Ministry of Education and Science of Ukraine
Mykolaiv National Agrarian University

ISSN 2313-092X
E-ISSN 2411-9199

Вісник аграрної науки Причорномор'я

Том 25, № 3

Науковий журнал

Ukrainian Black Sea Region Agrarian Science

Scientific Journal

Volume 25, No. 3

Year of establishment: 1997
Publication frequency: Four times a year

Mykolaiv
2021

DOI: 10.31521/2313-092X/2021-3(111)

Recommended for printing and distribution
via the Internet by the Mykolaiv National Agrarian University
(Minutes No. 1 of August 26, 2021)

Certificate of state registration of the print media
Series: KB No. 19669-9469 PR of January 11, 2013

The journal is included in the list of professional publications of Ukraine of category "B":
Economic, technical, agricultural, veterinary sciences by specialty 051 – Economics,
071 – Accounting and taxation, 072 – Finance, banking and insurance, 073 – Management, 075 – Marketing,
076 – Entrepreneurship, trade and exchange activity, 181 – Food technologies,
183 – Environmental protection technologies, 201 – Agronomy, 202 – Protection and quarantine of plants,
204 – Technology of production and processing of livestock products, 205 – Forestry,
207 – Water bioresources and aquaculture, 208 – Agricultural engineering,
281 – Public management and administration
(Order of the Ministry of Education and Science of Ukraine of May 7, 2019 No. 612; of July 11, 2019 No. 975)

The journal is presented at scientometric databases, repositories:
Google Scholar, Academic Resource Index ResearchBib, Open Academic Journals Index,
National Library of Ukraine named after V. I. Vernadskyi, IJIFACTOR,
Directory of Research Journals Indexing | DRJI, Crossref, Professional Editions of Ukraine

Ukrainian Black Sea Region Agrarian Science / Ed. by V. S. Shebanin (Editor-in-Chief) et al. Mykolaiv: Mykolaiv National Agrarian University, 2021. Vol. 25, No. 3. 107 p.

Publishing Address:
Mykolaiv National Agrarian University
54008, 9 Georgiy Gongadze Str., Mykolaiv, Ukraine
tel.: +38(0512) 70-93-54
E-mail: info@bsagriculture.com.ua
www: https://bsagriculture.com.ua/en

ЗМІСТ / CONTENTS

UDC 626.84:330.341.11
DOI: 10.31521/2313-092X/2021-3(111)-1

Ukrainian Black Sea Region Agrarian Science
Vol. 25, No. 3

The role of irrigation in the formation of the innovation and investment environment of the region

O. Novikov*
Full Doctor in Economics, Professor
https://orcid.org/0000-0003-0413-472X
ResearcherID F-3859-2018

N. Potryvaieva
Full Doctor in Economics, Professor
https://orcid.org/0000-0002-9781-6529
ResearcherID D-3726-2018

M. Karpenko
Director of the Science Park "Agroperspective"

O. Sadovy
PhD in Technical Sciences
https://orcid.org/0000-0002-7369-0714
ResearcherID D-3144-2018

Mykolaiv National Agrarian University

Abstract. The article substantiates the expediency of irrigation development in the South of Ukraine as an important condition for the formation of a favorable innovation and investment environment in the region. It is proved that the development of irrigation in Mykolaiv region requires a systematic approach with mandatory scientific support on the terms of public-private partnership. The economic and budgetary efficiency of the project for the creation of an innovative landfill for sprinkler farming using Smart-technologies has been determined. It is proved that the implementation of the project for 2021-2023 will increase revenues to the state budget and get budget efficiency at 22%

Keywords: irrigation, investments, innovations, South of Ukraine, agriculture, sprinkler, economic efficiency, budget efficiency

INTRODUCTION

Since the twentieth century, there has been a global increase in the world's population, causing a food crisis. According to [1-3], the state of food security and starvation in the world is extremely serious, and by 2030 may worsen further if the effects of the COVID-19 pandemic caused by the coronavirus SARS-CoV-2 persist.

Almost one tenth of the world's population – up to 811 million people – went hungry in 2020. After nearly five years of tackling the world's hunger and food problems, world hunger has risen sharply in the past year. In addition, it is estimated that about 660 million people may still face famine in 2030, which is

Article's History:
Received: 13.03.2021
Revised: 7.06.2021
Accepted: 26.08.2021

Suggested Citation:
Novikov, O., Potryvaieva, N., Karpenko, M., & Sadovy, O. (2021). The role of irrigation in the formation of the innovation and investment environment of the region. *Ukrainian Black Sea Region Agrarian Science*, 25(3), 4-11.

30 million more than analysts estimate that there was no pandemic due to the long-term impact of COVID-19 on global food security. [1-3].

One of the main reasons for this is climatic change, imperfection of technologies for growing agricultural products, the constant increase in the cost of energy, increasing production of energy crops, which are raw materials for alternative fuels [4].

According to UN forecasts, by 2050 the world's population will increase by 30% and will be about 9 billion people, but a proportional increase in agricultural area will not happen [5,6].

As a result, it is difficult to meet the overall goal of sustainable development, which aims to eradicate hunger and reduce all forms of starvation.

One of the most effective and widespread measures to intensify crop production at the present stage of its development is artificial humidification, in particular in regions with insufficient natural moisture.

Today, 80% of the world's fresh water is consumed by agriculture. Up to 40% of the world's grain stocks are grown on irrigated land. In the United States, only 18% of agricultural land is irrigated, providing 50% of the crop [7, 8].

The world's freshwater reserves are 35 million m^3, of which about 8.5% are fresh water resources, which are concentrated in rivers, lakes and reservoirs, which are the world's traditional source of water supply. Uneven distribution of world water resources necessitates the introduction of economical ways of water use in all sectors of the economy and especially in agriculture.

For countries with limited water resources, which include Ukraine, this issue is particularly relevant. Ukraine has one of the lowest indicators of water supply from the world's water resources in terms of territory – 0.3%, while in the post-Soviet countries this figure is 32 times higher [7, 8].

Formulation of the problem. The steppe zone of the South of Ukraine is characterized by a harsh arid climate, where irrigation is one of the determining factors of the general state of agricultural production, its export and food security of the state. However, the once powerful water management complex of Mykolaiv, Odesa and Kherson oblasts is not fully used today. Of the available area of irrigated land (about 2.17 million hectares), only a quarter is irrigated. Due to this situation, according to EBRD analysts, Ukraine annually loses about $ 1.5 billion in profits. In addition, climate change combined with the reduction of irrigated land in Ukraine threatens the desertification of the southern region. In the Mykolaiv area almost 6 times in comparison with 90s years of the 20th century the areas on irrigation are reduced, as of 31.12.2020 they make 27 thousand hectares [9]. In addition, further climate change will only worsen the natural conditions of soil moisture. Given this fact, the role of irrigation in the full development of agricultural production in the region will only grow. After all, irrigation, as the most effective means of reducing the negative impact of climate change and increasing the efficiency of domestic agricultural production, requires a systematic approach with mandatory scientific justification and support.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

The main direction of development of the modern agro-industrial complex is the formation of efficient and competitive agricultural production, which will meet the needs of the population in food and will receive budget revenues through the sale of crop products on world markets [10, 11]. Growing agricultural products on bogar has reached maximum values, further increase in yields is possible only with the use of artificial irrigation in regions with insufficient levels of natural moisture, which include the south of Ukraine [9, 12-15]. A significant contribution to the development of irrigated agriculture was made by R. Vozhegova, V. Gamayunova, L. Granovska, L. Didkovska, S. Doroguntsova, V. Izyumov, V. Koryunenko, V. Limar, P. Morozov, S. Malyarchuk, M. Romashchenko, M. Khvesyk, A. Shatkovsky, V. Shebanin and other. In their work, leading scientists have considered the spread of resourcesaving methods of irrigation of crops and the effectiveness of irrigation.

In their works [9, 16], scientists proposed a model of the process of increasing the efficiency of irrigation, the basis of which is the creation of innovative solutions with practical use and the possibility of commercialization. Today, the main irrigation systems are drip irrigation and sprinkler. Each of the systems, as noted by the authors [9], has its financial and technical and economic advantages and disadvantages. Practical research M. Fomichova [17] indicate the effectiveness of drip irrigation in the cultivation of melons. On drip irrigation, the increase in yield is 11.4 t/ha (89.8%), but the use of this method of irrigation in the cultivation of cereals does not give the desired result [9, 18]. When growing maize hybrids, depending on irrigation methods and different schemes of plant protection against diseases, scientists [9] found that the method of watering has a great influence on plant productivity, which amounted to 16.3% of the total share of grain yield.

US farmers have a very strong practice of growing agricultural products under irrigation. Analyzing long-term research, it was found that with an annual rainfall of 350-400 mm is insufficient for growing agricultural products. With a rainfall of 350-500 mm, the cultivation of field crops is risky. To obtain a high yield, the total rainfall of 625 mm is too small.

At the beginning of the twentieth century, the area of irrigated land in the United States was only 5.7 million hectares, and in the second half of the twentieth century increased more than 3.6 times. In the 21st century, in areas with insufficient rainfall and semi-arid states, the use of irrigation systems has increased yields by 2-2.5 times. Given the growing shortage of water resources in the United States, the optimization of irrigation regimes becomes especially important. For this purpose, there is an irrigation management service, which carries out centralized planning of irrigation regimes from the computer center. The information collection cycle (on meteorological conditions, soil properties, available moisture reserves, etc.) covers irrigated areas of hundreds of thousands of hectares with analysis of current information and issuance of scientific recommendations within 24 hours. [19, 20].

High technical level of irrigation systems in combination with advanced methods of water distribution management and innovative technologies of artificial humidification provide sustainable productivity of irrigated agriculture. Since the 90s of the XX century, under the influence of the failed reform of the agricultural sector of Ukraine, the infrastructure of irrigated lands only deteriorated, there was a process of sharp reduction of areas with artificial moisture: from 2291 thousand hectares – in 1990 to 472.2 thousand hectares – in 2015. In 2016, the area of actual irrigation began to increase gradually from 477.2 thousand hectares to 532 thousand hectares – in 2019. [25] However, today almost 19 million hectares of arable land are in constant need of irrigation, and 4.8 million hectares are in need of water regulation, and these figures will only increase every year. Drought, according to Mami Mizutori, the UN Secretary-General's Special Representative for Disaster Risk Reduction, is a major factor in land degradation and declining crop yields. [26] Such a difficult situation can be prevented by modernizing the agricultural sector of the economy, developing and implementing the latest technologies for growing crops using modern technologies of irrigation and spreading them among agricultural producers to create a favorable innovation and investment environment in the country and the region in particular.

