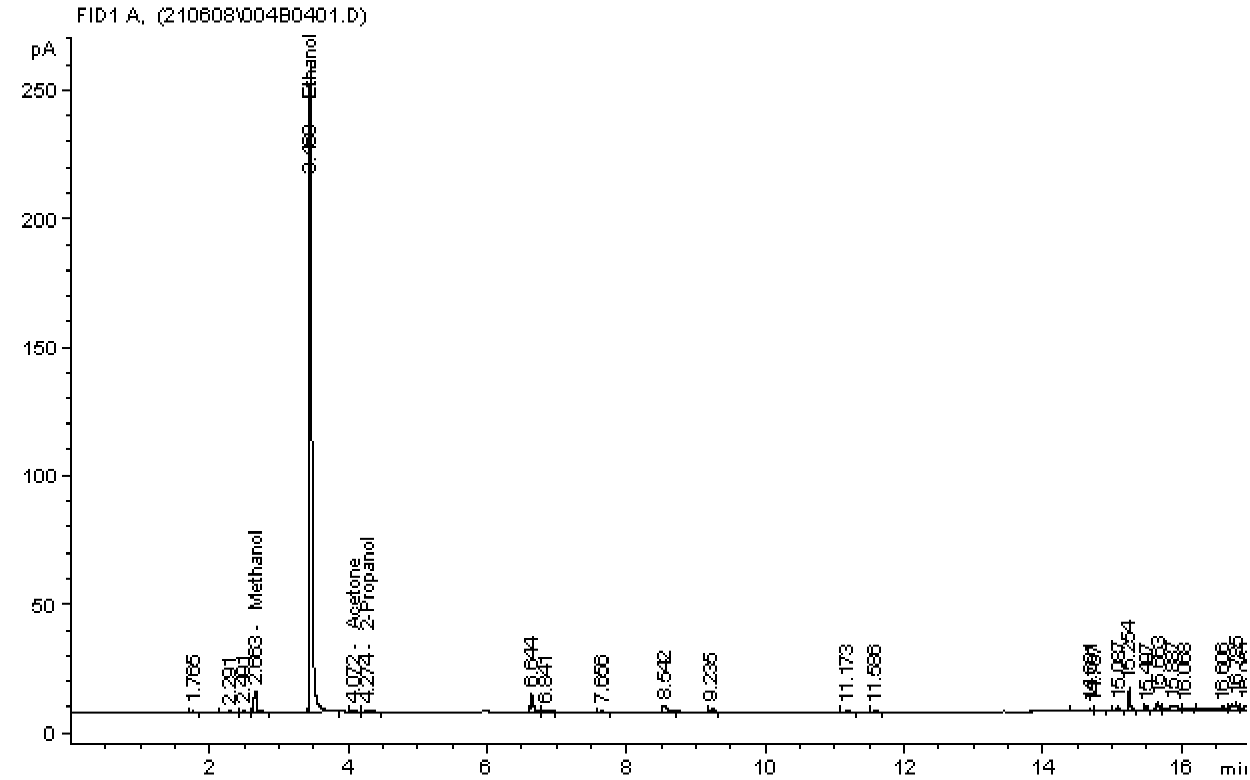

Fig. 2 Chromatogram of a sample of a water-alcohol solution of a hand sanitizer (ethanol – 87 %, methanol – 0.5 %, acetone – 0.1 %, 2-propanol – 0.5 %).

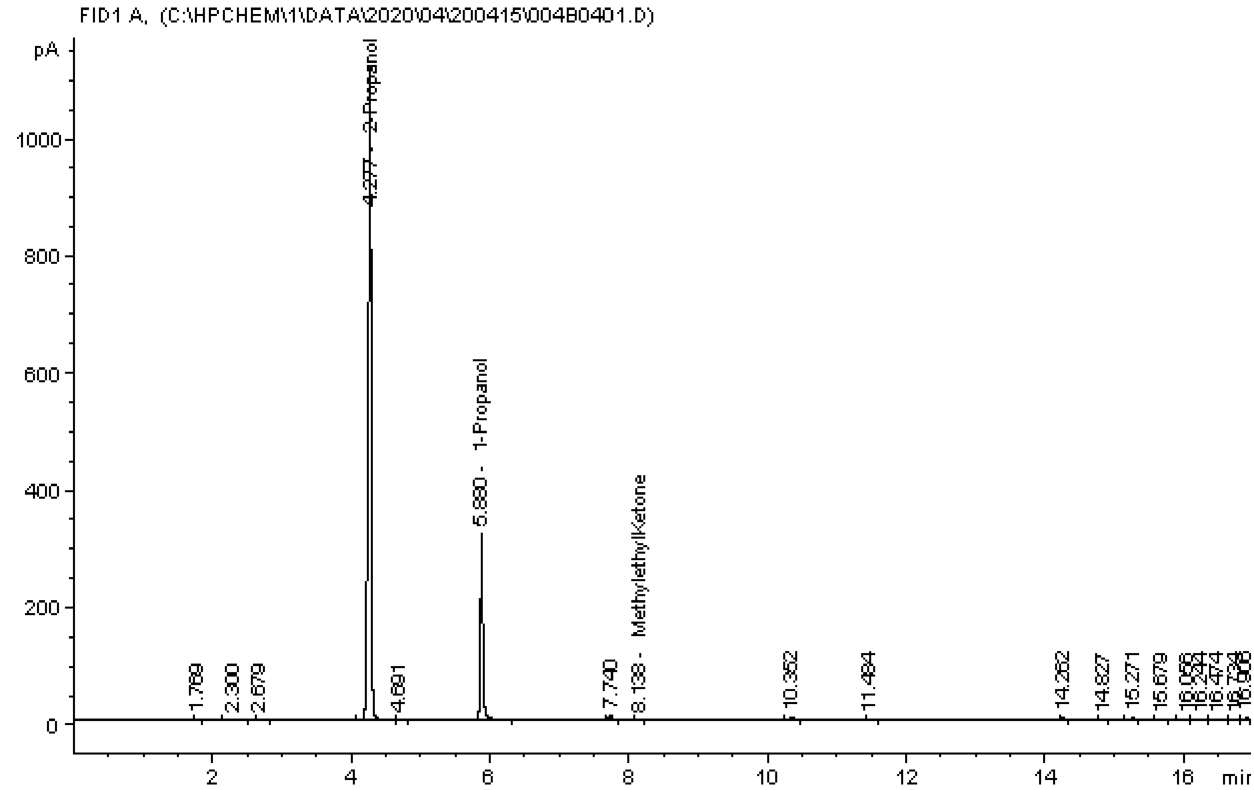

Fig. 3 Chromatogram of a falsified sample of a hand sanitizer
(2-propanol – 76%, 1-propanol – 15%, MEK – 0,01%, no ethanol according to the label)

Figure 3 shows a chromatogram of a hand sanitizer sample falsified with propanol alcohols, with an ethyl alcohol content of 85% declared when labeling. Instead, the sample contains alcohol 2-Propanol in the amount of 76% and toxic substances, namely, 1-propanol in the amount of 15% and MEK in the amount of 0.01%.

Isopropanol (2-propanol) is routinely used as an active ingredient in hand sanitizers and surface disinfectants and is regulated as a separate product (Mahmood et al., 2020) with its own risks. In the current context of technical-grade ethanol as an ingredient, Health Canada identifies and controls isopropanol as an “impurity” and places a limit of 1000 ppm (Timothy et al. 2021). Isopropanol can cause hypotension and coma. The content of 2-propanol in medicinal products should not exceed 0.05% (State Pharmacopoeia of Ukraine, 2014).

1-Propanol or 1-propyl alcohol is used to make industrial solvents (a type of cleaner) and can be toxic to humans when swallowed. Hand sanitizer with 1-propanol contamination can irritate skin (or eyes, if exposed) and cause allergic reactions. According to the Technical Regulations on cosmetic products of Ukraine, the content of 1-propanol should not exceed 2.0%.

Conclusions. The improved technique makes it possible to control raw materials based on denatured alcohol and to test cosmetic products for the content of ethyl alcohol in water-alcohol and gel solutions, which will allow to confirm its quality and safety in accordance with the requirements of the Technical Regulation of cosmetic products. The technique is fast, reliable and requires no sample pre-treatment. Based on the results of studies of the composition of hand sanitizers, the effectiveness of an improved technique for determining the mass fraction of ethyl alcohol and microimpurities has been proved.

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EVALUATION OF THE ENERGY EFFICIENCY OF THE PROCESS OF VIBRATORY MIXING OF MULTICOMPONENT BULK RAW MATERIAL OF FOOD INDUSTRIES

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Abstract. *The purpose of the work is to substantiate the technological modes of preparation of multifunctional loose ingredients using the developed design of the vibrating mixer, determined power and energy parameters of the oscillating system and grapho-analytical analysis of their changes. An experimental sample of a vibrating drum machine with kinematic vibration excitation was developed. When using combined kinematic vibration excitation, energy consumption for the drive of the investigated vibration massage machine is reduced by 2–2.5 times. The use of vibration as a force action in the mixing process allows to reduce the forces of internal friction in the technological mass. On the basis of the conducted studies, the effective parameters of the working mode of the capacity of the vibrating mixer can be noted according to the kinematic criteria of evaluation as follows: the amplitude of oscillations Ap=6.5 mm, the value of the eccentricity of the shaft drive e=2 mm and the ratio of the masses of the container and the kinematic vibrator m1/m2=5 according to energy consumption , which do not exceed 3.5 kW. The practical value of the performed work consists in the application of an eccentric combined vibration exciter to obtain power for controlling the process of preparing a multicomponent mixture, which reduces the amount of oscillating masses of the drive and, accordingly, minimizes energy costs for the process.*

Introduction. The need to create energy-saving technologies and equipment for their implementation is due to the following reasons: the predicted decrease in natural resource reserves [Nikolaienko et al., 2020]; increasing productivity, obtaining high-quality products and reducing their cost [Zheplinska et al., 2023]; strengthening the export potential of Ukraine as an agrarian country that owns significant land resources, which are economically more profitable to use in the form of deep processing products [Bal-Prylypko et al., 2023]; restriction of import of the raw material base of agricultural products and development of the own market for competitive products of processing and food industries; independence from external technologies and manufacturers is a guarantee of economic freedom and the formation of a strategic foreign trade policy on the world market [Bal-Prylypko et al., 2022a]. The main technological task of the production of combined high-calorie and multifunctional food additives is to obtain a homogeneous mixture [Zheplinska et al., 2022a]. The degree of perfection of this process depends on the economic indicators of production, consumption of energy resources, which affects productivity, product quality, and cost of production [Palamarchuk et al., 2015]. The peculiarity of the mixing process is multi-stage, significant duration, in particular in the production of premixes, the processing time lasts up to 20–25 minutes. with an energy intensity of 1.3–2.3 kWh/t, which is due to the need to simultaneously introduce 10–15 components of premixes with different physical and mechanical properties, the share of which in the total technological mass is 0.5–5% [Palamarchuk et al., 2020]. These are amino acids, vitamins, enzyme preparations, antioxidants, antibiotics, emulsifiers, tranquilizers, antibacterial substances and other components [Bal-Prylypko et al., 2022b; Zheplinska et al., 2022b; Vasyliv et al., 2022]. Mixing, as a rule, is carried out in gravity, screw and blade mixers, none of which provides a combination of high homogeneity of the mixture, speed of the process and low energy consumption [Sukhenko et al., 2018].

Among various forms of mechanical action on dispersed systems in technological processes, vibrational action occupies an important place as one of the most effective means for creating the necessary dynamic state of dispersed systems [Stadnyk et al., 2021]. Applying a vibration field to the technological environment significantly activates and intensifies the mixing of the components of the mixture, increases the quality of mixing materials with different physical and mechanical properties, and contributes to reducing the duration of work cycles and energy consumption.

Numerous studies of the process of preparation of various bulk mixtures in the conditions of a vibration field allowed to highlight the main advantages of vibration mixing over traditional mixing. This is, first of all, a significant reduction in the effective coefficients of internal and external friction, a weakening of the bonds between the particles of the material [Zheplinska et al., 2021]. Compared to conventional vibratory mixers, they have higher specific productivity (by 5–6 times), reduce mixing time by 2–3 times, metal consumption by 17%, energy consumption by 30%, capital costs for manufacturing by 18% and drive power by 30–35%, which leads to a 3–4 times decrease in total energy consumption [Palamarchuk et al., 2019].

In mixing processes, one of the most important technological tasks is not only increasing the intensity of technological action, but also reducing energy consumption in the processing process, which is implemented in vibro-impeller and pendulum schemes of drive devices [Ivanets et al., 2015; Palamarchuk et al., 2016].

Therefore, modern trends in the development of the vibration mixing process are aimed at the application of combined mechanical, pneumodynamic, physico-chemical action on the technological environment, improvement of the structural schemes of working containers, the use of progressive methods of vibration action under the condition of consistency of technological solutions and their constructive implementation [Yanovich et al., 2015; Palamarchuk et al., 2015].

The technological features of the vibration action determine the possibility of creating equipment with perfect constructive solutions. At the same time, a number of technological processes of agricultural processing production require fast and high-quality mixing of solid, dusty, viscous and liquid components [Carrillo et al., 2007; Rogovskii et al., 2020]. Taking into account the wide range of physical and mechanical properties of the materials being mixed, the number of components and their concentration, the possible occurrence of the phenomenon of segregation, it is possible to intensify these processes and guarantee the level of quality of the final product with the help of vibration technologies, which justifies the relevance of the conducted research.

The purpose of this scientific work is to substantiate the energy-efficient technological mode of preparation of multicomponent loose mixture using the developed design of the vibrating mixer, determined energy parameters of the oscillating system and grapho-analytical analysis of their changes.

Materials and methods. During the theoretical analysis and substantiation of the force, moment and energy characteristics of the developed apparatus for dissolution with vibro-centrifugal agitation of the technological environment, methods of mathematical analysis and their processing in the MathCAD mathematical environment were used to obtain the necessary graphic and analytical dependencies of the main mode parameters of the system.

When performing experimental studies, the desired parameters of vibration machines were obtained using Robotron equipment, namely, spectrum analyzers, level meters and vibrometers, which allow obtaining, for given processing modes, the values of vibration amplitude, vibration speed and vibration acceleration, vibration trajectories and other parameters of vibration technological action [Ashtiani et al., 2017].

When performing theoretical studies of the specified vibration drive, we make its mathematical model in the form of a calculation scheme (Fig. 1).

This drive is characterized by a kinematic method of vibration excitation and the presence of elastic elements of the drive shaft.

To the degrees of freedom of the oscillating system presented in Fig. 1, refer to:

- x_1, y_1, z_1 – linear movements of the working container along the selected coordinate axes;
- φ_1 – angular movement of the working container around the vertical axis 0Z;
- φ_2 – angular movement of the drive shaft of the vibration exciter around the 0Z axis;
- Θ_1 – angular movement of the working container in the horizontal plane.

Among the main masses of the studied system can be noted:

$$m_1 = m_k + \xi_m m_d$$

$$m_0 = m_1 + m_2$$

$$m_2 = m_в + m_p + m_{p1}$$

where m_k is the mass of the working container; m_d – loading mass; ξ_m – coupling mass coefficient; $m_в$ – mass of the drive shaft of the vibration exciter; m_p – mass of bearing assemblies; m_{p1} – mass of counterweights; m_0 is the total mass of the system.

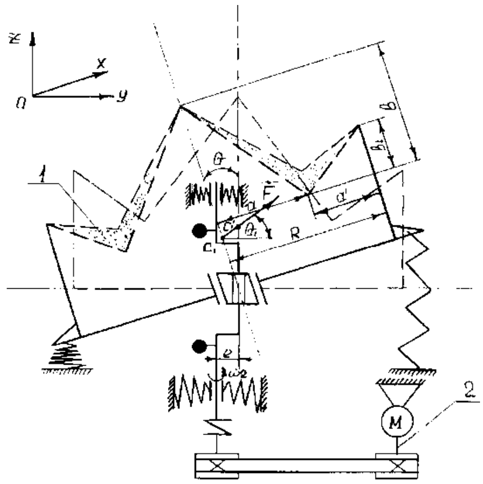

Fig. 1 Calculation scheme of the investigated vibration drive with combined mechanical vibration excitation of the spatial movement of executive bodies: 1 – technological loading; 2 – drive

Results and discussion. Mathematical modeling using the Lagrange formula allowed us to obtain the equation of motion of the oscillating container (Fig. 1):

$$x = \frac{Pg\cos\omega t}{2G_2(\omega^2 - \omega_0^2)}(2\cos\omega t - e^{\omega_0 t} - e^{-\omega_0 t}) + \frac{1}{2\omega_0^2}(2 - e^{\omega_0 t} - e^{-\omega_0 t})$$

$$z = \frac{Pg\cos\omega_0 t}{\omega_0 G_2(\omega^2 - \omega_0^2)} + (\frac{G_2}{C_z} - \frac{G_1}{\omega_0^2})\cos\omega_0 t + \frac{G_1}{\omega_0^2} + \frac{Pg\sin\omega t}{G_2(\omega^2 - \omega_0^2)} \qquad (1)$$

where $P = (m_1+m_2)g$ is the mass of the moving parts of the vibration drive; $G_2 = m_2 g$; $G_1 = m_1 g$; ω and ω_0 – forced and free rotation frequency, respectively; t – processing time; C_z is the stiffness of elastic elements in the direction of the 0Z axis.

Given that some components of equations (1) characterize the system's own oscillations, such movements have a damping character for steady motion. The components of these equations describing the forced oscillations of the system determine the operating mode parameters [Zavialov et al., 2015]. Among the latter, expressions of the amplitude of oscillations and the speed of movement of the working container can be noted.

$$A_p = \frac{Pg}{G_2(\omega^2-\omega_0^2)} = \frac{m_1 e\,\omega^2}{m_2(\omega^2-\omega_0^2)}\,;\ \vartheta_x = \dot{x} = \frac{2\,Pg\,\omega\sin 2\omega\,t}{G_2(\omega_0^2-\omega^2)}\,;\ \vartheta_z = \dot{z} = \frac{Pg\,\omega\cos\omega\,t}{G_2(\omega^2-\omega_0^2)} \qquad (2)$$

The study of the amplitude-frequency characteristics of the studied oscillating system revealed that up to the value of the angular velocity ω=28 rad/s, a resonant processing mode can be noted, which is characterized by a jump-like change in the operating amplitude, which complicates the process of regulating and stabilizing the operating mode. After reaching the value of the angular velocity ω=45-50 rad/s, a more stable resonance mode is observed, which facilitates the conditions of dynamic equilibrium control in the system. This mode is characterized by the constancy of the operating amplitude, which contributes to a significant reduction of dynamic loads on support nodes [Palamarchuk et al., 2013].

Using formulas (1) and (2), we determine the dependencies for accelerating the movement of the working container a_v and its components ah and z according to the formulas

$$a_x = \dot{\vartheta}_x = \frac{4\,Pg\,\omega^2\cos 2\omega\,t}{G_2(\omega_0^2-\omega^2)} \qquad (3)$$

$$a_z = \dot{\vartheta}_z = \frac{Pg\,\omega^2\sin\omega\,t}{G_2(\omega_0^2-\omega^2)} \qquad (4)$$

$$a_k = \sqrt{a_x^2 + a_y^2} = \frac{Pg\,\omega^2}{G_2(\omega_0^2-\omega^2)}\sqrt{4cos^2 2\omega t + sin^2\,\omega t} \qquad (5)$$

The amplitude value of the forcing force, which disturbs the oscillatory motion, is

$$P = m_1 e\,\omega^2 \qquad (6)$$

We determine the power consumption for giving the container oscillating motion as

$$N = P\,\vartheta_k = \frac{m_1^2\,e^2\,\omega^5}{m_2(\omega^2-\omega_0^2)}\sqrt{\cos^2\omega t - 4\sin^2 2\,\omega t} \qquad (7)$$

When constructing the given characteristics of the studied oscillating system, we vary the m1/m2 ratio at a fixed value of the eccentricity e of the drive shaft; as well as the amplitude-frequency characteristics of the vibromassage container when the eccentricity e changes at a fixed ratio m1/m2.

Using formula (5), we construct graphs of acceleration of the motion of the oscillating system under study. At the same time, we vary the ratio m1/m2 (Fig. 2), assuming a constant value of the eccentricity e=2 mm.

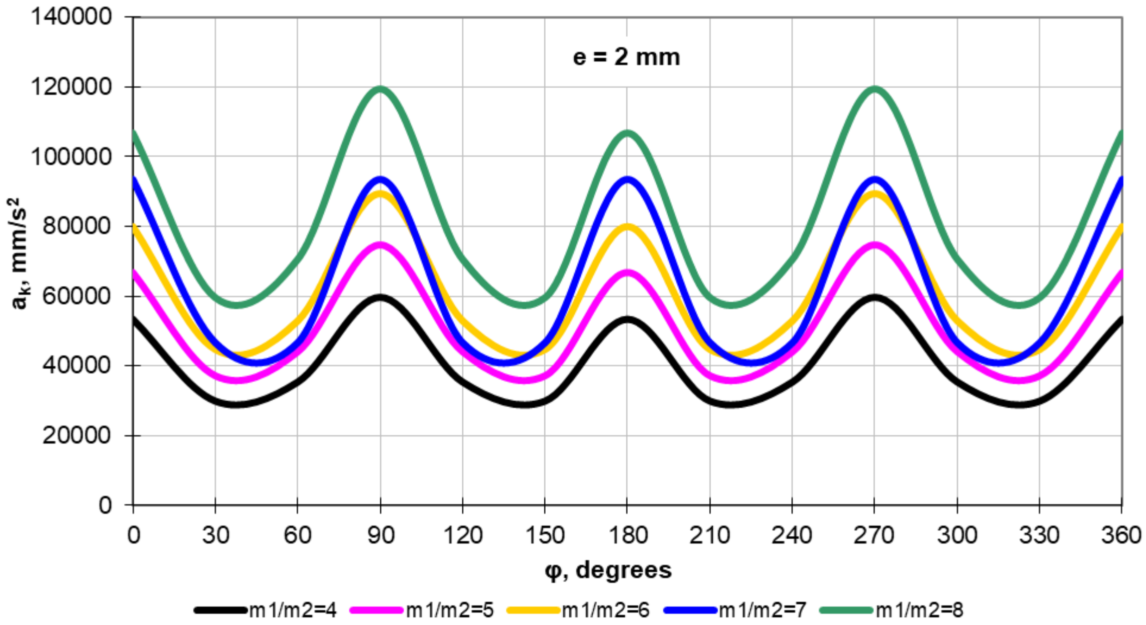

Fig. 2 Dependencies of the acceleration of the movement of the center of mass of the working container of the oscillating system under study with a change in the ratio m1/m2 and a constant value of the eccentricity e=2 mm

Using formula (7), we construct the energy characteristics of the studied oscillatory system. At the same time, we vary the m1/m2 ratio (Fig. 3) at a constant eccentricity value of e=2 mm; with a change in the eccentricity e and a constant ratio m1/m2=5 (Fig. 4).

Dependencies of the amplitude-frequency characteristics indicate that at the value of the angular velocity ω=50 rad/s there is stabilization of the working mode of processing loose products at the value of the amplitude of oscillations A=6.5 mm. Therefore, in further grapho-analytical research, we believe that the working parameters of the vibratory mixer are ω=ωp=50 rad/s and A=Ar=6.5 mm.

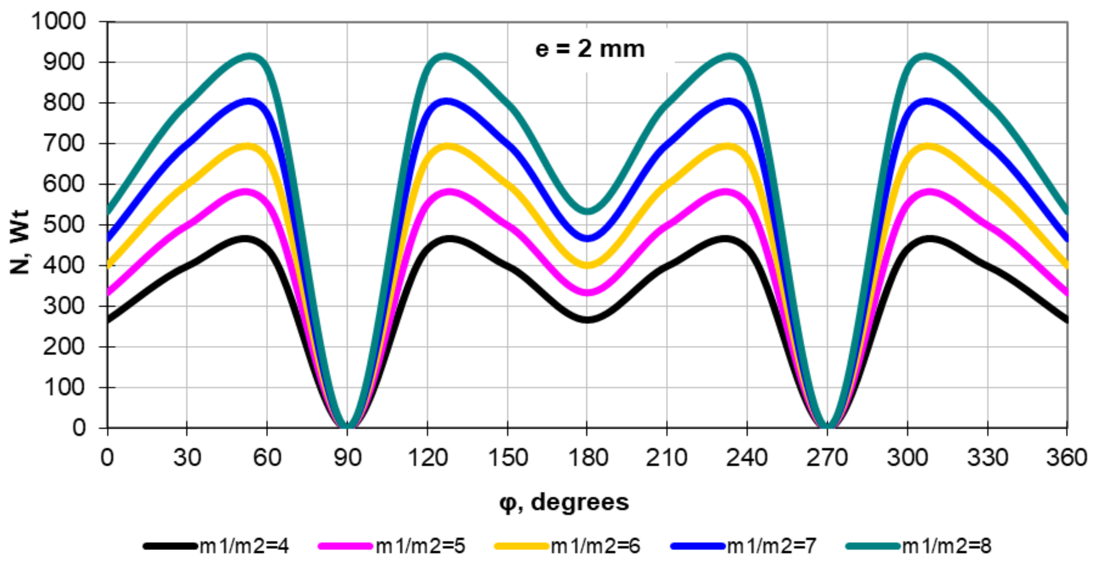

Fig. 3 Dependencies of power consumption for providing the working container with oscillating motion when the ratio m1/m2 changes and the eccentricity constant e=2 mm

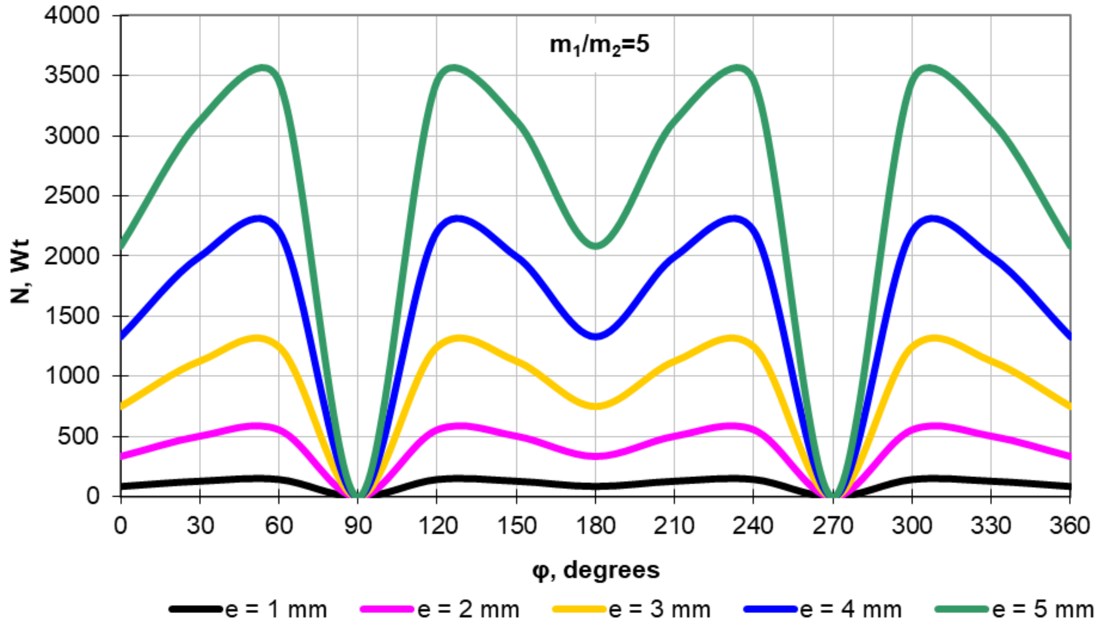

Fig. 4 Dependencies of power consumption for providing the working container with oscillating motion with a change in the eccentricity e and a constant ratio m1/m2 =5

Dependencies of energy characteristics (Figs. 3, 4) indicate that for the working parameters of the vibromassage ω=ωp=50 rad/s and A=Ap=6.5 mm, the eccentricity value e=2 mm and the ratio m1/m2= 5, minimization of power consumption is observed to provide the working container with oscillating motion with sufficient intensification of the mass transfer process in the product mass.

Conclusions. A structural and technological diagram of a vibrating mixer has been developed, which implements kinematic vibration excitation of the movement of the working container, which, thanks to the reduction of oscillating masses, makes it possible to reduce the power consumption for the process by 1.5–2 times.

The main operating parameters of the oscillating system under study are substantiated: angular speed of the drive shaft ωp=50 rad/s; vibration amplitude Ap=6.5 mm, the eccentricity of the drive shaft e=2 mm and the mass ratio of the container and the kinematic vibration exciter m1/m2=5, under which the minimization of power consumption is observed to provide the working container with oscillating motion with sufficient intensification of the mass transfer process in the products.

On the basis of mathematical modeling, the main operating parameters of the oscillating system under study were determined: angular speed of the drive shaft ωp=50 rad/s; vibration amplitude Ap=6.5 mm, the eccentricity of the drive shaft e=2 mm and the mass ratio of the container and the kinematic vibration exciter m1/m2=5, under which there is a minimization of power consumption to provide the working container with oscillating motion with sufficient intensification of the mass transfer process in the product mass.