In view of the above, the issues of determining the role of irrigation in the formation and further development of the innovation and investment environment of the Southern region of Ukraine remain insufficiently studied today.

The aim of the work is to assess the effectiveness of irrigation systems in a region with difficult climatic conditions on the example of the steppe zone of southern Ukraine.

PRESENTING MAIN MATERIAL

Today, one of the priority areas of economic development of the southern region of Ukraine is to increase yields through the introduction of modern irrigation systems [21].

The development of irrigation, as the most effective means of reducing the negative impact of climate change and increasing the efficiency of domestic agricultural production, requires a systematic approach with mandatory scientific justification and support.

The issue of energy conservation, conservation of water resources is relevant today. Rational use of water resources can be solved only with the use of the latest technologies and integrated energy saving during the operation of sprinklers.

The use of automated and computerized irrigation of crops with a clearly defined water consumption, accurate navigation can increase crop yields by 2-3 times compared to the conditions on the bog [9].

Existing irrigation systems use mostly obsolete types of multi-part sprinklers, which have twice exceeded their planned service life (Fig. 1).

Figure 1. *Sprinkler unit two-console (DDA-100V)*

Source: *[22]*

At present, about 5.5 thousand sprinklers are in working order, which can provide irrigation on an area of about 600-700 thousand hectares. Today, foreign companies began to operate actively in the domestic market: Sigma (The Czech Republic), R. Bauer (Austria), Valley, Zimmatis (USA). Among their models are stationary sprinkler systems with circular and frontal trajectories, a wide range of drum sprinklers. Such systems are characterized by wide functionality, provide sprinkling at low water pressure, supply through the pipeline with water intake from the open or closed network, as well as the use of a diesel generator or electric drive makes the system independent in use and reduces energy use.

In Mykolaiv National Agrarian University with the participation of research institutions of NAAS and industrial enterprises of Ukraine-members of the Educational Research and Production Consortium "Southern" in 2019 created an innovative landfill for the transfer of modern technologies in the agroindustrial complex (Fig. 2).

The operation of the landfill creates conditions for the development and implementation of new technologies for growing crops using Smarttechnologies on modern irrigation, optimization of artificial moisture, variety testing and study of adaptive characteristics of new varieties and hybrids of grain and technical crops of domestic and industrial crops. them among agrarians of the Southern region, and also implementation of training of members of associations of water users by modern methods of implementation of hydraulic reclamation and ecologically safe use of reclaimed lands.

a) b) c)

Figure 2. *Fragments of the system of sprinkler agriculture of the Mykolaiv National Agrarian University: a) general view of the sprinkler "Zimmatis"; b) growing corn on irrigated; c) an element of the automation system of the sprinkler.*

This will provide an opportunity to address such important issues that hinder the effective development of agricultural production in the region. Including:

- insufficient level of investment attraction and introduction of innovative technologies in agroindustrial production, in particular in farms;
- low level of use of irrigated lands and deterioration of material and technical base of water management organizations;
- high cost of the latest sprinkler systems and complexes;
- lack of regional centers for monitoring and integrated management of irrigated land fertility;
- lack of sufficient reclamation specialists in the region;
- lack of own production of competitive energy-efficient sprinklers;
- Insufficient introduction of highly efficient, modern, latest technologies for growing agricultural products, etc. [21, 23].

These shortcomings also exacerbate the environmental problem of irrigation, unregulated use of natural resources, energy consumption, increase the cost of agricultural products and reduce guaranteed yields.

The development of family farms and agricultural cooperatives on the basis of irrigated agriculture will enable the Mykolayiv region to develop and specialize in the sectoral areas of commodity producers, which will promote the formation of stable market channels, prevent speculative intermediation, provide transparent traffic patterns participants and will contribute to the transformation of small producers into equal market participants [21, 23].

Modern sprinkler systems are a significant reserve for reducing water consumption, energy conservation and fertilizer application. Therefore, increasing the energy efficiency of sprinklers by even 10% is economically justified. One of the ways to solve the problem of reducing the cost of production is the introduction of energy-saving systems and complexes in the irrigation system [21-24].

A promising direction is the creation of new irrigation systems and sprinklers of a new generation based on autonomous renewable power sources, automated irrigation systems. Such systems and machines must be low-pressure, provide quality irrigation by optimizing the algorithm of work with the simultaneous supply of fertilizers and chemical ameliorants with irrigation water.

In order to fulfill the tasks of agricultural development, nature conservation, as the main direction of agricultural research, it is necessary to create an innovative landfill, which will install a sprinkler "Zimmatis" Pivot 662 meters with fertilizer for modern irrigation system on 71 hectares of university land.

The project will be the basis for the creation of an innovative landfill for irrigated agriculture using Smarttechnologies and a Training Center for members of the organization of water users (DEC), which will be created on the basis of the existing innovative landfill for transfer of modern agricultural technologies to the Research and Training Consortium "Southern". The organization of modern irrigation on 71 hectares in the cultivation of cereals will provide economic and budgetary efficiency (Table 1).

Table 1. *Economic efficiency of the project to create an innovative landfill for sprinkler farming using Smart-technologies*

Indexes	2021	2022	2023	Together
Discount rate (discount rate 11%)	1.0000	0.9009	0.8116	x
Operational activity				
Sowing area, ha	71.1	71.0	71.0	x
Yield, c per 1 ha		60.0	60.0	x
Gross collection, t		426.0	426.0	852.0
Revenue from sales of grain, thousand UAH		3621.00	3834.0	7455.0
Production costs – total, thousand UAH	715.8	744.9	769.7	2230.4
Operating profit, thousand UAH	715.8	2876.10	3064.3	5224.6
Discounted cash flow from operating activities, UAH thousand	715.8	2591.08	2487.05	4362.34
Investment activity				
Capital investments – total, thousand UAH	4290.0	-	-	4290.0
including: - sprinkler	4110.0	-	-	4110.0
- node of fertilizer application	180.0	-	-	180.0
Total costs, thousand UAH	5005.8	744.9	769.7	6520.4
Discounted cash flow from investing activities, UAH thousand	-4290.0	0.00	0.00	-4290.0
Discounted free cash flow, UAH thousand	-5005.8	2591.08	2487.05	72.34
Cumulative discounted free cash flow, thousand UAH	-5005.8	-2414,72	72.34	-
Net present value (NPV), thousand UAH				72.34
Internal rate of return (IRR), %				12.1
Return on investment (PI), %				101.7
Discounted payback period of DPP, years				2 years 11 month

According to the data corresponding to the forecast of table. 1, the economic efficiency of the project of the innovative landfill of sprinkler agriculture with the use of Smart-technologies discounted free cash flow will be 72.34 thousand UAH. The discounted payback period of DPP is 2 years 11 months, which is sufficient in an unstable economic situation.

Tax revenues to the budget for the years of project implementation are estimated at UAH 1620,4 thousand (Table 2).

Table 2. Revenues to the state budget from the implementation of the project to create an innovative landfill for sprinkler farming using Smart-technologies

Indexes	2021	2022	2023	Together
1	2	3	4	5
Cash proceeds, thousand UAH	-	3621.0	3834.0	7455.0
Tax liability, thousand UAH	-	603.5	639.0	1242.5
Investment costs (sprinkler, fertilizer application unit), UAH thousand	4290.0	-	-	4290.0
Project implementation costs, thousand UAH	715.8	744.9	769.7	2230.4
incl. - salary	275.3	295	315.3	885.6
- material costs	160	170	170	500
- services	200	195	195	590.0
Tax credit, thousand UAH	60.0	60.8	60.8	181.6
Receipt of VAT in the budget, thousand UAH	-60.0	542.7	578.2	1060.9
Personal income tax (18%), thousand UAH	49.5	53.1	56.8	159.4
Single social contribution (22%), thousand UAH	60.6	64.9	69.4	194.9
Military fee (1.5%), thousand UAH	4.1	4.4	4.7	13.2
Rent for special use of water (UAH 63.97 per 100 m^3), UAH thousand	-	96.0	96.0	192.0
Total payments, thousand UAH	54.2	761.1	805.1	1620.4
Budget efficiency, %				22.1

For three years of realization of the project to the state budget the Mykolaiv National Agrarian University will increase incomes by 1620 thousand UAH and received budget efficiency at the level of 22.1%. Such indicators are essential for the development of irrigated agriculture in the steppe zone of southern Ukraine and the formation of innovation and investment environment in the region.

CONCLUSIONS

The development of irrigation in the South of Ukraine is an important condition for the formation of a favorable innovation and investment environment in the region, the realization of the country's agricultural potential, increase agricultural production, exports and food security.

The high technical level of irrigation systems in combination with the optimization of artificial humidification regimes is the foundation of sustainable productivity of irrigated agriculture. The introduction of modern irrigation systems can reduce the negative impact of climate change, promotes the rational use of water resources, energy conservation and material savings for fertilizers, increase crop yields and more.

The project to create an innovative landfill for irrigated agriculture using Smart-technologies aims to create a favorable innovation and investment environment, conditions for intensification of innovation processes, integration, science, education and production in the region, modernization of the agricultural sector of the region by introducing new scientific technologies for growing crops. on irrigation. The implementation of the project on the area of 71 hectares for 2021-2023 will increase the state budget revenues by UAH 1.6 million and get budget efficiency at the level of 22.1%.

Stimulating the development of irrigation in Mykolaiv region requires a systematic approach with mandatory scientific support on the terms of publicprivate partnership, is a guarantee of high yields of crops, stability of revenues to state and local budgets and strengthening leadership in agricultural markets.

REFERENCES:

[1] The State of Food Security and Nutrition in the World 2021: Transforming food systems for food security, improved nutrition and affordable healthy diet for all World. Retrieved from https://reliefweb.int/report/world/state-foodsecurity-and-nutrition-world-2021-transforming-food-systems-food-security. [in English].

[2] Ukraine will help halve the number of hungry people in the world. Retrieved from https://a7d.com.ua/agropoltika/aktualna_tema/firsthands/1716-ukrayina-dopomozhe-udvichi-skorotiti-kilkist.html [in Ukrainian].

[3] The State of Food Insecurity in the World 2015. Retrieved from https://www.fao.org/publications/sofi/2015/en/.. [in English]

[4] Climate change and agriculture in Ukraine. German-Ukrainian agro-political dialogue 2020. Retrieved from: https://mepr.gov.ua/files/docs/Zmina_klimaty/2020. [in Ukrainian].

[5] How many humans tomorrow? The United Nations revises its projections. Retrieved from https://theconversation.com/how-many-humans-tomorrow-the-united-nations-revises-its-projections-118938 [in English].

[6] Pison, G. (2017). The Population of the World. Population and Societies, (547). [in English]

[7] Xvesyk, M. A., & Mandzyk, V. M. (2009). Water resources are an investment of the present and a prospect for the future. Investytsiyi: praktyka ta dosvid, (1), 2–8 [in Ukrainian].

[8] Didkovs'ka, L. I. (2013). Ecological and economic aspects of microirrigation implementation. Ekonomika APK, (10), 98 [in Ukrainian].

[9] Shebanin, V. S., Novikov, O. Y., & Karpenko, M. D. (2020). Substantiation of expediency of introduction of sprinkler irrigation in modern conditions. Ukrainian Black Sea region agrarian science, (1), 4-10. doi: 10.31521/2313092X/2020-1(105)-1 [in Ukrainian].

[10] Romashchenko M. I. (2012) Naukovi zasady rozvytku zroshennya zemel' v Ukrayini. Kyiv: Ahrarna nauka [in Ukrainian].

[11] Romashchenko, M., Shatkovs'kyy, A., & Ryabkov, S. (n.d.). Drip irrigation in Ukraine: problems and prospects. Retrieved from https://a7d.com.ua/agropoltika/agri-work/5097-kraplinne-zroshennya-v-ukrayin-problemi-perspektivi.html [in Ukrainian].

[12] Alymov, O. M., Danylenko, A. I., & Trehobchuk, V. M. (2005). Ekonomichnyy rozvytok Ukrayiny: instytutsional'ne ta resursne zabezpechennya. Kyiv : Ob'yednanyy instytut ekonomiky NAN Ukrayiny. [in Ukrainian].

[13] Biliaieva, I. M. (2015). Scientific and methodological substantiation of irrigation productivity models for the conditions of the south of Ukraine. Zroshuvane zemlerobstvo, (64), 75-78. [in Ukrainian].

[14] Motuzova, G. V., & Bezuglova, O. S. (2007). Ekologicheskij monitoring pochv. Moscow: Akademicheskij Prospekt, Gaudeamus. 237. [in Russian].

[15] Filipenko, L. A., Zhovtonoh, O. I., & Demenkova, T. F. (2010). Adaptation of water use plans to changes in climatic conditions in the irrigation zone of Ukraine. Vodne hospodarstvo Ukrainy, (4), 23-29. [in Ukrainian].

[16] Nechyporenko, O. M. (2015). Directions of innovative development of irrigation farming in Ukraine. Bulletin of Agricultural Science, (8), 61-65. [in Ukrainian].

[17] Fomichov, M.V. (2019). Irrigation systems as an economic category and their effectiveness. Efektyvna ekonomika, (3). https://doi.org/10.32702/2307-2105-2019.3.153 [in Ukrainian].

[18] Kokovikhin, S.V., & Bilyaeva, I.M. (2017). Productivity And Economic Efficiency Of Growing Of Hybrids Of The Corn Depending On The Methods Of Watering And Protection Of Plants In The South Of Ukraine. Naukovì dopovìdì Nacìonal'nogo unıv̀ ersitetu bı̀oresursiv ı̀ prirodokoristuvannâ Ukraïni, (4(68)). https://doi.org/10.31548/dopovidi2017.04.013 [in Ukrainian].

[19] Randall, D.A., Wood, R.A., Bony, S., Colman, R., Fichefet, T., Fyfe, J. … Taylor, K.E. (2007). Climate models and their evaluation. Climate Change 2007: the physical science basis. contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridg: Cambridge University Press, 589-662. [in English].

[20] Bykov, A.Y. (2020). Investment Climate of Economic Stability. Jurist, 1, 59–66. https://doi.org/10.18572/1812-39292020-1-59-66 [in Ukrainian].

[21] The program of development of an agro-industrial complex of the Nikolaev area for 2021-2025, the Order № 1 (2021) (the Mykolaev area) (Ukraine). Retrieved from https://www.mkoblrada.gov.ua/UserFiles/decree/1633430495615c2bdf8ac1e.pdf [in Ukrainian].

[22] Дощувальні машини ДДА – 100В. URL: https://itexn.com/573_dozhdevalnaja-mashina-dda-100ma.html (дата звернення: 02.08.2021).

[23] Novikov, O., Potryvaieva, N., & Sadovyi, O. (2021). Introduction of sprinkler irrigation is a guarantee of stability of development of the southern region of Ukraine. Sustainable Development: Modern Theories and Best Practices: Materials of the Monthly International Scientific and Practical Conference (February 24-26, 2021, Tallinn). Tallinn: Teadmus OÜ, 2021, 30-32 [in English].

[24] Deineha, I., Maslov, A., Potryvaieva, N., Berezhnytska, U., Verbivska, L., & Koliadych, O. (2021). Institutional environment tools for small and medium-sized enterprises development. Studies of Applied Economics, 39 (3). https://doi.org/10.25115/eea.v39i3.4798 [in English].
[25] The need for irrigation in Ukraine: investment, countering the effects of drought, financial component. Retrieved from https://agropolit.com/spetsproekty/849-potreba-zroshennya-v-ukrayini-investitsiyi-protidiya-naslidkam-posuhifinansova-skladova [in Ukrainian].
[26] Drought could become the "next pandemic" – the UN. Retrieved from https://www.epravda.com.ua/news/2021/06/18/675134/ [in Ukrainian].

Роль зрошення у формуванні інноваційно-інвестиційного середовища регіону

О. Є. Новіков

Доктор економічних наук, професор
https://orcid.org/0000-0003-0413-472X
ResearcherID F-3859-2018

Н. В. Потриваєва

Доктор економічних наук, професор
https://orcid.org/0000-0002-9781-6529
ResearcherID D-3726-2018

М. Д. Карпенко

Директор наукового парку «Агроперспектива»

О. С. Садовий

Кандидат технічних наук
https://orcid.org/0000-0002-7369-0714
ResearcherID D-3144-2018

Миколаївський національний аграрний університет

Анотація. У статті обґрунтовано доцільність розвитку зрошення в умовах Півдня України, як важливої умови для формування сприятливого інноваційно-інвестиційного середовища регіону. Доведено, що розвиток зрошення у Миколаївській області потребує системного підходу з обов'язковим науковим супроводом на умовах державно-приватного партнерства. Визначено економічну та бюджетну ефективність від впровадження проєкту зі створення інноваційного полігону дощувального землеробства з використанням Smart-технологій. Доведено, що реалізація проєкту за 2021-2023 роки дозволить збільшити доходи до державного бюджету та отримати бюджетну ефективність на рівні 22 %

Ключові слова: зрошення, інвестиції, інновації, Південь України, землеробство, дощувальна машина, економічна ефективність, бюджетна ефективність

UDC 338.432+658.1
DOI: 10.31521/2313-092X/2021-3(111)-2

Ukrainian Black Sea Region Agrarian Science
Vol. 25, No. 3

Sustainable development of agricultural enterprises: Economic dimension

S. Strapchuk*

PhD in Economic Sciences, Associate Professor
https://orcid.org/0000-0003-2809-6633
Researcher ID AAF-4686-2020
Kharkiv National Agrarian University named after V.V. Dokuchayev

Abstract. The field of agriculture has a significant role in the context of providing the necessary amount of food resources for the population without causing degradation of natural sources. Sustainable agriculture aims to apply balanced food production systems and involve the most relevant agricultural practices that promote productivity and at the same time help sustain the ecosystem without affecting water and soil quality. During the study of the economic factor of sustainable development of agricultural enterprises, there is an urgent need to differentiate the dynamic characteristics of different levels, which reflect the processes of its transition to a new state. The relevance of the study is due to the need to study the progress of the economic component of the sustainable development of the agricultural sector. The purpose of the article is to analyze the available indicators at the country level that characterize the economic plane of sustainable development in the field of agriculture, as well as to analyze the efficiency and intensity of activity of industry enterprises of the Kharkiv region and Ukraine. Monitoring of indicators of relevant sustainable development goals in the national system of the Central Development System was carried out. The dynamics of indicators of efficiency and intensity in the sphere of agriculture of Ukraine over several years have been studied. The conducted research made it possible to identify a number of trends in the assessment of agricultural factors at the macro level.On the basis of individual enterprises of the Kharkiv region, the relationship between the efficiency and intensity of economic activity was analyzed and the highest indicator of profit per 1 ha of land was revealed in the group with a high efficiency indicator, which may be a consequence of the involvement of sustainable practices. The obtained results make it possible to identify actual problems, to determine the priority of solving the tasks of economic policy in the field of agriculture at different levels

Keywords: sustainable development, economic component, agricultural enterprises, production efficiency, gross added value

INTRODUCTION

Agriculture plays an important role in providing enough food for nearly 10 billion people by 2050 without critical degradation of natural resources. Sustainable agriculture involves the use of balanced food production systems and the implementation of better agricultural practices that increase productivity, which at the same time can help support ecosystems without losing water and soil quality. There is no single method for all regions or countries [1]. Each country must find its own way to achieve sustainable agriculture in the existing environmental, economic and social conditions. In the process of diagnosing the economic component of the sustainable development of agricultural enterprises, there is a need to distinguish dynamic characteristics of different levels that reflect the processes of its transition to a new state.

Article's History:
Received: 21.02.2021
Revised: 28.05.2021
Accepted: 26.08.2021

Suggested Citation:
Strapchuk, S. (2021). Sustainable development of agricultural enterprises: economic dimension. *Ukrainian Black Sea Region Agrarian Science*, 25(3), 12-19.

Monitoring of indicators of sustainable development made it possible to establish a conditional division of the Sustainable Development Goals (SDGs) into economic, ecological and social components, proposed by J. Rokström and P. Sukhdev under the name "SDG wedding cake" [2]. This country-wide approach includes inclusion in the economic dimension of SDG 8 Decent Work and Economic Growth, SDG 9 Industry, Innovation and Infrastructure, SDG 10 Reducing Inequality and SDG 12 Responsible Consumption and Production. We believe that it is appropriate to include SDG 2 Overcoming hunger, development of agriculture in the list of economic goals, since this is the key purpose of existence for agricultural production. SDGs 9 and 10 in the context of the agricultural sector should be attributed to the social component.