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EFFECT OF THE BLENDING METHOD OF PLANT RAW MATERIALS ON THE STATE OF PARENCHYMAL TISSUES OF RED BEETROOT AND PRESERVATION OF BETANINE IN THE DEHYDRATION PROCESS

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Abstract. *When drying red beetroot the main problem is high energy consumption and the destruction of the natural pigment - betanine, which gives this vegetable antioxidant properties. The article presents a new method of preparing plant raw materials for drying in order to preserve betanine - blending. Microstructural studies and IR-spectra studies confirm the influence of organic acids of vegetable raw materials (lemon, rhubarb, tomato), which were used in blending, on the cell membrane of red beetroot, which as a result becomes semi-permeable for the release of moisture during dehydration and reduces the duration of the process during drying. In addition, organic acids of vegetable raw materials partially stabilize betanine. The IR spectra obtained as a result of experimental studies made it possible to identify the fluctuations of the main groups of the main components of plant tissues (water, fibers, hemicellulose, sugars, proteins, acids) and to monitor more subtle chemical changes in red beetroot tissues under the influence of lemon blending.*

Introduction. The processing of agricultural raw materials into food products should ensure the maximum preservation of functionality of original raw materials with minimal energy consumption. One of the most effective methods of technological processing of plant raw materials is drying. Due to this, the duration of plant product storage is significantly increased, the need for storage facilities and costs for packaging and transportation are reduced. However, dehydration processes are energy-consuming. Therefore, it is important to investigate the preliminary preparation of raw materials for dehydration and correctly choose the technical parameters of drying, which can ensure the preservation of biochemical properties and initial nutritional value of plants and reduce energy costs in comparison with existing technologies. That is, the further development and increase in the efficiency of technologies for drying plants, in particular red beetroot, is important. Dried red beetroot are used as a functional powder (a source of betanine, natural vitamins and minerals), and for the production of food dye E-162 for use in the meat, dairy, confectionery, and medical industries.

In most cases, the basis of research is the use of red beetroot to obtain food coloring from its juice. In this case, energy-consuming methods of drying (spraying, sublimation, vacuum) and such auxiliary materials as maltodextrin, xanthan gum are used. The influence of vacuum drying on the preservation of biologically active substances of red beetroot was studied (Sz´ekely D. et al., 2016). Spray and freeze drying and the influence of pH on the stability of microcapsules of red beet extract were investigated (Duenha J. et al., 2018). The influence of preliminary osmotic dehydration on convective drying of red beetroot was studied (Kowalski S.J. et al., 2015). In Malaysia, the method of drying with foaming was used (Ling M. et al., 2018).

Water-soluble red beetroot pigments can be used as a food coloring are betalains found in cell vacuoles, which are structurally and chemically different from anthocyanins, because they contain nitrogen in their structure. Betalains are aromatic indole compounds whose biosynthesis precursor is the amino acid tyrosine. Each of the betalains is a glycoside, that contains sugar and a dye part (Robinson et al., 1963). Synthesis of betalains in aerial parts of plants is stimulated by light. Betalains contain two groups of pigments: red betacyanins and yellow betaxanthins. Their ratio determines the difference in the color of red beetroot. Betanine is the best studied pigment (Gonçalves L. et al., 2012; Guesmi A. et al., 2012), which is also called red beetroot. Preservation of betanine, i.e. the natural color of red beetroot, is the main technological problem, since during long-term storage, red beetroot lose up to 70 % of coloring substances, and under the influence of high temperatures, up to 85 %.

The loss of red beetroot color is due to the hydrolysis of betanine into glucose and betanidin at the site of the double bond near C-11 (Wegler R., 1982). It is known, that even a small change in the acidity of the environment can lead to changes in biochemical processes. This is true not only for reactions involving ions H^+, and for many others, since most biomolecules contain groups capable of ionization. The color of the betadine food coloring is sensitive to the environment pH, therefore, to stabilize red beetroot pigments, it is recommended to change the acidity of the environment to pH = 3 - 5 (Dubinina A.A. et al., 2013) by adding ascorbic, sorbic, citric, acetic, lactic acid, or apple, rowan, sauerkraut juice. Caramel molasses, phosphate and sodium chloride can also be added as stabilizing additives. The stabilizing effect is provided by extracts of grape, cherry and dogwood seeds, tea, decoction of oak acorns. All these methods increase the stability of betaninw, but they have not been widely used in the food and canning industry. Therefore, further search for storage methods of red beetroot pigments during processing is relevant.

The purpose of this study is to determine how exactly the mixing method affects the state of red beetroot parenchymal tissues and the preservation of betanine in the process of drying with the help of microscopy, infrared spectroscopy and spectrophotometry.

Materials and Methods. Parenchymal tissues of red beetroot, tomato, rhubarb and lemon were selected for research. Preparation of samples was done according to the following stages: washing and cleaning of plants; mechanical grinding; mixing red beetroot in certain proportions with plants, that contain organic acids; exposure of the composition for a time equivalent to the time of convective heat drying of the selected plant material (~ 1 hour).

To determine the pH of the samples, the prepared plant parenchyma tissues and their compositions were transformed into a liquid porridge-like mass with the help of a blender, which was filtered through filter paper. The acidity of the filtered solution was measured according to the method (Nelson D.L. et al., 2008), using a pH-meter, that has glass electrodes, that are extremely sensitive to H+ ions but not to other cations.

The Light microscope Axio Imager Z1M (Carl Zeiss, Germany) transmission microscope equipped with a micro photography camera was used to study the effect of organic acids on the cell membrane of red beetroot.

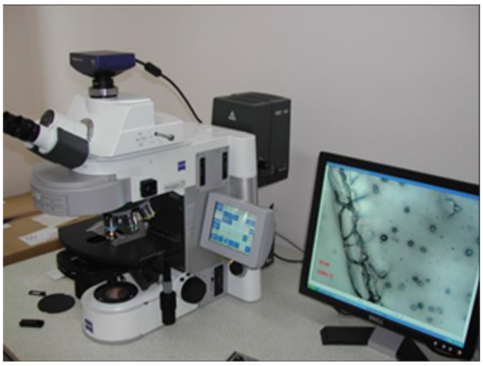


Fig. 1. Light microscope Axio Imager Z1M (Carl Zeiss, Germany)

The device was put into operation by the Institute of Engineering Thermophysics of the National Academy of Sciences of Ukraine in 2008 under the program of centralized acquisition of imported scientific instruments and equipment at the expense of budget funds of the National Academy of Sciences of Ukraine. In 2019, the device was modernized.

Axio Imager Z1M - universal motorized light microscope, which equipped with lenses with a flat field EC image «Plan-Neofluar» 5x/0,16 M27; 10x/0,3 M27; 20x/0,5 M27; 40x/0,75 M27; 100x/1,30 Oil M27; IC2S- optics of ultra-high resolution and contrast; a set of fluorescent light filters.

The study of internal chemical changes in red beetroot tissues was carried out by IR spectroscopy of disturbed total internal reflection on an IR Fourier spectrometer with standard grading capabilities. Experiments were conducted in transmission format, in the wave range 4000…400 $см^{-1}$. Infrared spectra were recorded on a spectrometer Vertex 70 firm Bruker with KBr beam refractor and RT-DLaTGS detector at room temperature (20 ± 1^{o}C). 16 scans of each spectrum with a resolution of 2 cm^{-1} were averaged. Bruker Optics software version 6.0 was used for data processing.

The betanine content in parenchymical tissues of untreated and blended red beetroot was determined by direct spectrophotometry (Florian C. et al, 2006). Betanine, a water-soluble pigment, therefore it was extracted from red beetroot parenchymical tissues with water until the weight was completely decolorized. On a spectrophotometer SF-26, in a cuvette with a layer thickness of 10 mm, the optical density of the obtained solution was determined at a wavelength of 530-536 nm, which was converted to the extinction coefficient for 1% of the solution under study according to the formula:

$$D_{1sm}^{1\%} = \frac{D \cdot v}{a \cdot 100}, \qquad (1)$$

where *D* - indicator of the optical density of the investigated solution at a wavelength of 530-536 nm; *a* - weight, g; *v* - volume of aqueous extract after complete decolorization of the sample, ml; 100 in the denominator - conversion to 1% solution.

Knowing the extinction coefficient for a standard aqueous solution of pure betanine and the test solution, the betanine content *C* in the experimental samples was calculated in percent, according to the formula:

$$C = \frac{D_{1sm}^{1\%} \cdot 100}{D_{st-1sm}^{1\%}} = \frac{D \cdot v \cdot 100}{a \cdot 100 \cdot D_{st-1sm}^{1\%}} = \frac{D \cdot v}{a \cdot 1100}, \qquad (2)$$

where $D^{1\%}{}_{st\text{-}1sm}$ = 1100 - extinction coefficient for a standard solution of pure betanine; 100 in the numeral - recalculation in %.

This technique makes it possible to estimate the content of dyes in red beetroot in objective units, in terms of betanine, in contrast to previously used methods that helped to estimate the content of dyes in conditional cobalt units of enine, cyanide or amaranth.

Results and discussion. Difficulties in drying plant raw materials are related to the fact that under the influence of heat treatment, light, oxygen in the air, pH of the environment, losses of biologically active substances (betanine of red beetroot) occur, therefore, to determine the most promising ways, the development and improvement of new methods of preparing raw materials for drying. The environment pH is important and should be in the range of 3.7-4.2 (Pavliuk R. Yu. et al., 2008; Petrova et al., 2018).

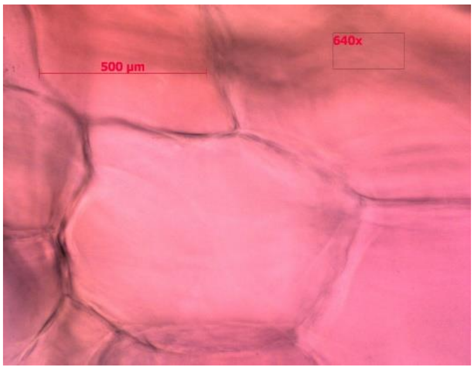
As it was indicated above, scientists are constantly engaged in research on the processing of red beetroot into a dry product in order to obtain a useful food powder with a high content of betanine (Telezhenko L. N., 2004; Pavliuk R. Yu. et al., 2008; Kowalski S.J. et al., 2015; Sz´ekely D. et al., 2016; Duenha J. et al., 2018; Ling M. et al., 2018; Kerr L. W. et al., 2020; Szadzińska Ju., et al., 2020). In Ukraine, scientists (Telezhenko L.N., 2004) developed a method of reducing the pH of red beetroot at the stage of preparation for drying by adding whey, citric acid and lemon balm (for flavor). Red beetroot juice is most of the researches.

In previous studies, scientists of Institute of Engineering Thermophysics developed and investigated the preliminary preparation of red beetroot for drying, namely hydrothermal treatment in an acidified environment (Petrova et al., 2018). This method allows to preservation of betanine at the level of almost 96 % with a fairly long shelf life, but it is energy-consuming and takes a lot of time. Also, this method is energetically impractical to use on an industrial scale.

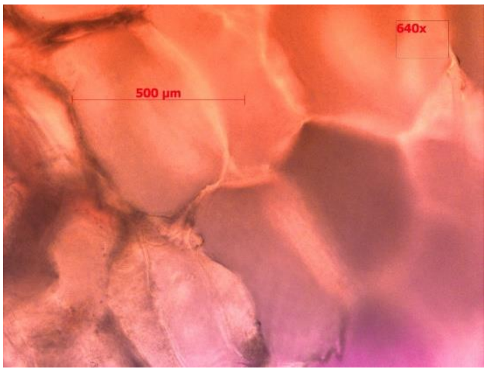
Therefore, at the stage of preparation for drying, it was proposed to create functional compositions based on red beetroot with the addition of plants, that contain organic acid (Petrova et al., 2018). When reviewing the literature, no such method was found.

After that it was investigated the effect of such mixing on the drying process, heat of dehydration and thermal stability of components and plant composition investigated. The conducted experiments showed that: with the correct selection of compositions and the use of a graded drying mode (100/60ºC), the rate of dehydration of a mixture of red beetroot and rhubarb (2:1) is 10 %, and red beetroot and tomato (3:1) is 40 % higher, than the average rate of dehydration of red beetroot tissues; specific heat consumption for water evaporation from red beetroot-based compositions with the addition of tomato (3:1), rhubarb (2:1) and lemon (3:1) decreased by 4-5 % compared to only red beetroot; mixing red beetroot with rhubarb (2:1) leads to the almost complete disappearance of the peak of thermal destruction of beet tissues at 210 °C (Sniezhkin Yu.F. et al., 2013; Sniezhkin Yu.F. et al., 2022). These methods confirmed the interaction of organic acids on the permeability of the red beetroot cell membrane.

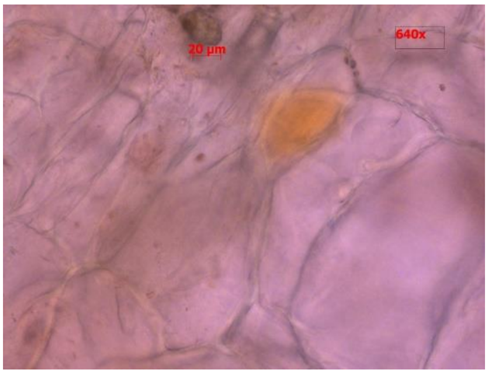
In fig. 2 presents electron-microscopic photographs of sections of parenchymical tissue of red beetroot untreated and blended with tomato and rhubarb in different proportions. In photo 2*a*, shows the rounded convex cells of red beetroot, which are surrounded by a clearly visible cell membrane. In the photos of red beetroot tissues, that were mixed with tomato and rhubarb, observed different degrees of damage to cell membranes. These damages are more significant, when the direction of pH movement is towards an acidic environment.