One of the solutions to ensure sustainability is the development of organic farming systems. In the FAO reports, the division of indicators in this context involves the separation of the following components: production, environment, economy and social well-being. The economic dimension includes indicators of profitability, total costs and ecosystem services [3].

The division of indicators into agricultural, environmental and population welfare indicators was carried out by D. Kanter and co-authors in the process of evaluating trade-offs in agriculture during the period of sustainable development [4]. In our opinion, it is possible to correlate with the economic dimension agricultural indicators, which the authors include yield, yield gap, resource efficiency, personnel productivity, sowing intensity, fodder production, resource use intensity and stock level.

Worthy of attention is the study by L. Campagnolo and co-authors, which offers a comprehensive index of sustainable development assessment – FEEM SI for measuring general balance at the country level [5]. The indicator is divided into three sub-indices, including economic, ecological and social dimensions. The economic block includes indicators: GDP per person; R&D and investment in the industry; public debt and the relative balance of the trade balance.

Determining the necessary list of indicators of the economic dimension of sustainable development of agricultural enterprises will allow to establish trends, compare them with established benchmarks and provide opportunities to identify the influence of factors on existing processes. In particular, the economic interest in conducting business in the industry, which is determined by high profitability, has the reverse side, which consists in increasing the anthropogenic load on land and water resources of agricultural territories. The author O. Nikishyna offers a comprehensive assessment of the natural resource potential of Ukraine's agriculture based on a system of complementary indicators of sustainable development, shifting the emphasis towards the ecological component. In particular, the dynamics of the water capacity of the gross added value of the agricultural sector, the indicators of waste generation in the industry and the amount of capital investments for the protection of the natural environment were analyzed [6]. In the work of A. Uzhva, the diagnosis of the economic component of the sustainable development of agricultural enterprises at the regional level was carried out by ranking regions according to increases in the volume of production of gross agricultural products and analyzing the level of profitability of production over a number of years [7].

The state and existing trends in the development of domestic agriculture are revealed in detail in O. Fryer's research, which points to a violation of the optimal ratio of crops in crop rotations, an increase in the volume of monoculture, and obtaining the highest income from the sale of products by enterprises with the lowest level of diversification.To ensure the reorientation of management in the direction of its sustainability, the author proposes to strengthen agricultural diversification, which will contribute to the natural efficiency of management, increase the productivity of plants, their ability to resist diseases and pests, and expand employment due to the introduction of labor-intensive crops [8]. The purpose of writing the article is the analysis of the existing indicators at the country level that characterize the economic dimension of sustainable development in agriculture, as well as the analysis of the efficiency and intensity of the functioning of industry enterprises of Ukraine and the Kharkiv region.

RESULTS AND DISCUSSION

Study of indicators of the economic dimension of sustainable development of agriculture in Ukraine

Based on the guidelines for the development of Ukraine until 2030, which were formed in the national report "Sustainable Development Goals: Ukraine", the actual state of achieving the SDGs was analyzed in comparison with the planned indicators. The indicators established at the national level for SDG 2 Overcoming of hunger, agricultural development, SDG 8 Decent work and economic growth and SDG 12 Responsible consumption and production were selected based on the specifics of the agricultural sector and the economic dimension they allow to be assessed.

The set tasks are supported by a list of indicators and benchmarks for achievement in 2020, 2025 and 2030 (Table 1).

***Table 1.** Monitoring of indicators for Central Development Goals 2, 8 and 12 in the field of agriculture of Ukraine*

Indicators/Years	Fact					Target values		
	2015	2016	2017	2018	2019	2020	2025	2030
CDG 2 Overcoming hunger, development of agriculture								
2.1.1. Meat consumption per person, kg/year	50.9	51.4	51.7	52.8	53.6	61.0	71.0	80.0
2.1.2. Consumption of milk and dairy products per person, kg/year	209.9	209.5	200.0	197.7	200.5	270.0	320.0	380.0
2.1.3. Fish consumption per person, kg/year	8.6	9.6	10.8	11.8	12.5	в/д	в/д	в/д
2.1.4. Consumption of vegetables per person, kg/year	160.8	163.7	159.7	163.9	164.7	в/д	в/д	в/д
2.2.1. Labor productivity in agriculture, thousands of US dollars per employed person	8.68	8.71	9.30	10.61	10.89	10.00	12.50	15.00
2.2.2. Index of agricultural products, %	95.2	106.3	97.8	108.1	101.4	102.0	102.0	102.0
2.3.1. Food production index,%	88.6	108.9	107.1	98.5	103.9	103.0	103.0	103.0
2.3.2. The share of products of the food industry and processing of agricultural raw materials in export, %	38.3	42.0	41.0	39.4	44.3	51.0	57.0	65.0
2.3.3. The share of agricultural land under organic production in the total area of agricultural land of Ukraine, %	1.0	0.89	0.67	0.72	1.1	1.10	1.30	1.70
2.4.1. Consumer price index for food products, %	144.4	108.5	113.4	111.5	108.3	105.0	105.0	105.0
SDG 8 Decent work and economic growth								
8.2.1. Rate of return on fixed assets	0.12	0.12	0.12	0.12	-	0.13	0.18	0.23
8.2.2. Labor productivity index, %	99.2	103.5	103.2	102.1	101.9	104	103.6	105.8
8.5.3 Share of workers employed in jobs with harmful working conditions, % (agriculture)	28.9	в/д	28.4	в/д	29.6	22	17	12
SDG 12 Responsible consumption and production								
12.2.1. The share of post-harvest losses in the total production of grain crops, %	2.3	2.0	1.8	1.8	1.8	1.8	1.0	0.5
12.2.2. The share of post-harvest losses in the total production of vegetables and melon crops, %	12.3	12.0	10.8	10.6	10	10	7.0	5.0

***Source:** compiled from [9]*

According to expert assessments, indicators 2.1.2 and 2.3.3 are related to the level of consumption of dairy and meat products per capita and an increase in the share of land under organic production, are almost unattainable and are characterized by negative dynamics. All other indicators have a high probability of reaching or have already reached the level of the established benchmark of 2020 [9]. The analysis of indicators at the regional level on the example of the Kharkiv region was carried out only according to indicators 2.1.1-2.1.5, which relate to the consumption of products by species per capita (Table 2). The rest of the indicators are developed only at the national level

***Table 2.** Dynamics of indicators of the Central Bank 2 Overcoming hunger, development of agriculture in the Kharkiv region*

Indicators/Years	Fact				
	2015	2016	2017	2018	2019
2.1.1. Meat consumption per person. kg/year	52.8	51.2	52.0	52.1	52.0
2.1.2. Consumption of milk and dairy products per person. kg/year	228.3	239.9	220.9	208.7	203.9
2.1.3. Fish consumption per person. kg/year	6.9	8.0	8.7	9.2	9.2
2.1.4. Vegetable consumption per person. kg/year	173.4	179.2	171.1	168.8	172.8
2.1.5. Fish consumption per person. kg/year	52.2	52.1	55.3	55.7	55.6

***Source:** compiled from [9; 10]*

Achieving the established benchmarks according to indicators 8.2.1 and 8.5.3, which relate to increasing the return on fixed assets and reducing the share of workers employed in harmful production in agriculture, according to experts, is unlikely and is characterized by negative dynamics [9]. Whereas the labor productivity index has a growing tendency, and the estimate of the probability of reaching the set level according to it is higher.

The task of reducing food losses in production and sales chains is planned to be implemented within the framework of achieving SDG 12 Responsible consumption and production, which is monitored only at the national level. In terms of SDG 12, only indicators related to post-harvest losses were selected.

Therefore, measures aimed at resource conservation, environmental protection, as well as the introduction into national legislation of the basic principles and provisions of European legislation in the field of waste management, made it possible to reduce the share of post-harvest losses in the total production of grain crops from 2.3% in 2015 to 1.8% in 2018 (1.8% in 2019 – data from the Ministry of Economy), which corresponds to the target guideline until 2020 [9].

Taking into account the context of the economic dimension of sustainable development, in agriculture there is a need to distinguish indicators of the level of economic efficiency, the share of created added value and the level of intensity, which are mainly based on the level of profit. The profit obtained is one of the prerequisites for expanded reproduction of production and a general indicator of the effectiveness of economic activity.

Agriculture creates a relatively low added value, being the main branch of the national economy. Moreover, in the dynamics over the last five years, there has been a significant decrease in economic efficiency indicators, both in the industry as a whole, and in crop production and livestock production in particular. Thus, the added value of expenditures in the agricultural economy of Ukraine has halved over the past five years, or by 47%. The negative dynamics of the indicator of the level of operational profitability also shows an annual decrease on average in agriculture – 16.6%, including crop cultivation – 16.1%, and in stockbreeding – 20.6% (Table 3).

Table 3. *Dynamics of the level of profitability of operational activity and added value by expenses of agricultural enterprises of Ukraine for 2015-2019*

Indicators/Years	2015	2016	2017	2018	2019	Tendence
Profitability of operational activities in agriculture, %	43.0	33.6	23.2	18.9	19.8	$y = -6.11x + 46.03$ $R^2 = 0.8702$
cultivation of crops, %	47.2	38.4	24.6	20.6	21.9	$y = -6.84x + 51.06$ $R^2 = 0.8536$
stockbreeding, %	33.1	16.0	20.0	13.8	10.4	$y = -4.76x + 32.94$ $R^2 = 0.7327$
Total value added by production costs in agriculture, %	12.83	10.07	8.41	7.78	6.74	$y = -1.447x + 13.507$ $R^2 = 0.9256$
cultivation of crops, %	10.98	8.69	6.85	6.48	5.59	$y = -1.299x + 11.615$ $R^2 = 0.9171$
stockbreeding, %	1.38	0.98	1.00	0.86	0.81	$y = -0.126x + 1.384$ $R^2 = 0.7925$

Source: *compiled from [11]*

A detailed study of the reasons for the decline in the economic efficiency of activities in the agricultural sector requires consideration of the dynamics of indicators of the profitability of production of the main types of products. Analysis of the annual growth rate of production profitability for each type of product allowed establishing a drop in efficiency at the level of 30% in crop production and 190% in livestock production (Table 4).

Table 4. *Dynamics of the level of profitability of production of the main types of agricultural products at enterprises of Ukraine in 2015-2019*

Indicators/Years	2015	2016	2017	2018	2019	Tendence
Profitability of production, %:	36.4	31.7	26.8	24.6	7.3	$y = -6.53x + 44.95$ $R^2 = 0.8686$
corn for grain	50.3	45.7	23.7	27.2	17.8	$y = -8.35x + 57.99$ $R^2 = 0.8589$
factory sugar beetrape and colza seeds	44.3	45	43.6	31.1	9.4	$y = -8.37x + 59.79$ $R^2 = 0.7529$

Table 4, Continued

Indicators/Years	2015	2016	2017	2018	2019	Tendence
sunflower seeds	80.5	63	41.3	32.5	23.5	y = -14.45x + 91.51 R^2 = 0.9638
pigs for meat factory sugar beet	28.2	24.3	12.4	-11.4	-15.4	y = -12.29x + 44.49 R^2 = 0.9345
cattle for meat	-17.9	-24.8	3.4	-17.7	-27.1	y = -1.13x - 13.43 R^2 = 0.022
pigs for meat	12.7	-4.5	3.5	6.9	4.7	y = -0.46x + 6.04 R^2 = 0.0137
poultry for meat	-6.1	5	7.0	5.7	-3.7	y = -0.46x + 6.04 R^2 = 0.0137
milk	12.6	18.2	26.9	16.1	20.6	y = 1.39x + 14.7 R^2 = 0.1681
poultry eggs	60.9	0.5	-9.0	5.4	-23.5	y = -16.39x + 56.03 R^2 = 0.6495

Source: *compiled from [11]*

A number of complex factors influence the formation and change of profit volumes: sales price, cost of production, the structure of changes in the product range and sales volumes. From the point of view of an individual enterprise, an inexhaustible reserve for increasing profits (subject to other favorable factors) is an increase in the volume of sales of agricultural products. In the dynamics of sales volumes of the main types of products in physical terms for the analyzed period of 2015-2019, no single trend can be traced (Table 5)

Table 5. *The dynamics of sales volumes in natural terms of the main types of agricultural products at enterprises of Ukraine in 2015-2019*

Indicators / Years	2015	2016	2017	2018	2019	Tendence
Scope of implementation:						
wheat, thousand tons	17631	16921	16903	16110	17062	y = -194.9x + 17510 R^2 = 0.3214
corn for grain, thousand tons	23311	15739	17251	22058	27697	y = 1509.1x + 16684 R^2 = 0.2454
seeds of oil crops, thousand tons	14631	12242	13696	13685	16729	y = 563.9x + 12505 R^2 = 0.2908
factory sugar beet, thousand tons	5819	10879	12534	5015	4078	y = -934.6x + 10469 R^2 = 0.1523
agricultural animals (in live weight) thousand tons	1947	2176	2001	1009	1024	y = -301.3x + 2535.3 R^2 = 0.7042
milk, thousand tons	2538	2543	2690	2603	2551	y = 8.6x + 2559.2 R^2 = 0.0449
poultry eggs, thousand tons	8897	7141	7223	8051	8359	y = -16.6x + 7984 R^2 = 0.0012

Source: *compiled from [11]*

Thus, an increase in the volume of sales in natural units was recorded for corn for grain, oil crops and poultry eggs, while a decline occurred for other types. Particular attention should be paid to wheat, the sales volume of which increased in 2019 against the background of a constant decline in the previous period, but the level of profitability of its production was the lowest – 7.3%, with the average values of the indicator for previous years at 25%. The main reason for the decrease in the level of profitability is the outpacing growth rates of activity costs compared to the volume of products sold. In addition, the orientation of domestic enterprises to foreign markets (if we consider export crops) makes Ukraine dependent on global price fluctuations.

Taking into account certain fluctuations in the volume of sales, the choice of the type of reproduction of production should be based on competitiveness and sustainability. Recently, a popular concept is constant intensification, which is primarily associated with best practices and innovation.

Limiting the expansion of agricultural land at the national level requires the search and use by producers of agricultural products of intensive forms of extended reproduction, which provide for a constant increase in production volumes based on the use of more efficient means of production, improvement of technologies, rational placement and specialization, scientific organization of work, etc.

In this regard, the statement of researchers V.V. Vasyuta & V.B. Mormul, who consider the intensification of agricultural production as the concentration of production resources on one and the same land area, which implies the qualitative improvement of the means of production and the use of advanced technologies [12]. The tasks of production intensification should be directly related to the introduction of progressive technologies, techniques and methods of labor organization in agriculture and animal husbandry [13].

Further analysis of the intensity of production involves determining the level of concentration of production costs per 1 ha of land and crop yield/animal productivity by individual species (Table 6).

Table 6. *Dynamics of the level of production intensity of the main types of products of agricultural enterprises of Ukraine for 2015-2019*

Indicators/Years	2015	2016	2017	2018	2019	Tendence
Production costs						
wheat, UAH/ha	4829.0	6384.7	7495.2	8476.7	9431.7	y = 1129.7x + 3934.2 R^2 = 0.9888
corn for grain, UAH/ha	7245.7	9274.9	10851.6	14398.8	14611.1	y = 1985.5x + 5320 R^2 = 0.9544
sunflower seeds, UAH/ha	5873.8	7193.1	8335.9	9498.8	10221.0	y = 1100x + 4924.5 R^2 = 0.9909
factory sugar beet, UAH/ha	22589.2	30800.1	29513.6	33965.4	33210.8	y = 2440.9x + 22693 R^2 = 0.7281
milk, UAH/ha	345.6	420.8	520.4	610.8	627.9	y = 75.46x + 278.72 R^2 = 0.9646
poultry eggs, UAH/ha	220.5	296.0	344.7	819.3	802.6	y = 168.75x - 9.63 R^2 = 0.8442
Production/productivity of livestock and poultry						
wheat, c/ha	38.9	42.1	42.6	38.4	43.4	y = 0.53x + 39.49 R^2 = 0.1359
Corn for grain, c/ha	61.1	66	59.5	87	77.7	y = 5.42x + 54 R^2 = 0.5308
Sunflower seeds, c/ha	21.6	22.4	21.3	24.1	27.0	y = 5.42x + 54 R^2 = 0.5308
factory sugar beet, c/ha	448	481.5	484.1	518.8	470.3	y = 8.19x + 455.97 R^2 = 0.254
milk, kg/cow	4691.5	4791.6	4874.8	4987.6	5034.5	y = 88.2x + 4611.4 R^2 = 0.9879
Poultry eggs/hen.	78.7	74.0	76.9	78.8	78.8	y = 0.5x + 75.94 R^2 = 0.1436

Source: *compiled from [11]*

We estimate the level of intensification using the indicator of production costs per 1 ha of land for the studied types of products, which shows steady growth. Yield of individual crops, animal productivity and production of individual species in natural measurements per 100 hectares of relevant land are effective indicators of intensity. The dynamics of the latter are characterized by significant fluctuations over the period, which requires the analysis of longer time intervals.

Analysis of the dependence between the intensity and efficiency of economic activity of individual enterprises of the Kharkiv region.

Using the example of enterprises of the Kharkiv region, the indicators of intensification and efficiency of economic activity in wheat cultivation were determined and analyzed, followed by a search for the dependence between them according to the created groups (Table 7).

Table 7. *The relationship between the efficiency of agricultural enterprises of the Kharkiv region and the level of intensity of wheat production in 2019*

Indicators	Intervals according to the production cost per 1 ha					Average
	Group 1	Group 2	Group 3	Group 4	Group 5	
	below 10 thous UAH/ha	10-12 thous UAH/ha	13-15thous UAH/ha	16-20 thous UAH/ha	more 20 thous UAH/ha	
Number of enterprises	87	126	137	72	58	480
Production cost per 1 hectare, thousand UAH/he	7.909	11.550	14.405	17.648	28.608	16.024
Sown area, ha	482.1	815.4	742.1	892.9	691.9	724.9
Commodity products, centner	14355.0	27979.4	31712.8	39929.8	47065.6	32208.5
Yield, c/ha	29.2	33.1	39.4	46.1	70.1	43.6
Profit per hectare, thousand UAH/hectare	2.718	2.030	2.069	1.794	2.872	2.297
Profitability of sold products	41.8	20.5	15.5	13.4	13.7	20.9

Source: *compiled from [14]*

The selected groups show tendencies to change the level of profitability of implementation, profit, productivity depending on the increase in costs per 1 ha. The direct relationship between the cost of production and yield is explained by the comparison of the input and output of intensification, while there is an inverse relationship between costs and profitability or profit. It is interesting that the enterprises that are included in group 5 with significant expenses have the highest profit per 1 ha, which requires a more detailed study of economic entities that spend on wheat cultivation from 20 thousand UAH per 1 ha and above. If we compare the rate of growth between costs and productivity in the section of the selected groups, the latter indicator grows at a lower rate, and the gap is the smallest in the third and fourth groups.

CONCLUSIONS

The study of the indicators of the economic dimension of the sustainable development of agriculture in Ukraine in the context of the Central Development Fund demonstrated the possibility of using indicators for analysis at the national level and certain difficulties at the level of enterprises and regions. The selection of indicators for the further formation of a complex index may differ depending on the tasks set, such as the assessment of the effectiveness of the country's national economic policy or the effectiveness of the implementation of sustainable practices at the enterprise level. The conducted research made it possible to determine a number of trends in the assessment of indicators of agriculture at the macro level. The positive trends include a significant increase in crop productivity and animal productivity, due to an increase in the level of intensification of farming by increasing costs per 1 ha. The negative trends should include a decrease in the level of profitability of operational activities (by 23%), added value at the expense of agricultural enterprises (by 6%) against the background of an annual decrease in the profitability of the main types of crops; a permanent decrease in the volume of sales in real terms.

At the level of individual enterprises of the Kharkiv region, the dependence between the intensity and efficiency of economic activity was analyzed, and the group with a high level of efficiency showed the highest rate of profit per 1 ha of land, which may be the result of the implementation of sustainable practices. Adherence to the principles of balanced management will contribute to the achievement of the goals of sustainable development thanks to the effective use of natural mechanisms in combination with innovative principles of sustainable agricultural production in Ukraine. Prospects for further research consist in the identification of existing models of complex indicators of sustainable development, their approbation on the example of the agricultural sector at the macro level and the level of an individual enterprise.