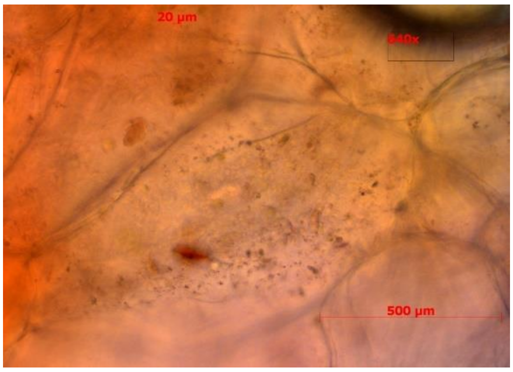
a) pH=6.26



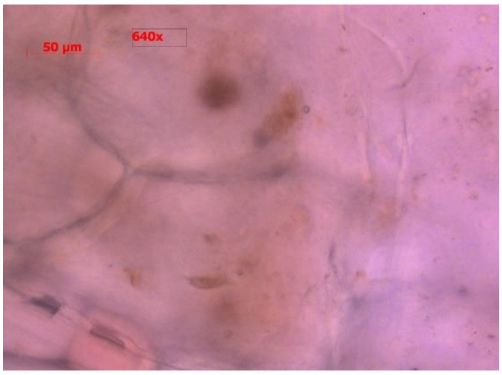
e) 4:1, pH=5.2



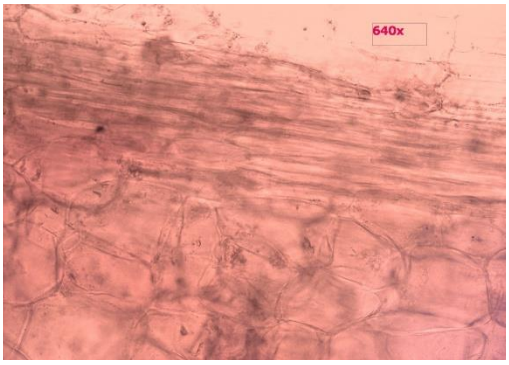
b) 3:1, pH=3.9



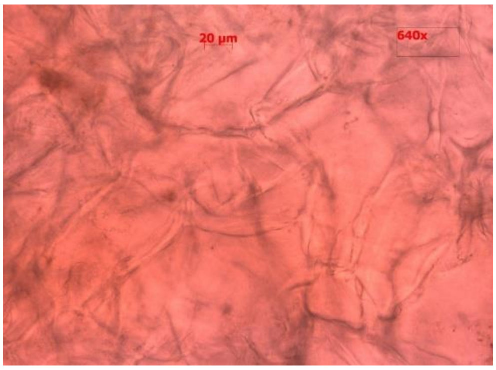
f) 3:1, pH=4.9



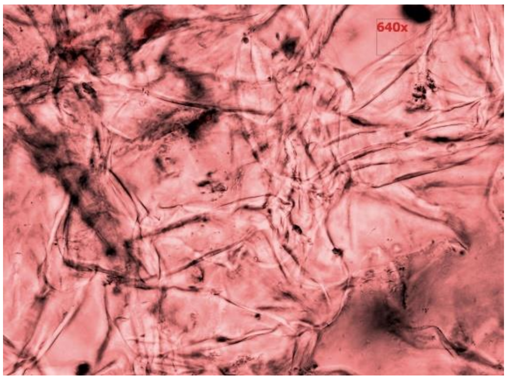
c) 2:1, pH=2.5



g) 2:1, pH=3.75



d) 1:1, pH=2.3



h) 1:1, pH=2.6

Fig. 2. Microphotographs (x 640) of parenchymical tissues of the fresh red beetroot *(a)* and red beetroot which was blending to tomato *(b, c, d)* and rhubarb *(e, f, g, h)* in different ratios

One of the properties of the cell membrane is its selective permeability. The membrane is ultra microporous, the holes in it are so small that molecules of small sizes, for example, water molecules, can pass through them (albeit with some effort). Larger molecules, such as sugar, cannot pass through the pores of the shell. Thus, it is, as it is customary to say, semi-permeable. The semi-permeability of the cell membrane complicates diffusion and physical processes in food production and must be taken into account when developing technologies.

To stabilize betanine during red beetroot processing, it is nesessary to change the pH of its cell environment to acidic, to pH=3.7 - 4.2 (Telezhenko L. N., 2004). To increase the permeability of the cell membrane of red beetroot tissues and change the cytoplasm pH, a certain irritating action is required. No matter, what stimulus is applied to the cell (mechanical damage, high temperature, electric current, etc.), the reaction of its shell is always the same: the orientation of the lipid layer is destroyed, colloidal micelles stick together into large aggregates, between which large passages are formed, which leads to increase in membrane permeability.

To irritate red beetroot cell membranes, it was used other plant materials with a sufficient content of organic acids: rhubarb (pH=4.5), tomato (pH=4.4), lemon (pH=3.0), which were mixed in different proportions with red beetroot (pH=6.26). Organic acids of the selected plants became an irritating factor for red beetroot cell membranes and, at the same time, changed the pH of its cellular environment to acidic. As we can see from fig. 2*e*, when creating a composition of 4 parts of red beetroot and 1 part of rhubarb, the effect of rhubarb juice on the cell membranes of red beetroot parenchymical tissues is insignificant. With a decrease in the proportion of red beetroot to 3:1, the acidity of the mixture changed insignificantly (pH=4.9), but the cell membranes of the red beetroot had already begun to break down (Fig. 2*f*). At a ratio of 2:1 (Fig. 2*g*), there was already an obvious effect of rhubarb oxalic acid on the membranes of red beetroot cells, which led to an increase in the marginal permeability of the membranes and a decrease in their barrier function. Substances were able to diffuse more freely inside the plant tissue and interact in a variety of ways, significantly changing the acidity of the intracellular environment (pH=3.75). When the ratio of components is 1:1 (Fig. 2*h*), completely destroyed cell membranes. This destruction enabled a number of chemical reactions, that interfered with the membranes and led to an increase in the acidity of the environment (pH=2.6) far beyond the level of acidity of the individual components of the mixture. In addition, due to the ruptured membranes, all substances were able to flow out of the tissues together with cell juice. And this leads to the loss of biologically active substances, including betanine, and significantly worsens the quality of finished products. So, from the conducted experiment on determination of pH and those shown in fig. 2 photo shows, that the partial increase in the permeability of red beetroot cell membranes, need to increase its acidity to pH=3.75 can be achieved by creating a red beetroot-rhubarb composition in the ratio 2:1.

A similar pattern is observed for red beetroot tissues blended with tomato. But here the cell membranes of the red beet are partially damaged already at the ratio of the components of the composition of 3 parts of red beetroot to 1 part of tomato (Fig. 2*b*). There is an obvious effect on the membranes of tomato organic acids, which already at this ratio increased the acidity of the medium to pH=3,9. When combining 2 parts of red beetroot and 1 part of tomatoes, there was already noticeable destruction of cell membranes (Fig. 2*c*). When the ratio of plant tissues is 1:1, then the destruction of almost all cell membranes, and complete mixing of intracellular components (Fig. 2*d*). Therefore, it is possible to damage the red beetroot cell membranes only partially and increase its acidity to the required pH 3.7 - 4.2 by creating a beet-tomato composition in the ratio 3:1.

The obtained IR spectra (Fig. 3) made it possible to identify the fluctuations of the main groups of the main components of plant tissues (water, fiber, hemicellulose, sugars, proteins, acids) and to monitor more subtle chemical changes in red beetroot tissues under the influence of lemon blending.

Spectra of parenchymical tissues of lemon, red beetroot and red beetroot which were kept in a mixture with lemon in a ratio of 5:1 (pH=4.6), 3:1 (pH=3.8) and 1:1 (pH=2.1), are generally similar.

The influence of the blending process is evident in the details. As part of a wide high-frequency band of reduced transmission with a maximum in the region of 3310 cm^{-1}, there are bands of valence vibrations of NHn and OH groups of all major biocomponents, with a preference for valence vibrations of OH groups of water. The band in the region of 1750...1540 cm^{-1} belongs to the vibrations of carbonyl C=O groups and indicates the presence of free carboxylic acids and protein components in the samples.

This band in the spectrum of lemon has practically no shoulder corresponding to vibrations of protein components. In the spectra of red beetroot this shoulder is clearly expressed. With an increase in the amount of crushed lemon in which the red beetroot tissue was immersed before the study, this shoulder decreases, which indicates the degradation of the protein components of the red beetroot tissue, i.e. destruction of intracellular protein membranes in it.

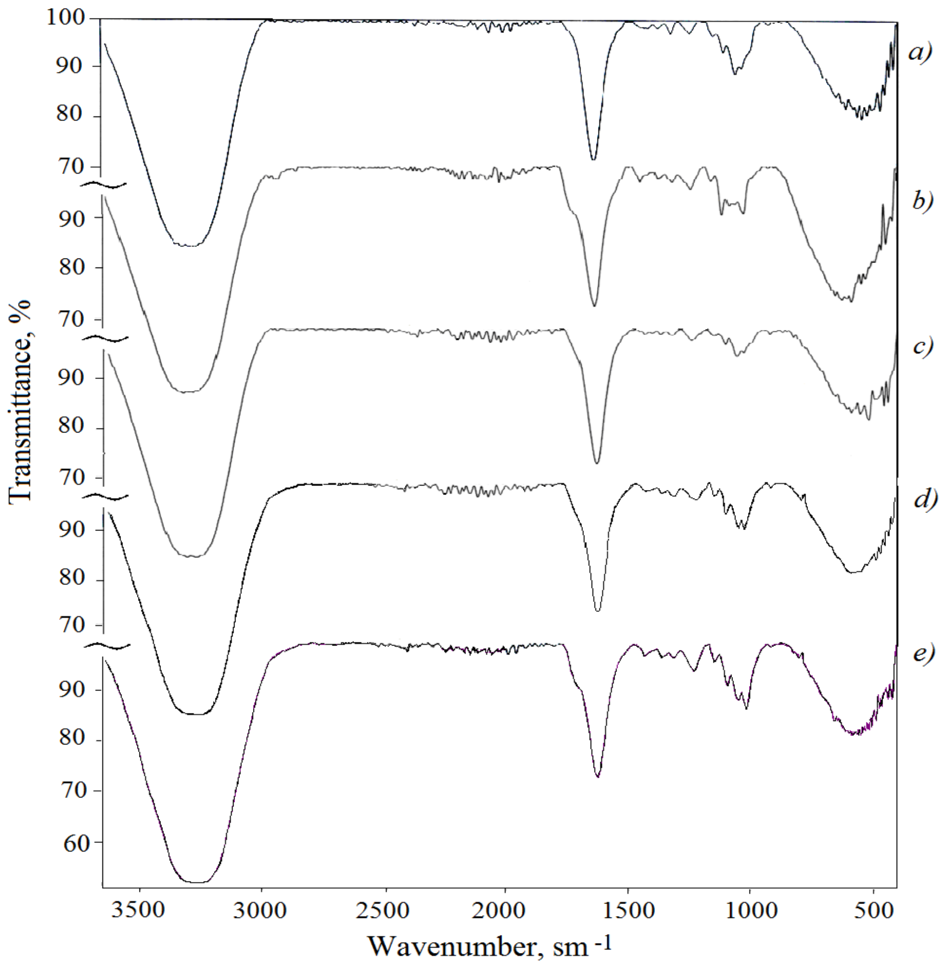
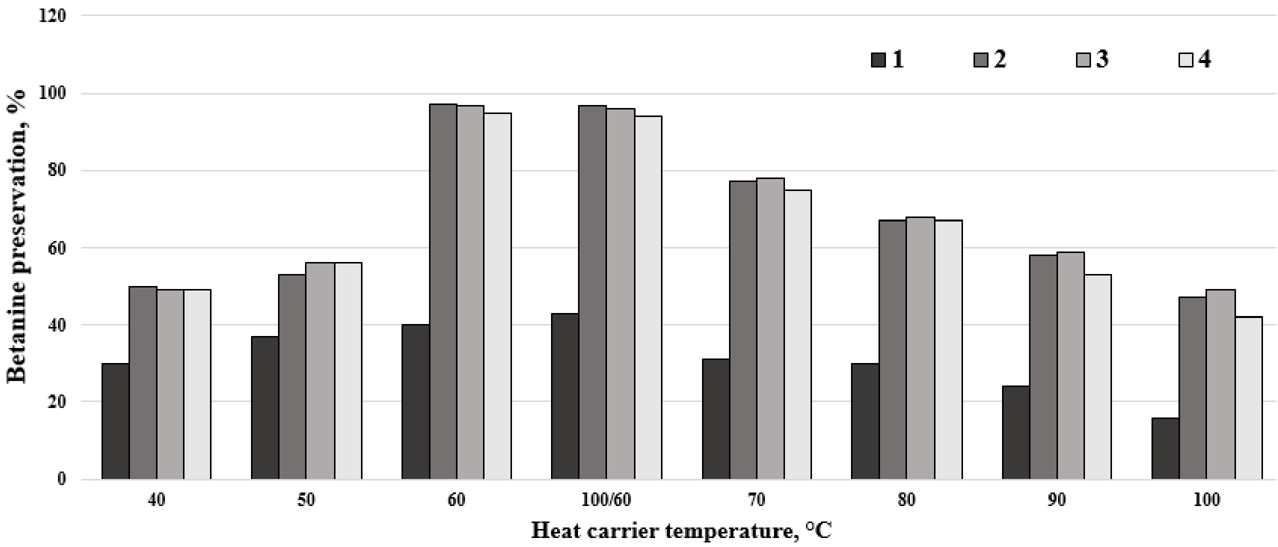


Fig. 3. Infrared spectra of parenchymical tissues of lemon *(a)*, beetroot *(b)* and beetroot, which was blending with a lemon in a ratio of 5:1 *(c)*, 3:1 *(d)*, 1:1 *(e)*

The complex band at 1400...990 cm^{-1} corresponds to vibrations of the C–O bonds of mono-, oligo- and polysaccharides. It is already very different in shape in the spectra of lemon and beet due to the different composition of their saccharides. From Fig. 3*b* and 3*c* it is observed, that after blending the shape of this band in the spectrum of red beetroot has changed significantly. This can be explained by the fact that some of the C–O bonds in the red beetroot polysaccharides were destroyed, which caused the polysaccharides to disintegrate into smaller fragments, i.e. changes in the qualitative composition of saccharides in beet tissue. With an increase in the amount of crushed lemon in which the red beetroot tissue was immersed before the study (from 1:1 to 5:1), this band also significantly (almost 3 times) decreased in area and intensity (Fig. 3 c, d, e). This indicates a more significant destruction of C–O bonds, i.e. significant destruction of the polysaccharide cellular framework of red beetroot tissues. This result is quite consistent with the results of our microscopic study.

Destruction of the polysaccharide framework and degradation of protein shells naturally leads to a decrease in the number of centers capable of retaining moisture inside beet tissue. Water partially passes from a bound state to a free state. This is evidenced by a change in shape and a significant decrease in the intensity and area of the complexly structured band 900 - 400 cm^{-1} in the spectrum of red beetroot after blending (compare fig. 3 b and fig 3 c, d, e). It is in this band that deformation vibrations of various water associates manifest themselves.

The effect of acid blending on the preservation of betanine was investigated depending on the temperature of the heat carrier, after thermal convective drying of red beetroot and compositions based on it (Fig. 4).



1 – red beetroot are not processing, 2 – red beetroot-lemon (3:1),

3 – red beetroot-rhubarb (2:1), 4 – red beetroot-tomato (3:1)

Fig. 4. Dependence of betanine preservation on heat carrier temperature for drying

Fig. 3 shows, when drying unprepared red beetroot, betanine is kept at the level of 30 - 40 % in all the investigated drying modes. The production of compositions allows you to increase the preservation of betanine in the dry product by 1.5 - 2 times at any temperatures of the heat carrier during drying. At a coolant temperature of 40 - 50 °C and its high moisture content, even blended red beetroot spoils, and betanine after drying is stored for no more, than 50 %. The same results are obtained by drying at temperatures of 90 - 100 °C, in this case, significant thermal decomposition of betanine occurs. The maximum, 96 – 97 % betanine preservation was achieved after drying the composition at a heat carrier temperature of 60 °C and a step mode of changing the heat carrier temperature 100/60 °C (). Separately, it should be noted, that the composition of red beetroot with tomato made it possible not only to preserve betanine in the dry product at a high level, but also to enhance its red color due to the chemical interaction of the components of this mixture.

Conclusions. The conducted research made it possible to track changes in red beetroot parenchymical tissues under the influence of mixing with crushed rhubarb, tomato, and lemon parenchymical tissues: disruption of cell membranes due to the degradation of protein and polysaccharide structures and complex changes in water associates due to the degradation of water-retaining centers.