REFERENCE:

[1] Niemmanee, T., Kaveeta, R., & Potchanasin, C. (2015). Assessing the Economic, Social and Environmental Condition for the Sustainable Agricultural System Planning in Ban Phaeo District, Samut Sakhonn Province, Thailand. *Procedia – Social and Behavioral Sciences*, 197, 2554-2560. doi:10.1016/j.sbspro.2015.07.621.

[2] Rockström, J., & Sukhdev, P. (2016). How food connects all the SDGs – Stockholm Resilience Centre. Retrieved from https://www. stockholmresilience.org/research/research-news/2016-06-14-how-foodconnects-all-the-sdgs.html.

[3] Reganold, J.P., & Wachter, J.M. (2016). Organic agriculture in the twenty-first century. *Nature Plants*, 2(2), article number 15221. doi: 10.1038/nplants.2015.221.
[4] Kanter, D.R., Musumba, M., Wood, S.L.R., Palm, C., Antle, J., Balvanera, P., Dale, V.H., Havlik, P., Kline, K.L., Scholes, R.J., Thornton, Ph., Tittonell, P., & Andelman, S. (2016). Evaluating agricultural trade-offs in the age of sustainable development. *Agricultural Systems*, 163, 73-88. doi:10.1016/j.agsy.2016.09.010.
[5] Campagnolo, L., Carraro, C., Eboli, F., Farnia, L., Parrado, R., & Pierfederici, R. (2017). The Ex-Ante Evaluation of Achieving Sustainable Development Goals. *Social Indicators Research*, 136(1), 73-116. doi:10.1007/s11205-017-1572-x.
[6] Nikishina O.V. (2020). Methodological regulations regarding the assessment of the natural resource potential of agriculture in the coordinates of sustainable development of Ukraine. *Economics of the Food Industry*, 12(1), 64-76. doi: 10.15673/fie.v12i1.1670.
[7] Uzhva, A.M. (2017). Complex diagnosis of the economic component of sustainable development of agricultural enterprises in a competitive environment. *Economic Analysis: Collection of Science Works*, 27(3), 228-235.
[8] Fryer, O.V. (2018). Trends in crop production and sustainable development of agriculture in Ukraine – opportunities for harmonization. *Economy APK*,10, 117-125.
[9] Sustainable development goals: Ukraine. Monitoring report./ State Statistics Service of Ukraine. (2020). Retrieved from www.ukrstat.gov.ua/menu/st_rozv/publ/SDGs-MonitoringReport_v08_24.09. 2019.pdf.
[10] Sustainable Development Goals: Ukraine. National report. (2017). Retrieved from http://surl.li/eljaj
[11] State Statistics Service of Ukraine.(n.d.). Retrieved from www.ukrstat.gov.ua.
[12] Vasyuta, V.B., & Mormul V.V. (2013). Intensification of agricultural production. *Efficient Economy*, 11. Retrieved from www.economy.nayka.com.ua/?op=1&z=2453.
[13] Nikishina O.V. (2020). Methodological regulations regarding the assessment of the natural resource potential of agriculture in the coordinates of sustainable development of Ukraine. *Economics of the Food Industry*, 12(1), 64-76. doi: 10.15673/fie.v12i1.1670.
[14] Statistical data of the Main Department of Statistics in the Kharkiv region. Retrieved from http://kh.ukrstat.gov.ua/.

Сталий розвиток сільськогосподарських підприємств: економічний вимір

С. І. Страпчук

Кандидат економічних наук, доцент
https://orcid.org/0000-0003-2809-6633
Researcher ID AAF-4686-2020
Харківський національний аграрний університет ім. В. В. Докучаєва

Анотація. Актуальність дослідження обумовлена необхідністю діагностики прогресу економічної складової сталого розвитку сільськогосподарського сектора. Здійснено моніторинг індикаторів відповідних цілей сталого розвитку в національній системі ЦСР. Досліджено динаміку показників ефективності та інтенсивності галузі сільського господарства України за декілька років. Отримані результати дозволяють виявляти актуальні проблеми, визначати пріоритетність вирішення завдань економічної політики в галузі сільського господарства на різних рівнях

Ключові слова: сталий розвиток, економічна складова, сільськогосподарські підприємства, ефективність виробництва, валова додана вартість

UDC 330.341.1.001.572:338.432:502.131
DOI: 10.31521/2313-092X/2021-3(111)-3

Ukrainian Black Sea Region Agrarian Science
Vol. 25, No. 3

Theoretical and methodological assessments of the formation of an innovative model of the agrarian sector on the basis of sustainable development

V. Rybachuk*

PhD in Economic Sciences
https://orcid.org/0000-0001-9153-9674
Mykolayiv National Agrarian University

Abstract. The idea of the principles of sustainable development is important and a priority in the context of ensuring the effectiveness of the functioning of economic systems. The agricultural sector, which is of great importance in the socio-economic and economic dimensions, requires a favorable organization of innovations in order to achieve the principles of sustainability. In view of this, it is important to build an innovative model in the agricultural sector to obtain sustainability criteria, which requires the dissemination of theoretical and methodological assessments of its formation – which is the purpose of the article. The article examines the theoretical and methodological foundations of assessment and conducts a conceptual analysis of the foundations of the formation of an innovative model of the agricultural sector based on the principles of sustainable development. The methodological context of the formation of an innovative model on the basis of sustainable development is revealed, taking into account the critical importance of the agricultural sector as a system in which relations are implemented to guarantee national food security. Strategic priorities, ideological guidelines for the implementation of the concept of sustainability in the agricultural sector of the economy within the framework of solving the task of innovating the industry with the subsequent increase in its competitiveness are proposed. Methodologically compared and implemented into the system of scientific discourse, the aspect of implementation of measures to implement the goals of sustainable development within the framework of the formation of an innovative model of the agro-industrial sector. The theoretical value of the article lies in the improvement of the specified research vector, the expansion of theoretical and methodological assessments of the formation of an innovative model of the agrarian sector on the basis of sustainability with a concentration on the organizational and regulatory component. Such theoretical and methodological improvement is logical along with the development of the agricultural management system, changing priorities for determining and ensuring its socio-economic effectiveness

Keywords: agricultural sector, innovative model, sustainable development, innovation of the industry

INTRODUCTION

Today, the concept of the principles of sustainable development is a priority for building and ensuring the efficiency of economic systems, as well as positioning criteria for the effectiveness of management. The agrarian sector, as a special branch in socio-economic and economic terms, needs a constructive organization of innovations in order to achieve the principles of sustainability. In this regard, achieving sustainability criteria is not possible without building an innovative model in the agricultural sector, therefore it is always time to deepen the theoretical and methodological assessments of its formation. The problem is considered in general in order to satisfy the need to take into account the features of the state of the competitive

Article's History:
Received: 23.02.2021
Revised: 11.06.2021
Accepted: 26.08.2021

Suggested Citation:
Rybachuk, V. (2021). Theoretical and methodological assessments of the formation of an innovative model of the agrarian sector on the basis of sustainable development. *Ukrainian Black Sea Region Agrarian Science*, 25(3), 20-28.

environment of business entities and the principles of the functioning of the agrarian sector of the economy. Given the current state of economic relations in the agricultural sector of Ukraine, the problem of forming an innovative model based on the principles of sustainable development is critical and requires constant additional theoretical and methodological consideration with the assessment and determination of organizational and economic priorities for its solution. The concept of an innovative model of the economy in relation to the elements of the ideology of sustainable development, particularly regarding the agrarian sector, was formed thanks to the scientific understanding of the principles of the activities of organizations and systems of facilitating the satisfaction of ever-growing needs, increasing labor productivity, etc. A. Smith [1], Y. Schumpeter [2], J. Galbraith [3], B. Santo [4], and M. Tugan-Baranovsky [5] carried out general theoretical, basic studies of issues of innovation, components of sustainable development in their works. and other. The sectoral specificity of innovations in the agricultural sector, along with the determination of ways to achieve competitiveness and entrepreneurial activity, are noted in the scientific works and practical recommendations of O. Krysalny [6], V. Shebanin [7], O. Shpykulyak [8], V. Pokotilova [9], V. Geitsa [10], S. Volodina [11], L. Kurylo [12]. Emphasis on the ideology of sustainable development in the context of various aspects of the functioning of the agricultural sector was made in the works of M. Khvesyk [13; 17], P. Sabluka [14], Yu. Lupenko [15; 16], M. Malik [17; 18], as well as noted in normative and methodological [19; 20] and other publications [21-30].

In the development of the specified direction of research, we propose to deepen the theoretical and methodological assessments of the formation of an innovative model of the agricultural sector on the basis of sustainability with an emphasis on the organizational and regulatory component. We consider such theoretical and methodological deepening to be logical with the evolution of the agricultural management system, changing priorities for determining and ensuring its socio-economic efficiency.

The purpose of the article is to deepen the theoretical and methodological assessments of the formation of an innovative model of the agricultural sector on the basis of sustainable development.

RESULTS AND DISCUSSION

The concept of an innovative model as a guarantee of progress in the socio-economic development of the state

The formation of an innovative model is a classic way for the state, organization, industry to achieve: progress in socio-economic development, which was particularly noted in the scientific work of J. Galbraith [23], tested by the experience of H. Ford [24]; efficient diffusion of innovations, especially in an extremely conservative sector, such as farming, as noted by Everett M. Rogers [25]; formation of the effective potential of energy independence due to the use of renewable energy sources – the conclusion of H. Kaletnik [26]. The specified list of theoretical, methodological and practical conclusions regarding the lack of an alternative to the formation of an innovative model of the agricultural sector on the basis of sustainable development is not exhaustive, but it proves the confirmation of this scientific truth by practice.

Revealing this issue with reference to the agrarian sector of the economy of Ukraine, we note the presence of systemic opportunities and the general need to rebuild the foundations of the organization of the industry's functioning from a raw material model to a high-tech model that embodies the practices of the movement towards sustainable development. We note that, possessing sufficiently competitive resource potential of the agricultural sector, our state sets world records in the production of certain types of agricultural products every year. However, it dominates mostly in the commodity sectors (cereals, sunflower seeds, rapeseed). Every time it sets records for the production of raw materials, the Ukrainian agricultural sector is moving away from the principles of sustainable development, towards which the principles of the innovation model are directed (innovations are actively involved mainly in the sector of establishing competitive production of several agricultural crops – export-oriented). Accordingly, such important aspects of ensuring sustainable development, achieving UN goals [19] and their national implementation [20-22] as: "green" energy [26; 27] – especially at the local level of providing it to rural households; secondary processing of unused food and agricultural products; organic agriculture; systematic development of animal husbandry; strengthening the role and innovative development of family farming [18]; improvement of the system of training of personnel in agricultural specialties [7; 12; 30].

Taking into account the problematic arguments of the functional assessment of the nature of relations in the system of building an innovative model and its relation to the implementation of the principles of sustainable development of the agrarian sector of the Ukrainian economy, it is worth paying attention to the current world trends, which other scientists characterize as follows: "...the strategy of economic development, which was based on export, exhausted itself. Countries will achieve better results if their strategies for economic growth focus on a more important role of increasing demand in the domestic market, raising wages, strengthening the public sector and, in addition, on meeting demand through the development of domestic production in those activities that belong to the processing industry, which is especially important. The return from them increases due to "technological creativity, which will eventually strengthen the role of exports" [10]. It is believed that for a long time in the world, this also applies to the field of agro-industrial production (author), the so-called commercial expansion dominated, which led to the expansion of exports, thereby acting as a model of economic growth [10]. For Ukraine, for its agricultural sector, the model also has a raw material character, and in order to get out of the "welfare crisis" it is necessary to switch to an innovative model – this is the main priority.

An innovative model in the development and implementation of strategic priorities of state policy in all fields of implementation of management decisions should become the norm.Only such a general-context proposal in its practical implementation, based on the results of scientific and analytical assessments of the state of the agrarian sector of the national economy, its scientific and innovative support, as well as the entrepreneurial component, is considered by us to be a constructive basis for the development of tools for the transition of the industry to sustainable development and, most importantly, ensuring the formation of an innovative model.

It is the innovative model that is the recognized landmark of the strategic contours of the development of the agricultural sector, which is desirable for achievement, because it makes it possible to construct such a type of interaction of productive forces and the implementation of industrial relations, which carries the foundations of progressivity.

Innovativeness of the development of the agricultural sector in a practical sense as the quality of development actually ensures the appropriate level of technologies for the production of agricultural products and food, energy saving, sustainability, renewable resources. That is, agro-innovations introduced as a result of the innovation process constitute the construction of the effects of sustainability, competitiveness, food and energy security, etc. The multiplicity of agricultural innovations is systemic, but the connection with the nature of the industry itself, its dependence on climatic and weather conditions normalizes significant risks that can level out innovativeness, positive effect – much more often than in other spheres of entrepreneurial activity. The consequences of the innovation process cannot be considered unconditionally achievable, therefore, in the fundamental understanding of the theory of the innovation model of the agricultural sector, there are many differences from the classical innovation process.Based on the content of theoretical and methodological developments and analytical generalizations of the characteristics of the model of the agricultural sector and the production of the same name, which is recognized as resource-raw, clear priorities emerge that must be implemented first of all at the institutional level for the successful implementation of the concept of sustainability.

Among the strategic priorities or ideological guidelines, we see the following:

- formation and approval of the national idea of agro-industrial production as a basic industry for achieving national well-being;
- determining the priorities of the state agrarian policy, taking into account the idea of specialization of the agro-food complex, in accordance with its natural, economic and resource potential for the formation of the industry as a national brand;
- unconditional support of Ukrainian agricultural science and education, contrary to world trends of their globalization;
- support for agrarian entrepreneurs who contribute to the introduction of innovations in the development of rural areas and produce renewable, ecologically oriented products;
- stimulation of innovations in the processing industry and infrastructure development;
- developing a strategy for the transition from the supply of agricultural raw materials to external markets to products with high added value;
- the gradual transformation of Ukraine and its agricultural sector at the national and regional level into a world "center" for the development of sustainable agriculture with developed eco-agriculture, bioenergy, etc.;
- the introduction of the agricultural industry into the system of national priorities for its development as an unconditional guarantor of national security in the economic, social, ecological, and innovative spheres of human life.
- background and priorities in the formation of an innovative model of the agricultural sector.

Today, in the development of proposals and justification of directions for the development of agro-industrial production in the format of an innovative model, scientists pay attention to the improvement of the conditions of innovation, which can be generally agreed, because the effectiveness of innovative activity depends on the level of favorability of the socio-economic environment. The introduction of innovations here means the formation of a stable, logically ordered market mechanism for the introduction of scientific developments into the production process of the agrarian complex. In other words, it is the creation of an organizational and orderly system with the participation of scientific and educational institutions, the state, and production structures, which would provide conditions and opportunities for the transfer of innovations into production. Moreover, in the conditions of Ukraine, only the formation of an innovative model of the agrarian sector will make it possible to turn it into an industry for the production of goods with high added value, the driving force of economic growth.

This requires an effective innovative policy of breakthrough, creative direction. The need for budgetary and tax stimulation of innovative activity in Ukraine has been proven. We also consider this regulatory lever to be one of the important ones in the formation of the national and regional ideology of supporting the formation of an innovative model of agro-industrial production. Without the ideology of supporting innovative development, which is identical to national business traditions, the efficiency of the industry will remain low, in particular in the socio-economic dimension of sustainable management.Without innovations, the "green" model is unattainable, and in general, an innovative nationally identical model would be positioned as a mechanism for an innovative breakthrough. State and institutional-legal support for the effective use of the innovative potential of the agro-food sector should become a priority, both at the level of the industry and at the level of specific structures. We consider the path of building a balanced organizational, economic, ecological and social development of the industry based on an active process of development and implementation of domestic agro-innovations, as well as in education and science. This is a complex ideological priority, which we consider to be the basis of the concept of sustainable development in the formation of an innovative model, but with necessarily unconditional consideration of the priorities of scientifically based specialization of regions. This ideology is defined by us, based on the results of analytical assessments of the development of the agricultural sector and production

Regarding the principles and priorities of the formation of an innovative model of the agrarian sector, it is necessary to decide at the state level with the development of the state agrarian policy in the priorities of sustainable development (Fig. 1).

It's believed that these should essentially be social messages, even with short-term incentives of a coercive nature, which to some extent do not satisfy the "interests" of large agrarian capital, for which such a model (innovative) with a highly intellectual society, a highly competitive transparent, and therefore a demonopolized, developed market local governments do not need, because it increases the risks for business.

However, there can be no other wa y, because the further consolidation of Ukraine in terms of the income base of life, among the countries of the "third world", will lead to the inevitable loss of high-powered national agro-industrial potential.

The article considers it institutionally acceptable the fact that the innovative model of the agricultural sector is a toolkit, a mechanism for ensuring sustainable development, it is incorporated accordingly by state policy into the system of organizing the practice of managing the relations of agricultural market participants. In the given context of the conceptual vision of the problem, a functional basis or a conceptual scheme for the implementation of the principles of sustainability should be embedded, taking into account the fact that agriculture is an environment of life and management at the same time. The first basis for defining the concept should be clearly defined contours or "points of contact" (see Fig. 1), which should be oriented to the development of innovation policy. A complex problem, which proves the main priorities of building an innovative model, is the natural, opportunistic, de-innovative, raw nature of labor productivity, production efficiency; systemic deterioration of the functionality and effectiveness of the development of the structure of scientific and educational support of the industry; "consumer" nature regarding the priorities of resource use, entrepreneurial activity; the low level of effectiveness of the introduction of innovations in the agrarian sector of the economy and their significant inconsistency with the principles of sustainable renewable development; the general stability of the resource model with a low level of intellectualization of labor; the predominance of quantitative guidelines over qualitative ones in the implementation of agrarian policy to support the industry; detachment of the producer from the problems of ensuring the sustainable functioning of the agroecosystem; the systematic outflow of researchers from agricultural science and the secondary nature of its status.

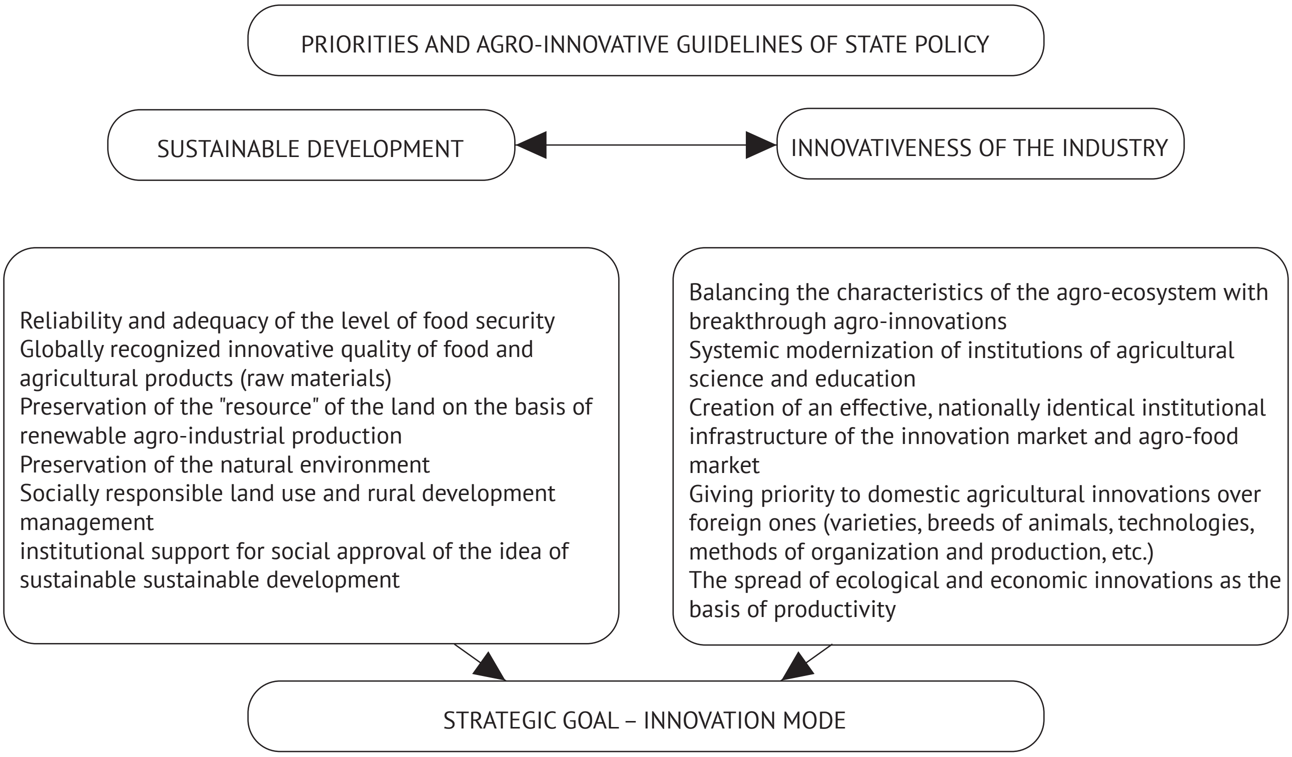

Figure 1. *Priorities of sustainable development and innovative model of the agrarian sector of the economy*
Source: *determined by the author based on his own research*

The identification of the given "points of contact" was carried out taking into account the problems that exist today in the functioning of the national and regional system of agro-industrial production and confirmed by empirical assessments of the state of affairs in various formations of efficiency (social, economic, ecological, institutional, innovative).