We consider the most likely reason for the obtained results to be a change in the structure and composition of the components of the mixture under the conditions of blending with plants that contain organic acids. The proposed method of changing the pH of the environment led not only to a change in the permeability of the cell membranes of red beetroot tissues and a decrease in the number of water-retaining centers, but also to the stabilization of betanine.

The developed vegetable compositions based on red beetroot are a fundamentally new material that stabilizes and protects red beetroot betanin at the biochemical level from the effects of high temperatures during convective heat drying. Compared to the components of the compositions, this material has a lower heat of vaporization and increased thermal stability. That is, the creation of plant compositions at the stage of preparing plants for drying made it possible to reduce energy costs for the process of their dehydration and preserve the maximum amount of biologically active substances.

The studied compositions can be used in the mass production of functional powders, which are an available source not only of food pigments, but also of natural vitamins and minerals to strengthen human immunity during epidemics and exacerbations of viral diseases.

As a result of these developments and research, when it was possible to preserve the betanine of red beetroot as much as possible, a quick-cooking dry borscht was developed, that does not require a cooking process and is actively used by the soldiers of the Armed Forces at the front.

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THE PROSPECTS OF USING LACTOBACILLUS DELBRUECKII FOR APPLE JUICE FERMENTATION

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Abstract. *Functional foods are a crucial component for maintaining individuals' well-being and nutrition in individuals with specific constraints, for example, gastrointestinal issues, intestinal disorders, lactose and gluten intolerance. The ability to modify the composition of food products by lactic acid bacteria (LAB) fermentation processes makes it possible to obtain functional products that could be the basis of healthy or wellness nutrition. The study examined the potential use of Lactobacillus delbrueckii for the fermentation of apple juice and investigated the organoleptic properties, as well as the concentration of macro- and microelements, total acidity, and vitamin C content. Organoleptic indicators are better in fermented juices than in non-fermented ones because they have a richer taste and aroma. The apple aroma is less strong in the sample without glucose added at the beginning of fermentation than in the sample with glucose added at the beginning of fermentation. The work showed that fermented L. delbrueckii apple juice with pre-added glucose at a final concentration of 2% before the start of fermentation, has more potassium and vitamin C content than unfermented juice. There was no significant influence on the content of magnesium and glucose in fermented apple juice. During fermentation, the total acidity of fermented apple juice with pre-introduced glucose decreased by 12%. The obtained results indicate that adding glucose at the beginning of fermentation allows for better modification of the final properties of the juice. It has been demonstrated that this method could be used to develop a functional product based on apple juice.*

Introduction. Functional foods are not only an essential component of a healthy diet, but also have potential for use in the treatment of a variety of chronic diseases. Furthermore, functional products help maintain a healthy balance of vitamins, minerals, antioxidants, fiber, phenolic compounds and omega-3 fatty acids in the diet of people with restrictions, such as lactose intolerance and celiac disease (Arshad et al, 2021).

One example of functional products can be apple juice fermented by lactic acid bacteria. Due to fermentation processes, apple sugar is transformed into lactic acid, which leads to a sharp sour taste. Furthermore, the fermentation of LAB juice may confer enhanced cellular antioxidant activity and radical scavenging activity (Zhang et al, 2021). The fermentation of apple juice with lactic acid bacteria such as *Lactobacillus plantarum* ATCC14917 increases the content of 5-O-caffeoylquinic acid, quercetin, and phloretin, which are compounds with strong antioxidant properties. Despite a reduction in the total phenolic and flavonoid content, fermentation by lactic acid bacteria can increase the bioavailability of polyphenols in apples, making them more available for consumption as functional food (Li et al, 2018). The range of LAB organisms suitable for juice fermentation includes *Lactobacillus collinoides*, *Oenococcus oeni*, *Pediococcus parvulus*, *Lactobacillus casei*, *Lactobacillus plantarum*, *Lacticaseibacillus paracasei*, or *P. ethanolidurans* (Liang et al, 2022; Guiné et al, 2021; Cousin et al, 2017; Dimitrovski et al, 2015). The research team of Chen S. and co-authors examined the effects of four LAB strains on the distinctive taste profile of fermented apple juice in a study. The diverse assortment of strains included *Lactobacillus acidophilus, L. rhamnosus*, *L. casei*, and *L. plantarum*. In apple juice, all four strains showed good growth ability, but *L. casei* and *L. rhamnosus* showed higher microbial viability and produced higher total acid concentration than the other strains. Lactic acid formation from malic acid was a common feature of the fermented samples. This trend was most obvious in those samples with *L. acidophilus* (Chen et al, 2019).

The fermentation process by lactic acid organisms has a significant impact on the quantity of essential nutrients present in apple juice. During fermentation, changes in organic acids such as succinic acid, tartaric acid, malic acid, and pyruvic acid affect the taste and aroma of apple juice. Also, fermented apple juice has a higher level of polyphenols, such as gallic acid and protocatechuic acid, which makes it more antioxidant. The fermentation process also influences the distinct phenolic compounds present in apple juice and its sugar content (Yang et al, 2022).

Lactobacillus delbrueckii is a probiotic strain of lactic acid bacteria that has been used in yogurt production for hundreds of years. *L. delbrueckii* has an immunomodulatory effect, has beneficial properties for innate and acquired immune responses of the elderly (Moro-García et al, 2013), and has inhibitory properties against other bacteria such as E. coli and Salmonella spp. (Nicdao et al, 2022; Abedi et al, 2013), has the potential to reduce lead toxicity and improve immune function *in vivo* (Evivie et al, 2020). In addition, yogurt prepared using *L. delbrueckii* ssp. Bulgaricus is more effective at improving lactose digestion because it has a higher level of β-galactosidase activity. Several studies have shown that this probiotic strain can improve lactose digestion in people who have lactose malabsorption (Oyeniran et al, 2020).

The importance of developing and implementing functional products for human health and the proven benefits of fermented *L. delbrueckii* dairy products prompted the creation of this study, which sought to create fermented *L. delbrueckii* apple juice and analyze its properties.

Materials and Methods. The main fermentation was conducted in an environment based on fruit juice, which consisted of freshly squeezed apple juice of the Golden variety. The juice was obtained using a home juicer (TEFAL, China). The juice was pasteurized before starting fermentation according to the scheme of double heating to 90°C and sharp cooling to 20°C. The fermentation of a 250-ml volume of juice was carried out in flasks, and glucose was added to one of the samples at a final concentration of 2%. The fermentation was carried out without the use of forced aeration in closed containers without air access. The volume of the container was 80%. The choice of this concentration was based on the goal not to increase the glycemic index of the juice in order to keep it positioned as a dietary product.

In the study, we used a strain of *Lactobacillus delbrueckii* ssp. Bulgaricus isolated from Vivo's commercial yogurt starter, which contained only two strains of *Streptococcus thermophilus* and *L. delbrueckii* ssp. Bulgaricus. *L. delbrueckii* was isolated using repeated streaks by the depletion streak method on MRS (Condalab, Spain) medium at 37°C culture conditions. The purity of the culture was checked by microscopy and Gram staining of cells. Before fermentation experiment the culture of *L. delbrueckii* was previously grown in static anaerobic conditions on liquid MRS (Condalab, Spain) medium for 48 h at 37°. When the culture reached 2 OD (measured by spectrophotometry, UOSLab, Ukraine), it was sterilely added to apple juice in a ratio of 1:50 and fermented for 48 hours at a temperature of 37°C.

The following groups were formed in the studies: group 1 - juice before fermentation, group 2 - juice after fermentation.

Using a spectrophotometer and titrimetric methods, magnesium, glucose, vitamin C, potassium, and total acidity were measured before and after fermentation in two experiments: without pre-added and with pre-added glucose.

The concentration of magnesium was determined by spectrophotometric analysis using xylidyl blue (Chromý et al, 1973), glucose by the glucose oxidase method (Kubihal et al, 2021), and potassium by the turbidimetric method (Tubino et al, 1992).

Iodometric titration was used to quantify vitamin C (Abe-Matsumoto et al, 2020), and acidity was measured using the potentiometric method (MIT, 2019).

The organoleptic properties of apple juice were evaluated using the descriptor-profile method with extended taste indicators according to taste sensations (Lilishentseva and Smoliar, 2019).

All data are presented as medians with interquartile range. For statistical evaluation, Wilcoxson signed rank test has been used in comparison of the control and experimental values of the same group's variables. Statically significant level was set at 0,05.

Results and Discussion. To compare the properties of apple juice before and after two days of *L. delbrueckii* fermentation with and without the addition of glucose, organoleptic indicators, the amount of magnesium, potassium, glucose, vitamin C, and total acidity were compared.

The organoleptic indicators are a key component of comparing apple juice before and after fermentation, with and without the addition of glucose. The results of these indicators are illustrated graphically in Figures 1 and 2.

In the study of organoleptic indicators, it was found that the juice without pre-added glucose after *L. delbrueckii* fermentation loses the apple smell by 45.0% ($p < 0.05$). However, total saturation and salinity increased by 25.0% and 100.0%, respectively ($p < 0.05$). No significant changes in the sensation of sweetness, tartness, and acidity were observed (see Fig. 1).

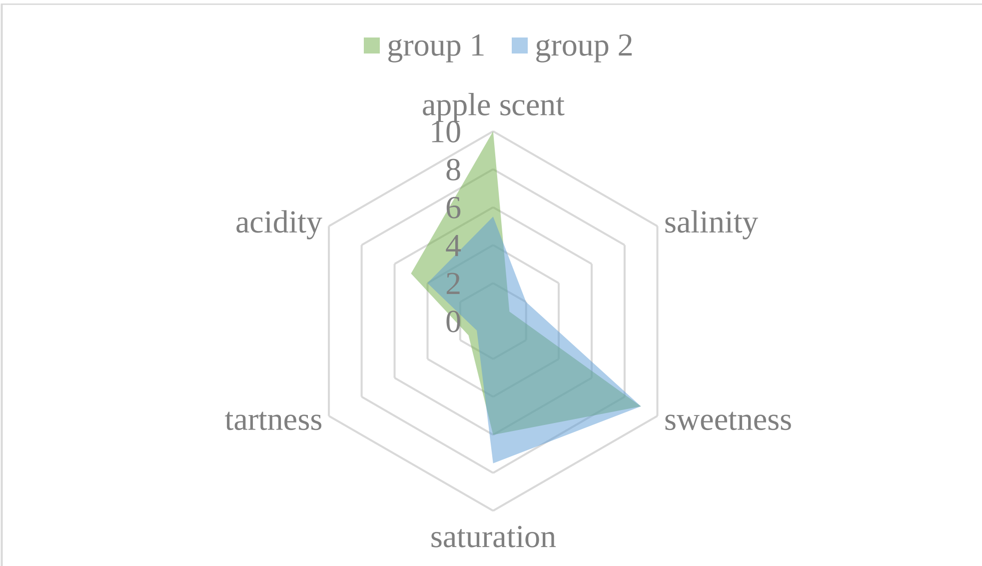


Fig. 1. Organoleptic indicators of apple juice without the addition of glucose before (group 1) and after fermentation (group 2)

When studying the organoleptic properties of fermented *L. delbrueckii* apple juice with the addition of glucose at the beginning of fermentation, it was established that the sensation of saltiness and sweetness decreased significantly – by 100.0% and 12.5%, respectively ($p < 0.05$) (Fig. 2).

Moreover, a significant increase in the apple aroma and overall saturation was observed – by 33.3% and 57.9% ($p < 0.05$) respectively, compared to the original juice. There were no significant changes in the sensation of tartness and acidity (see Fig. 2).

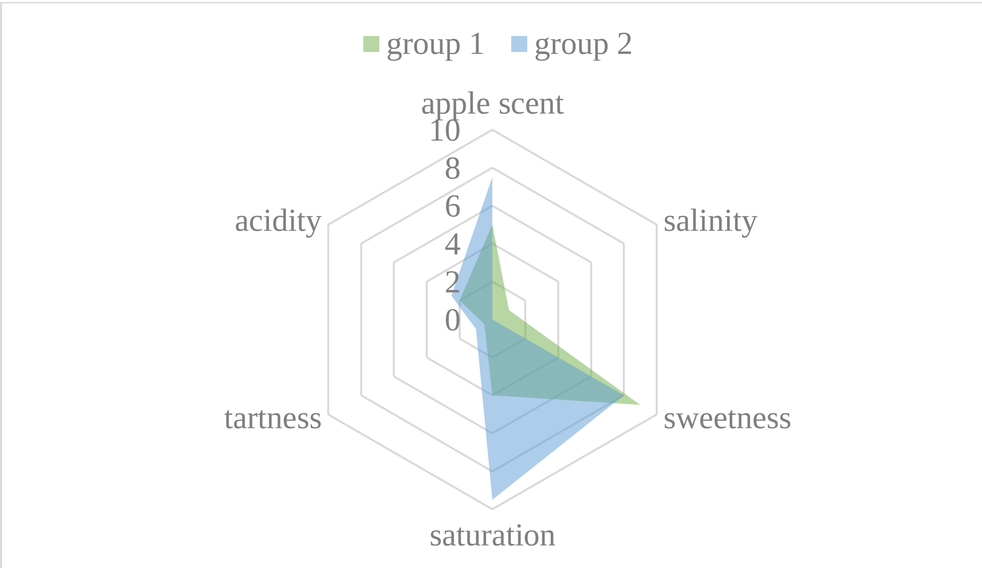


Fig. 2. Organoleptic parameters of apple juice with added glucose before (group 1) and after fermentation (group 2)

The results of the experiment suggest that the addition of glucose to the beginning of the fermentation of apple juice enhances the apple scent and saturation of the juice, thereby improving consumer perception. Without adding sugar at the beginning of the fermentation, the apple scent is lost, but the overall saturation increases. In both versions of the research, acidity indicators did not change. The flavor of fermented apple juice can be stronger than that of regular apple juice. During fermentation, organic acids, like citric acid, can be formed, which can make the product taste sour. Furthermore, fermentation may contribute to the degradation of sugars, which may have impact on the flavor of the product (Swain et al, 2014). Our research suggests that during fermentation, the acidity index does not change reliably, which may be a feature of the *L. delbrueckii* strain. It is possible for lactic acid bacteria to produce specific aromatic compounds, such as ethyl esters, aldehydes, and ketones, which give the product a special smell (Shokri et al, 2020). The rise in the overall concentration of the apple's distinctive scent and flavor after fermentation is a result of the possible accumulation of aromatic compounds, which could explain the observed intensification of the apple's distinctive fragrance.

The amount of glucose in fruit juices is an important indicator. The concentration of glucose in the samples with pre-added and non-added glucose was 5,9 mmol/L and 5.7 mmol/L respectively (see Fig. 3).

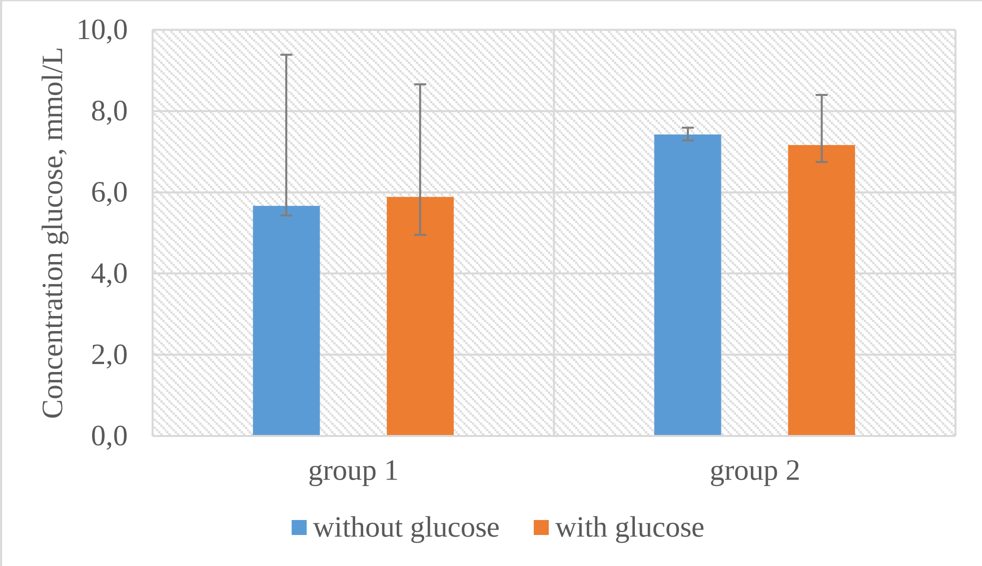
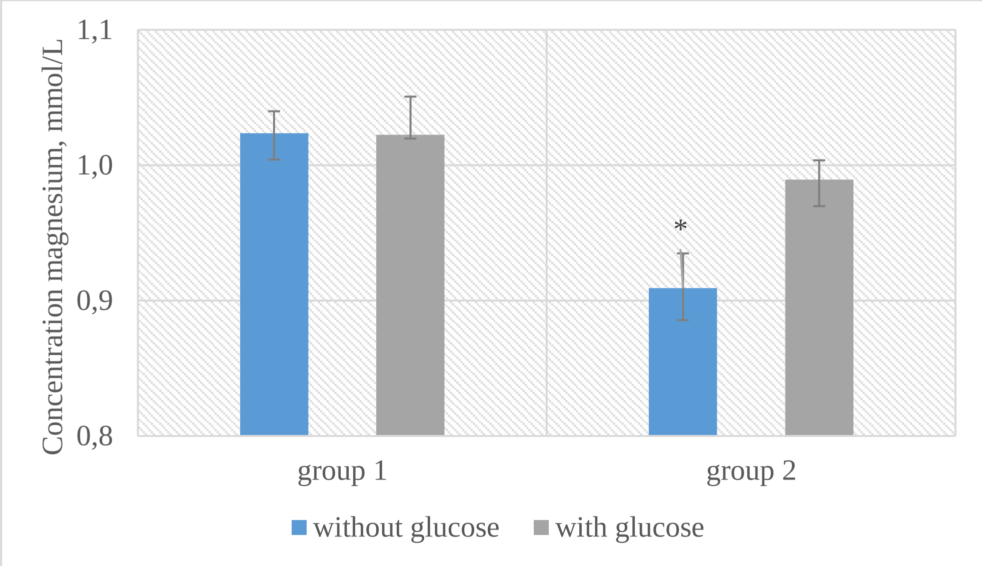


Fig. 3. Glucose concentration in the studied samples of apple juice before (group 1) and after fermentation (group 2)

After fermentation, there was a slight increase in its concentration in the samples with and without glucose before fermentation – 7.2 mmol/L and 7.4 mmol/L respectiveky. This difference in indicators, however, is not statistically reliable. The use of *Lactobacillus delbrueckii* to ferment apple juice could potentially change the sugar content of the drink. Research has shown that this bacterium is capable of quickly consuming the sugar in tomato juice (Kaprasob ey al, 2017), and other fruits, including oranges and apples (Pakbin et al, 2014). A significant decrease in the amount of sugar in the juice occurs only after four days of fermentation, according to another study. *L. delbrueckii* ATCC 9646 was used for apple juice fermentation at 37 °C and pH 6.5. The glucose content significantly decreased after four days of fermentation. Conversely, the sugar content of apple juice did not show significant changes during the first four days of spontaneous fermentation (Al Daccache ey al, 2020). Our research findings align with those found in the existing academic literature. Furthermore, the daily consumption of glucose ranges from 25 to 37.5 grams (138.8 to 205.4 mmol) (Johnson et al., 2009). Based on the obtained results, we can conclude that fermented *L. delbrueckii* apple juice can be a component of a healthy diet.

In two experiments, the magnesium index was analyzed before and after fermentation, without the addition of glucose and with the addition of glucose (see Fig. 4). The magnesium concentration was found to be significantly decreased by 12.6% when using juice without pre-added glucose ($p < 0.05$). But in the juice with the previous addition of glucose, there is no significant change in the magnesium index. The level of magnesium in the juice before fermentation with and without pre-added glucose is at the same level – 1.0 mmol/L.

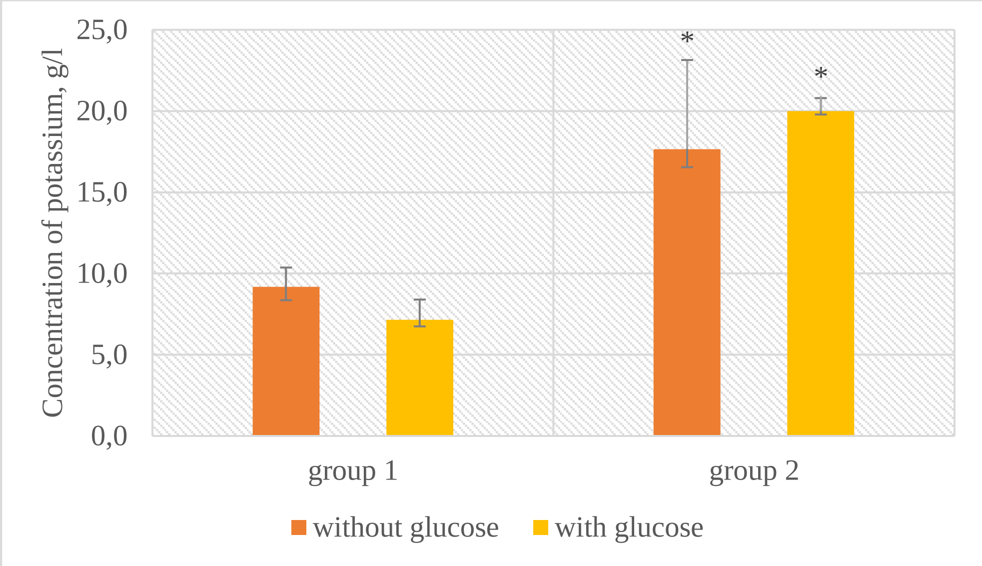


$p < 0.05$

Fig. 4. Concentration of magnesium in the investigated samples of apple juice before (group 1) and after fermentation (group 2)

Magnesium is an important mineral for human health. The presence of a sufficient level of magnesium in the body is associated with a reduced risk of developing cardiovascular diseases, such as hypertension, coronary heart disease, and stroke (Del Gobbo et al, 2013). Furthermore, magnesium has a significant impact on the regulation of glucose and insulin in the body. There is an increased risk of type 2 diabetes and insulin resistance associated with low magnesium levels Magnesium is an essential mineral for maintaining healthy bones and can be beneficial in the prevention of osteoporosis, especially when combined with vitamin D and calcium (Rude et al, 2009). It also plays an important role in the functioning of the nervous system, reducing stress and improving mood and sleep. Magnesium can also have a positive effect on the prevention of depression and anxiety disorders (Serefko et al, 2016). Magnesium affects many other body functions, including energy metabolism, protein synthesis, muscle function, and the immune system (Volpe, 2013). In a study with fermented *L. plantarum* NRRL-D-14768 fruit juices, the magnesium content increases in all the studied juices: in orange, pineapple, pear and tomato juices, except for watermelon juice - the magnesium content decreases from 37.1 mmol/L to 35.4 mmol/L (Zeng ey al, 2021). The results of this study demonstrate the possible consequences of diminishing the concentration of magnesium in the juice, which could be influenced by the composition of the juice. On the other hand, the daily magnesium requirement for an adult is 12,3-14,4 mmol (Fiorentini et al, 2021). In our study, we obtained quite low levels of magnesium. Just like in other studies, we found a pattern of decline in this indicator. It is important to investigate this indicator more deeply and analyze possible ways to preserve it.

The concentration of potassium in fermented juice without and with pre-added glucose was increased by 48.0% and 64.2%, respectively ($p < 0.05$) (Fig. 5).



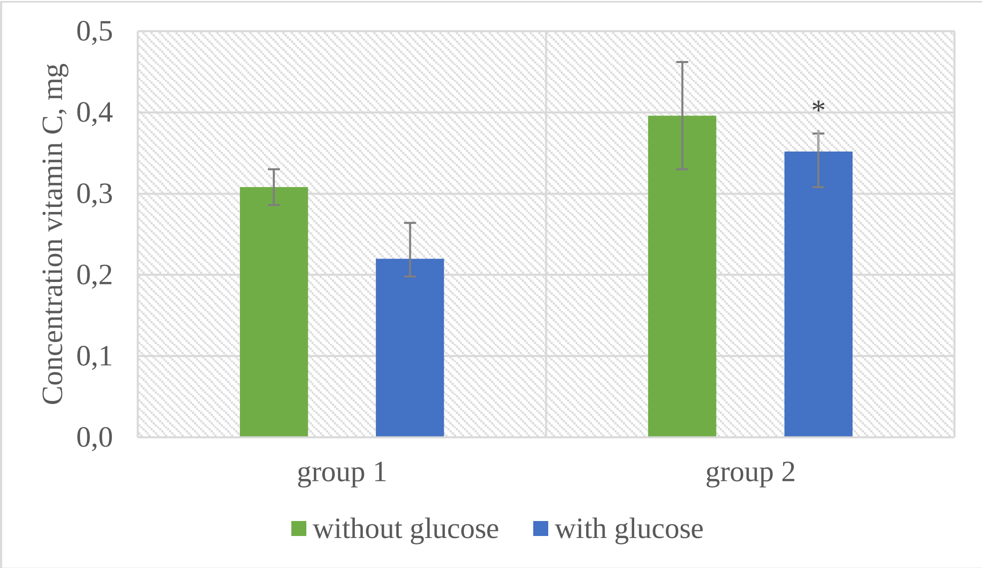
p < 0.05

Fig. 5. The concentration of potassium in the apple juice samples that were studied before (group 1) and after fermentation (group 2)

The addition of glucose to the juice resulted in a slight decrease in the potassium concentration, from 9.2 g/L to 7.2 g/L. However, the increase in potassium concentration after fermentation was greater in the juice with the previous addition of glucose – 20.0 g/L compared to 17.7 g/L in the juice without the previous addition of glucose.

A reduced risk of developing high blood pressure (hypertension) is associated with potassium consumption, which may have a positive effect on heart and blood vessel health (Aburto et al, 2013). Potassium affects the work of muscles, including the heart muscle. It helps ensure normal muscle coordination and contraction (McCartney et al, 2007). A high level of potassium in the diet can help reduce the risk of kidney stones and improve kidney function in people with chronic kidney disease (Siener et al, 2006). Potassium exerts a beneficial effect on the regulation of body fluid levels, thereby promoting a healthy balance of electrolytes. This is particularly important for maintaining normal blood pressure and kidney function (Geleijnse et al, 2003). Potassium can help reduce body fat and increase muscle mass (Kim et al, 2016). The high content of potassium in products has a positive effect on human health. An adult requires 90 mmol of potassium every day (Turck et al, 2016). The resultant fermented juice has more potassium than unfermented juice, even if the juice has additional glucose in it. This presents considerable prospects for the applying of fermented apple juice as an effective therapeutic agent.

An additional indicator determined in the work was the concentration of vitamin C. After adding sugar to the juice, we observed a decrease in the vitamin C content. According to the literature, the effect of glucose on vitamin C is poorly described. There is information about the effect of ascorbic acid on glucose oxidizing enzymes (Lielpetere et al., 2023), as well as the effect of sugars (sucrose, fructose and glucose) in the presence of ascorbic acid on anthocyanins (Gérard et al., 2019). However, we cannot confirm our hypothesis about the possible destruction of vitamin C by glucose when exposed to temperature. This issue requires additional research. The concentration decreased by 37.5% ($p < 0.05$). The concentration of vitamin C was not significantly changed in the sample without the previous introduction of glucose (Fig. 6)



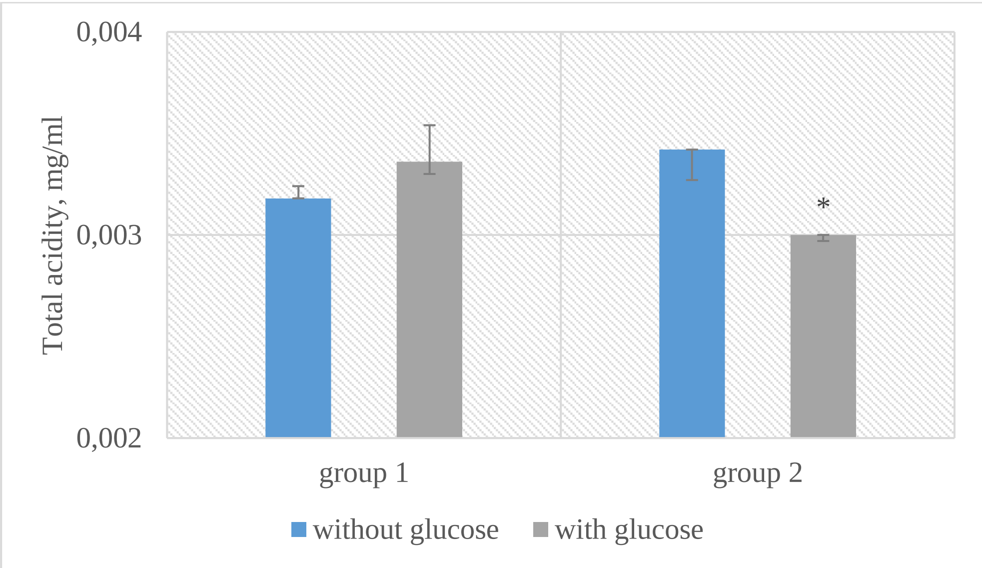
$p < 0.05$

Fig. 6. The concentration of vitamin C in the studied samples of apple juice before (group 1) and after fermentation (group 2)

Vitamin C plays a crucial role in supporting the immune system. It helps to fight against infectious agents by improving the barrier function of the skin and promoting the formation and functioning of immune cells (Carr et al, 2017). Vitamin C is a powerful antioxidant that protects cells from free radical damage and promotes vascular health. It contributes to maintaining a normal tone of blood vessels, reducing the risk of developing cardiovascular diseases, and improving the function of the endothelium (Ashor et al, 2015). Vitamin C plays an important role in the production of collagen, which promotes skin health, delays the aging process, and improves wound healing. Furthermore, it may help to mitigate the harmful effects of ultraviolet radiation and maintain a healthy complexion (Pullar et al, 2017). Vitamin C plays a role in the synthesis of collagen, which is the main component of the bone matrix. It also contributes to the maintenance of bone mineral density and may have a protective effect against the development of osteoporosis (Mosdøl et al, 2010). Vitamin C is involved in the protection of the nervous system, participating in the fight against oxidative stress and protecting neurons from damage. The findings of some studies indicate that vitamin C may improve mood, reduce the risk of depression, and enhance cognitive function (Padayatty et al, 2003).

A decrease in vitamin C content is caused by the fermentation of apple juice by *L. delbrueckii* (Pereira et al, 2011). A temperature of 30-34 °C also negatively affects the process of vitamin C accumulation (Nguyen et al, 2013). In addition to apple juice (Yim et al, 2016), it was also shown that the reduction of vitamin C after fermentation by lactic acid bacteria was also seen in kiwi juice (Kaprasob et al, 2017). The increased content of glucose at the beginning of fermentation may encourage the production of a larger amount of vitamin C. This may be due to the peculiarities of the biosynthesis of vitamin C in *L. delbrueckii*. According to literature, *L. delbrueckii* has been shown to accumulate ascorbic acid during fermentation of sheep milk (Bonczar et al, 2004). It is worth noting that the average daily recommended amount of vitamin C is 90 mg (NIH, 2020). The obtained fermented juice, of course, is not capable of providing such a quantity, since the maximum concentration of glucose in a sample with pre-introduced glucose is only 0.4 mg. The ability of *L. delbrueckii* to accumulate ascorbic acid in the juice with the previous addition of glucose can be used to further develop functional products.

The last indicator that was found for juice samples is the amount of total acidity. During fermentation, it was established that the total acidity in the sample to which glucose was added at the beginning of fermentation was significantly reduced. The decrease is by 12.0% ($p < 0.05$). No significant change in total acidity was observed in the sample without the previous addition of glucose (Fig. 7).



p < 0.05

Fig. 7. The total acidity of the studied samples of apple juice before (group 1) and after fermentation (group 2)

According to scientific studies, the fermentation of apple juice with *Lactobacillus delbrueckii* can result in a decrease in pH, which indicates an increase in the acidity of the juice. Lactic acid bacteria, particularly *L. delbrueckii*, are capable of converting sugars such as glucose and fructose into lactic acid through fermentation. This process contributes to the acidic taste of the juise by lowering the pH (Sossa et al, 2017). One 2017 study looked at the effects of *L. delbrueckii* fermentation on apple juice production. As a result of fermentation, a decrease in pH was observed from 3.8 to approximately 3.4, which indicates an increase in the acidity of the juice. The study also indicated that fermented apple juice had a sour taste because it had lactic acid (Chaves-López et al, 2018). However, in our experimentation, we found the opposite outcome. Total acidity decreased during fermentation, which was not reflected in the organoleptic indicators. The obtained data requires further analysis and research. It may be necessary to supplement the glucose-rich environment with lactose and other sugars to produce acids.

Conclusions. Due to the fermentation process of *L. delbrueckii* apple juice, it is possible to obtain a product with positive organoleptic properties, namely a rich aroma and taste. Adding more glucose at the beginning of fermentation makes the apple taste salty, while adding more glucose at the beginning of fermentation improves the apple scent. In juice with glucose introduced at the beginning of fermentation, there is no decrease in magnesium concentration, but a significant increase in potassium concentration. The concentration of glucose in both types of fermented juices is below the recommended limit. It is observed that juice with pre-added glucose has a greater accumulation of vitamin C. Furthermore, this sample shows a significant decrease in total acidity. Furthermore, the obtained results demonstrate that it is possible to use the bacterium *L. delbrueckii* for the fermentation of apple juice, as it provides more accumulation of potassium and vitamin C. This is also positive for the development of functional products.

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FATTY ACID COMPOSITION IN THE QUAIL'S BLOOD PLASMA UNDER NANOSELENIUM AND PROBIOTICS DIET

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Abstract. *For the prevention and treatment of oxidative stress, adaptogenic and anti-stress drugs are used, aimed at removing or neutralizing the pathogenic factor. Of particular interest is the study of omega-3 and omega-6 long-chain polyunsaturated fatty acids and their transformation into bioactive lipid mediators. Polyunsaturated fatty acids are structural components of biological membranes, substrates of lipid peroxidation and precursors of eicosanoids, the composition of which changes during oxidative stress. According to the gas chromatographic analysis of the blood plasma fatty acid composition, it was established that in birds receiving standard compound feed, an increase in the saturation of serum lipids was observed due to an increase in the content of palmitic ($p<0.01$) and myristic ($p<0.001$) fatty acids, and the sum of unsaturated fatty acids was probably reduced ($p<0.001$) due to the reduced content of essential fatty acids. By adding bionano-selenium to the diet, the relative content of saturated fatty acids decreases in the fatty acid composition of quails' blood plasma phospholipids compared to intact quails. A decrease in the content of monounsaturated fatty acids of the ω-9 family was also recorded. Since phospholipids are the basis of lipoproteins, their fatty acid composition listed above may indicate an improvement in the transport function of blood plasma. At the same time, the amount of cholesterol esterified with fatty acids decreased in the blood plasma of the experimental birds, which in the complex allows us to conclude about the positive effect of the complex drug on the fatty acid formula of blood serum lipids.*

Introduction. The introduction of effective means of prevention and treatment, the etiological factors of which are alimentary factors, is an integral condition for increasing the profitability of poultry farming (Цехмістренко et al., 2019). For the prevention and treatment of oxidative stress, adaptogenic and anti-stress drugs are used, which leads to the optimization of the process of free radical oxidation of lipids (Ahmadi et al., 2018).

The urgency of creating new complex drugs is determined by the insufficient therapeutic effectiveness of existing drugs, as well as a number of side effects from their use. This is, in particular, the occurrence of oxidative stress, which is a non-specific universal appropriate response of the body to damage and promotes the mobilization of protective systems aimed at removing or neutralizing the pathogenic factor, mobilization of antioxidant defense systems and adaptation of metabolism to extreme conditions. Such a reaction is associated not only with the activation of neurohumoral regulation links during homeostasis disturbances, but also with the fact that active oxygen metabolites are signaling molecules that induce the activity of compounds, in particular lipids, involved in biosynthesis and antioxidant protection.

In recent decades, the development of new technologies applied to lipidomics has increased the interest in the study and analysis of lipid profile changes and the understanding of the basic molecular mechanisms of lipid metabolism together with their involvement in the development of human and animal diseases. Of particular interest is the study of omega-3 and omega-6 long-chain polyunsaturated fatty acids (LC-PUFA), in particular EPA (eicosapentaenoic acid, 20:5n-3), DHA (docosahexaenoic acid, 22:6n-3), and ARA (arachidonic acid, 20:4n-6), and their transformation into bioactive mediators of lipids. In this sense, new families of PUFA-derived lipid mediators, including EPA- and DHA-derived resolvins and DHA-derived protecins and maresins, are increasingly being investigated for their active role in "return to homeostasis" and resolution of inflammation (Zhang et al., 2021).Lipids are necessary elements of the diet for providing energy, in particular for beta-oxidation of fatty acids (FA). Fatty acids are the simplest lipids, which, in turn, are components of other, more complex lipids. FAs contain a hydrophilic carboxyl group attached to a hydrocarbon chain ranging from C6 (six carbon atoms) to C32, with an additional terminal methyl group. Most naturally occurring FAs have an even number of carbon atoms and linear hydrocarbon chains, although some of them, found mainly in bacteria, may contain branched or even cyclic structures (Afonyna, Kuyun, 2000; Tsekhmistrenko et al., 2022; Koval′ova & Pasiyeshvili, 2021). In addition, these chains can be presented in two main forms, saturated without the presence of double bonds, or unsaturated, containing one or more double bonds, the latter being more physiologically important due to their medicinal properties. Of particular interest in the unsaturated family are long-chain polyunsaturated fatty substances (LC-PUFA), which can be divided into two main groups - omega-3 (n-3) and omega-6 (n-6), depending on the position of the first double bond from the methyl terminal group of FA. Common LC-PUFAs are EPA (eicosapentaenoic acid, 20:5n-3), DHA (docosahexaenoic acid, 22:6n-3), and ARA (arachidonic acid, 20:4n-6). The optimal substrate for the processes of lipid peroxidation (LP) are unsaturated fatty acids (PUFA) (Bityutskyy et al., 2021; Tsekhmistrenko et al., 2020), and the immediate target of the attack of oxidizing radicals is double bonds in the molecules of these acids (Afonyna, Kuyun , 2000; Tsekhmistrenko et al., 2022; Koval′ova & Pasiyeshvili, 2021).

Reactions of free radical oxidation and the antioxidant defense system (AODS) form the LP–AOD system, which is based on the maintenance of cell homeostasis. In the case of an imbalance of the AOD system, homeostasis disturbances occur, the nature of which depends on the intensity of LP processes, the state of cell membranes, the structural components of which are higher fatty acids and free cholesterol. Polyunsaturated fatty acids are structural components of biological membranes, substrates of LP and precursors of eicosanoids. Studies by many authors indicate changes in the fatty acid composition of blood plasma lipids and erythrocytes during oxidative stress (Afonyna, Kuyun, 2000; Tsekhmistrenko et al., 2022; Koval′ova & Pasiyeshvili, 2021).

Materials and Methods. In the case of studying the biological effect of nanoselenium, 120 Pharaoh breed quails were selected at the age of one day and 2 groups of 60 heads each were formed by the method of analogues. The conditions of keeping quails were the same and corresponded to zootechnical standards. Poultry of the control group (group 1) received complete compound feed. A probiotic preparation with nanoselenium (group 2) was added to the combined feed of experimental groups of poultry by multi-stage mixing. Probiotic and Selenium dosages correspond to established effective amounts according to previous scientific studies. Probiotic and biogenic nanoselenium were synthesized together with scientists of the Department of Interferon Problems and Immunomodulators of the Institute of Microbiology and Virology named after D.K. Zabolotny of National Academy of Sciences of Ukraine. The material for research was blood and blood serum. Lipids were extracted from blood plasma using a chloroform-methanol mixture. Separation of lipids into fractions was carried out on thin-layer silica gel plates in the solvent system hexane : diethyl ether : glacial acetic acid (85 : 15 : 1). Detection of individual fractions of lipids on both plates was carried out in iodine vapor. The identification of lipid fractions on the plates was carried out using standard lipids with the degree of purification of ChC. According to the results of thin-layer chromatography, the content of individual classes of lipids of the first plate was calculated according to the formula with correction coefficients for each studied fraction.

Results and Discussion. It is known that during pathological processes accompanied by peroxidation processes of biomolecules, the degree of saturation of fatty acids (FA) of lipids changes, so the ratio of saturated and unsaturated fatty acids in membrane lipids is of great importance for ensuring the functional state of cells (Danchuk et al., 2004). **The aim of our research** was to evaluate the fatty acid composition of blood lipids of birds after the introduction of a complex drug (Table 1).

Table 1.

Fatty acid composition of quail blood plasma phospholipids, % M±m, n=3

Fatty acids, their code and family	Control group	For the addition of bionano-selenium
Caprylic, 8:0	0,12±0,01	0,09±0,01*
Capric, 10:0	0,24±0,01	0,20±0,01*
Lauric, 12:0	0,34±0,01	0,28±0,01*
Myristic, 14:0	0,56±0,01	0,50±0,01*
Pentadecanoic, 15:0	0,38±0,01	0,32±0,01*
Palmitic, 16:0	8,85±0,04	8,25±0,17*
Palmitoleic, 16:1 ω-7	0,91±0,02	0,88±0,01
Stearic, 18:0	10,24±0,14	9,23±0,23*
Oleic, 18:1 ω-9	33,15±0,84	30,44±0,88*
Linoleic, 18:2 ω-6	14,98±0,45	15,34±0,49
Linolenic, 18:3 ω-3	6,68±0,21	6,97±0,23
Arachinic, 20:0	0,28±0,01	0,23±0,01*
Eicosaenoic, 20:1 ω-9	0,24±0,01	0,22±0,01
Eicosadienoic, 20:2 ω-6	0,30±0,01	0,32±0,01
Eicosatrienoic, 20:3 ω-6	1,17±0,01	1,31±0,04*
Eicosatetraenoic (arachidonic), 20:4 ω-6	5,34±0,06	5,96±0,14*
Eicosapentaenoic, 20:5 ω-3	1,65±0,02	1,82±0,04*
Docosadienoic, 22:2 ω-6	0,97±0,03	1,22±0,05*
Docosatrienoic, 22:3 ω-3	1,26±0,02	1,43±0,05*
Docosatetraenoic, 22:4 ω-6	2,37±0,10	3,05±0,11*
Docosapentaenoic, 22:5 ω-3	4,47±0,18	5,45±0,16*
Docosahexaenoic, 22:6 ω-3	5,50±0,16	6,48±0,17*

The gas chromatographic analysis data of the blood plasma fatty acid composition show that in the birds of the 1st group (control) there is an increase in the saturation of serum lipids due to an increase in the content of palmitic ($p<0.01$) and myristic ($p<0.001$) fatty acids, and the sum of unsaturated fatty acids was probably reduced ($p<0,001$). An increase in the content of palmitic acid indicates the intensification of LP processes and the accumulation of lysoforms of the lecithin fraction of phospholipids. The level of PUFA was probably reduced in comparison with the indicators of the birds of the 2nd group (experiment) due to the reduced content of essential fatty acids (linoleic and linolenic).

Therefore, the fatty acid formula of blood serum lipids of quails of the 1st group is characterized by increased hydrogen saturation of the lipid complex against the background of a deficiency of certain PUFAs, which is a compensatory reaction, because it is saturated fatty acids that are less susceptible to peroxidation processes (Lyzohub et al., 2003).

It was recorded (Fig. 1) that addition of bionano-selenium in comparison with intact quails changes the fatty acid composition of the quails blood plasma phospholipids by decreseing of the relative content of FA with even (caprylic, capric, lauric, myristic, palmitic, stearic and arachinic) and odd (pentadecanic) number of carbon atoms in the chain.

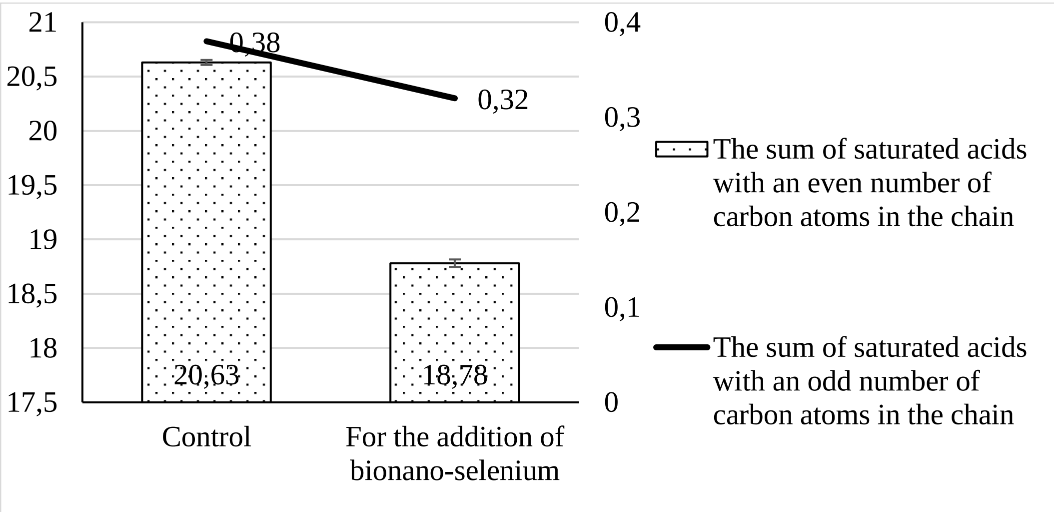

Fig. 1. Content of saturated acids in quail blood plasma phospholipids with even and odd number of carbon atoms in the chain

A decrease in the content of monounsaturated fatty acids of the ω-9 (oleic) family was recorded (fig. 2), but an increase in polyunsaturated fatty acids of the ω-6 (eicosatrienoic, eicosatetraenoic, arachidonic, docosatetraenoic) and ω-3 (eicosapentaenoic, docosatrienoic, docosapentaenoic, and docosahexaenoic) families.

At the same time, the content of long-chain and unsaturated derivatives of linoleic (1.48 vs. 1.29) and linolenic (0.52 vs. 0.46) acids increases in the fatty acid composition of quail blood plasma phospholipids due to the addition of bionanoselenium. Since phospholipids are the basis of lipoproteins, their fatty acid composition listed above may indicate an improvement in the transport function of blood plasma (Hopanenko & Rivis, 2015).

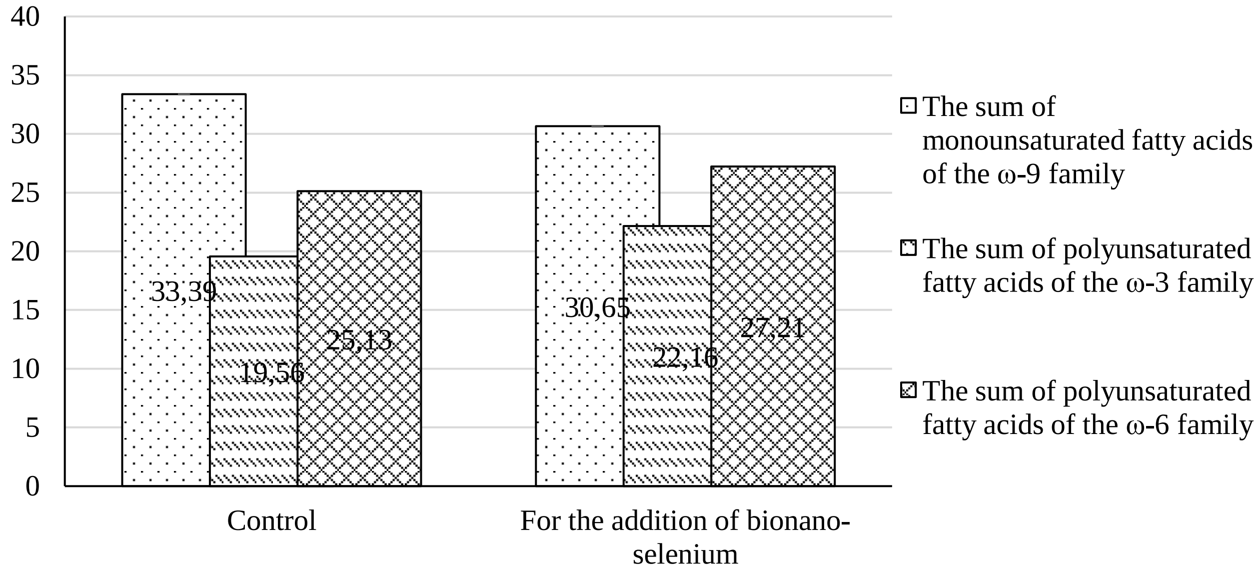

Fig. 2. The content of unsaturated acids of the ω-3 ω-6 and ω-9 families in the composition of quail blood phospholipids

The detected state of the fatty acid composition of lipoproteins in the blood serum of quails injected with sodium selenite is a consequence of the intensification of LPO processes and leads to a violation of the metabolism of fatty acids at the stage of eicosanoid formation, which is consistent with literature data (Afonyna, Kuyun, 2000; Tsekhmistrenko et al., 2022; Koval′ova, & Pasiyeshvili, 2021). Under stress, the concentration of individual PUFAs in cell membranes increases significantly. One of the important functions of PUFA is the synthesis of eicosanoids, the substrate of which is arachidonic and linoleic fatty acids. Metabolites of arachidonic acid – prostaglandins, thromboxanes and leukotrienes have high biological activity with a wide range of regulatory action.

After the drug introduction, the lipids fatty acid composition normalized due to a decrease in the content of palmitic acid by 18.9% ($p<0.05$), myristic acid content by 21.4%, ($p<0.01$) and arachidonic acid content by 19.6%, ($p<0.01$) acids. Research and analysis of data on the content of individual fatty acids in the erythrocyte membranes of birds of the experimental and control groups allowed to establish an increase in the percentage content of fatty acids 22:5 (ω-3) and 22:6 (ω-3) in the membranes of erythrocytes ($p<0.05$) of the 1st group of poultry, which may be a protective factor against peroxidic damage of membrane phospholipids, since ω-3 fatty acids are an imperfect substrate for cyclo- and lipoxygenases (Jump, 2004).

The imbalance of fatty acids in the blood erythrocytes of birds injected with sodium selenite is characterized by an increase in the content of certain polyunsaturated fatty acids (arachidonic and docosahexaenoic, $p<0.05$). The effectiveness of using the drug consists in normalizing the level of fatty acids and restoring their metabolism at the stage of eicosanoid formation.

The nature of the disorders caused by the introduction of pro-oxidant sodium selenite depends on the intensity of LPO processes, the state of cell membranes, the structural components of which are higher fatty acids and free cholesterol. Polyunsaturated fatty acids – structural components of biological membranes, substrates of LPO and precursors of eicosanoids are the connecting link of these processes. The studies of many authors indicate changes in the fatty acid composition of blood plasma lipids and erythrocytes during oxidative stress, which accompanies most diseases. Arachidonic acid, like other

PUFAs, interacts with the components of the respiratory chain of mitochondria, inhibits chain complexes and disrupts electron transfer processes, which leads to the formation of free radicals in mitochondria. Under physiological conditions, when the concentration of PUFAs in mitochondrial membranes is normal, this effect is insignificant. During stress, the concentration of PUFAs in cell membranes increases significantly.

In the fatty acid composition of the esterified blood plasma cholesterol, the content of saturated fatty acids with steam (caprylic - by 5.88%, capric - by 8.33%, myristic - by 5.77%, palmitic - by 1.93%), decreased lauric - by 6.25% and arachinic - by 5.41%) and odd (pentadecane - by 6.25%) number of C atoms in the chain and monounsaturated acids of the ω-7 family (palmitoleic - by 3.57%) (Table 2).

Table 2

Fatty acid composition of esterified cholesterol in quails' blood plasma, %, M±m, n = 5

Fatty acids and their code	Control group	Experiment
Caprylic, 8:0	0,17±0,01	0,16±0,01
Capric, 10:0	0,24±0,01	0,22±0,01
Lauric, 12:0	0,32±0,01	0,3±0,01
Myristic, 14:0	0,52±0,01	0,49±0,01
Pentadecanoic, 15:0	0,32±0,01	0,3±0,01
Palmitic, 16:0	8,62±0,11	8,95±0,12
Palmitoleic, 16:1 ω-7	1,12±0,03	1,16±0,02
Stearic, 18:0	8,99±0,39	9,76±0,31
Oleic, 18:1 ω-9	31,39±1,14	32,66±1,11
Linoleic, 18:2 ω-6	15,03±0,4	15,37±0,38
Linolenic, 18:3 ω-3	5,93±0,06	5,44±0,09**
Arachinic, 20:0	0,37±0,01	0,35±0,01
Eicosaenoic, 20:1 ω-9	0,19±0,01	0,21±0,01
Eicosadienoic, 20:2 ω-6	0,33±0,01	0,30±0,01
Eicosatrienoic, 20:3 ω-6	1,80±0,04	1,74±0,04
Eicosatetraenoic (arachidonic), 20:4 ω-6	5,13±0,13	5,42±0,13
Eicosapentaenoic, 20:5 ω-3	1,94±0,05	1,53±0,09**
Docosadienoic, 22:2 ω-6	1,02±0,02	0,98±0,02
Docosatrienoic, 22:3 ω-3	1,36±0,03	1,15±0,05**
Docosatetraenoic, 22:4 ω-6	3,22±0,07	2,98±0,07*
Docosapentaenoic, 22:5 ω-3	5,54±0,16	4,71±0,11**
Docosahexaenoic, 22:6 ω-3	6,44±0,06	5,82±0,14**

At the same time, there was an increase in the content of stearic (by 5%) and oleic (by 4.05%) acids, as well as polyunsaturated fatty acids of the ω-6 family: linoleic (by 2.26%), eicosadiene (by 10.53%), eicosatetraenoic arachidonic (by 5,6 %).

At the same time, in the experimental group of quails, with the addition of bionano-selenium, the content of acids of the ω-3 family decreased sighnificantly: linolenic (by 8.36%), eicosapentaenoic (by 21.13%), docosatric, penta- and hexaenoic acids (by 15.44%) , 14.98 and 9.63%, respectively) and ω-6 fatty acids - docosadienoic and docosatetraenoic (by 3.92 and 7.45%) and eicosadienoic and eicosatrienoic acids (by 9.09 and 3.33%). At the same time, the addition of bionanoselenium does not change the inclusion of long-chain and unsaturated derivatives of linoleic acid in the esterified blood plasma cholesterol of quails, but the inclusion of long-chain and unsaturated derivatives of linolenic acid increases (fig. 3).

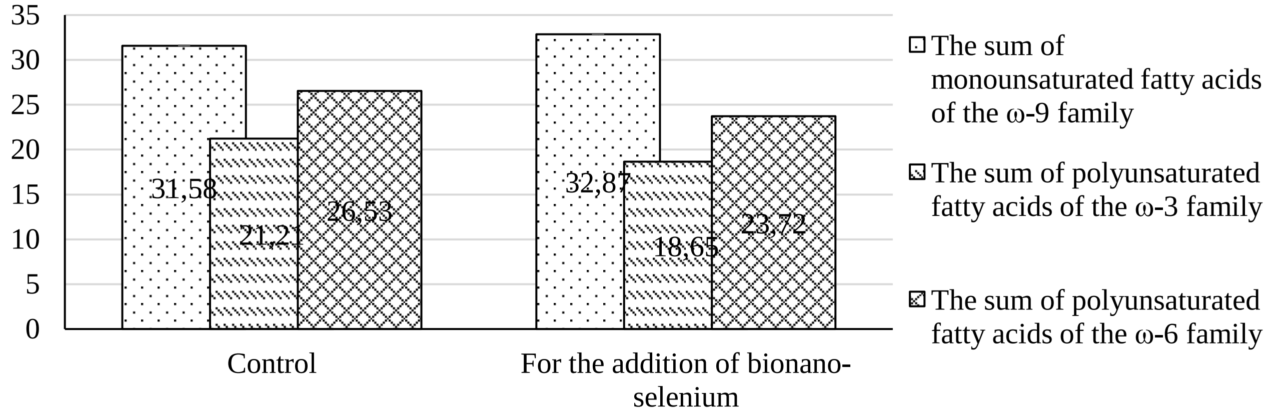

Fig. 3. The content of unsaturated acids of the ω-3 ω-6 and ω-9 families in the composition of esterified cholesterol in quail blood plasma

At the same time, with the addition of bionanoselenium in the blood of quails, it was established encreasing of the amount of saturated fatty acids with an even number of carbon atoms in the chain increased by 1.32%, the amount of monounsaturated fatty acids of the ω-9 family by 6.62%, and the amount of polyunsaturated fatty acids of the ω-6 family by 10.17%.

At the same time, there was a decrease in the amount of saturated fatty acids with an odd number of carbon atoms in the chain by 6.25 %, the amount of monounsaturated fatty acids of the ω-7 family by 4 %, the amount of polyunsaturated fatty acids of the ω-3 family by 2.07 %, and the ratio of ω-3/ ω-6 by 20.19 %.

A decrease in cholesterol esterification of quails' blood plasma with saturated and monounsaturated fatty acids due to the consumption of bionanoselenium as part of the diet may indicate a decrease in its crystallinity and an improvement in interstitial transport (Загайко et al, 2008). Cholesterol, which contains a large amount of saturated and monounsaturated fatty acids, can easily be deposited on the walls of blood vessels and exhibit atherogenic properties (Смоляр, 2003). At the same time, due to the presence of a relatively large number of polyunsaturated fatty acids in the composition of cholesterol, it is easily transported by blood and is not deposited on the walls of blood vessels (Смоляр, 2003).

Conclusions. The results obtained by us indicate an improvement in the transport and anti-inflammatory function of the blood plasma of quails fed with bionanoselenium as part of compound feed due to an increase in the content of polyunsaturated fatty acids in phospholipids. At the same time, the amount of cholesterol esterified with saturated and monounsaturated fatty acids in blood plasma decreases.

One of the important functions of PUFA is the synthesis of eicosanoids, the substrate of which is arachidonic and linoleic fatty acids. Metabolites of arachidonic acid - prostaglandins, thromboxanes and leukotrienes have high biological activity and belong to pro-inflammatory factors that contribute to the aggregation of platelets and the formation of pro-inflammatory cytokines.

The conducted studies indicate a positive effect of the complex drug on the fatty acid formula of blood serum lipids of experimental birds. The drug under study normalizes the lipid composition of blood serum, contributing to the optimization of the level of saturated and unsaturated fatty acids.

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Selected papers of the V International Conference on European Dimensions of Sustainable Development present peer-reviewed articles based on the reports of the Conference, which had place on June 1-2, 2023 at National University of Food Technologies, Kyiv, Ukraine in terms of the ERASMUS+ projects Jean Monnet EU Centre for the Circular and Green Economy JM ECO (620627-EPP-1-2020-1-UA-EPPJMO-CoE), EU renewable energy strategy as a roadmap for Ukraine (101085755 – JM RE – ERASMUS-JMO2022-HEI-TCH-RSCH) and European Union policies and best practices in academic project management (101085243 – ProEU – ERASMUS-JMO-2022-HEI-TCHRSCH). The Selected Papers cover economic, environmental and social aspects of sustainable development of the European Union and Ukraine; new technologies for the sustainable development; as well as European Union Studies on sustainable development.

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