The reality of building an innovative model within the institutional guidelines set by us is a problem without the solution of which the progressive development of the industry is impossible, until the priority of systemic, breakthrough innovations is intensively used, not only in the export segment of raw material production. It is necessary to ideologically and practically adjust the foundations of the national and regional model of the development of the agricultural sector of Ukraine to the goals of sustainable development recognized by the world community (Table 1).

One of the important priorities of the development model of the agricultural production sector is the need to "overcome the existing gap in competitiveness, which requires significant changes, not least in technologies, including managerial ones, due to appropriate investment and changes in the personnel training system" [10]. In parallel, a regulatory policy in the field of innovative development should be developed and implemented, the goal of which should be a reduction in the level of technological dependence and a course for the modernization of the agricultural industry in all its segments, including scientific and educational support.

Table 1. *Goals of sustainable development and contours of their implementation through the construction of an innovative model of the agricultural sector*

Goals of sustainable development	The goals of sustainable development Implementation contours in the innovation model through the development of effective innovations
Overcoming poverty	Implementation of breakthrough innovations in the development of entrepreneurial activity to ensure the growth of business profitability and increase the cost of labor in the system of agricultural labor
Solving the problems of hunger	Guaranteeing stable production of sufficient quantities of high-quality food
Maintaining good health	Systematic innovative quality control of produced and consumed food and other goods of agricultural origin

Table 1, Continued

Goals of sustainable development	The goals of sustainable development Implementation contours in the innovation model through the development of effective innovations
Quality education	Development and implementation of innovative training programs for the village
Gender equality	Ensuring compliance with the rules of equal participation of men and women in the system of determining priorities for the development of the sector
Clean water and proper sanitary conditions	Introduction of advanced water quality standards and methods of their observance, as well as the creation of viable sanitary conditions for the development of the agroecosystem
Use of renewable energy	The formation and innovative waste-free system of agricultural production based on the processing of organic waste of the agro-food system into energy with its subsequent use in the socio-economic development system
Decent jobs and economic growth	Creation of innovations to ensure decent conditions of agro-industrial work with a constructive symbiosis of income and labor microclimate
Innovations and infrastructure	Systematic support of agricultural science in the formation of a national priority and the creation of high-quality, accessible, functional infrastructure of rural development
Reducing inequality	Structuring the incomes of those employed in agro-industrial production for a fair assessment of property and labor investments
Development of cities and communities in accordance with the principles of sustainable development	The perspective of innovating relations in the "city-village" system on the basis of interdependent sustainable development
Responsible consumption	Rationalization of food supply
Protection of the planet	The use of only natural renewable factors in the organization of agrarian life activities
Ensuring life under water	Preservation of water bodies and introduction of sustainable aquaculture innovations
Ensuring life on earth	Progress towards a sustainable, ecologically renewable system of human life in the agricultural sector
Peace and justice	Fair distribution of agricultural goods
Cooperation to achieve goals	Agrarian activity on a partnership basis

Source: *proposed by the author based on research results and methodological generalizations*

The adaptability of the innovative model to a number of requirements, as well as the potential of manufacturers, is an extremely important fact of ensuring its functionality. It is important to create stable prerequisites for systemic innovative activity of economic entities in the agricultural production system, as well as their interaction with all participants of the innovation market. The model of interaction should meet the needs and trends of the development of agro-industrial entrepreneurship. In this context, the institutional policy of the state and its authorized bodies should create stable prerequisites for effective entrepreneurial activity, which will ensure the movement towards an innovative model

The functional key to building an innovative model of agro-industrial production in the region is institutional support for the growth of innovative activity of enterprises: from the production of agricultural products, raw materials, to enterprises for their processing. Organizationally and structurally, among the enterprises – participants of the agrarian market, which, in our opinion, are directly related to the formation of the innovative model, enterprises and structures for the production of agricultural products of all forms of ownership and management should be singled out; enterprises, organizations – subjects of market infrastructure, including innovative infrastructure; processing enterprises.

In general, in order to achieve visible success in the mentioned process, it is necessary to first eliminate the imbalance in the levels of innovation, when large, financially strong enterprises have unlimited access to advanced technologies, and small, small and even medium ones do not have the financial opportunity to buy the latest means of production.This paradox must be eliminated by the state, and financial levers do not necessarily have to be involved here, institutional support is of decisive importance – the formation of favorable institutional conditions for the development of the innovation market. Thanks to the strengthening of the innovative orientation of enterprises in the development of agro-industrial production, it will be possible to solve many problems.

The central role in ensuring the effective transition to the innovative model should be played by institutions of the scientific and educational sphere, which are engaged in training personnel and creating innovations. It is necessary to ensure, first of all, a sufficient level of financing of these institutions and ideological, institutional state support. When creating an innovative model, along with the available resource potential of the industry, institutions – legal, organizational-management, functional-economic, as well as infrastructural – are of exceptional importance.

When building the declared system of institutional support, it is necessary to take into account the nationwide process of innovation of the economy, the industry, because there cannot be isolation here, because everything happens in the environment of global competition. Conceptually, here we should talk about the institutional framework of the organization of the formation of the innovative model, as well as the creation of conditions for its effective functioning. This is a very complex process, the process is not instantaneous and requires comprehensive consideration of atypical institutional features of the changing business environment, including in relation to the components of self-regulation.Institutional policy is determined by institutions, understood by the "rules of the game" – this is the first thing that is needed for the systematic introduction of innovations, the arrival of investments in agro-industrial production. These are all the actions of subjects, from the generation of innovations to their direct use in the practice of production and infrastructural maintenance of institutional regulation. We emphasize the use of foreign experience in implementing an innovative model, which could form the institutional basis of this process. This, in our opinion, is a way out of the difficult situation of increased competition and the need to maintain competitiveness in the market. However, one should not forget about the institutional and legal support for the creation of a legal field of activity for the participants of the innovative model. We should move away from this, and in this regard, the state has already done a lot, the regulatory acts are characterized by a wide-ranging support for innovations – the problem is only in financial support. For various reasons and risks, the possibilities of practical implementation of the priorities of the innovation model remain possibilities. This is a serious gap, which can only be filled with an increase in the level of trust in the agribusiness sector of the national economy and in the state, which is empowered to build an effective system of innovative development institutions.

It is suggested that the agrarian sector of production has sufficient potential for the introduction of innovations, and as a result, the growth of production volumes, first of all, in animal husbandry.

However, in order to realize the potential due to the implementation of promising innovative projects, it is necessary institutionally:

- to improve the mechanism of state support for implementing manufacturers
- innovations, emphasizing their targeted financing;
- to organize effective advisory activities to ensure unimpeded access to information and financial resources;
- to stimulate the development of both production and service agricultural cooperation;
- to form a system of ensuring resource filling of the microcredit system of agricultural production;
- establish a system of innovative support for the development of small producers, in particular family farms.

When building the concept of an innovative model, it is necessary to talk about the organizational and regulatory involvement in its functioning, if possible, of all categories of business entities, including households. They also need to be involved in the system of innovative development, in particular through the cooperation mechanism, to give them the opportunity to use the latest developments and production technologies at their level. There is definitely a sense in this, because households, producing a fairly significant share of products in the national volume, essentially do not have the opportunity to use the latest technologies. This fact significantly reduces the productivity of production assets, in particular land.With the formation of an innovative model as an institutional reference point for the regulation of innovative development of the agrarian sector of the economy, the actual possibility of achieving the following global strategic goals appears: identification and permanent constructive adjustment of socio-economic and environmental problems; implementation of a sustainable environmental policy and ensuring rational use of natural resources; creation and introduction of breakthrough innovations of agrarian direction in the production and social segment of development; stabilization of the investment climate, stable investor confidence in the industry; guaranteeing the quality and safety of sustainable development; preservation of agricultural resources for future generations on the basis of innovation in nature and land use.

We consider the position of V. Pokotylova to be fair and well-founded that the transition of the economy to an innovative model requires appropriate resources aimed at the development and implementation of the latest technologies and productions, as well as the systematicity of innovations, the creation of institutional conditions that stimulate innovation processes [9].Creative tasks, the solution of which, in our opinion, will contribute to progress towards an innovative model of agro-industrial production, are the following: improvement of financial support for scientific activity; increasing results in the creation and implementation of innovations; preserving the existing scientific potential and strengthening it in accordance with the challenges of the competitive market; formation of a functional institutional infrastructure of the market of agricultural innovations, as they follow the specifics of the industry; development and implementation of a nationally identical agro-innovation policy with the concentration of "efforts" on potentially the most competitive types of activity.

CONCLUSIONS

The article claims that the innovative model of the development of the agrarian sector should take into account innovative, production, resource potential with a mandatory combination of them in the format of coordination with the innovative policy of the state and the prospects of competitiveness. This is the institutional construction of the foundations of formation, implementation and realization of institutional regulatory priorities. But it should be noted that the innovative model should not be positioned as a system closed in regional contours, because economic activity goes far beyond the borders of the state.

REFERENCES:

[1] Smith, A. (2018). *Research on the nature and causes of the wealth of nations*. Kyiv: Our Format.

[2] Schumpeter, Y.A. (2011). *Theory of economic development: study of profits, capital, credit, interest and the economic cycle*. Kyiv: Our Format.

[3] Galbraith, J. (1969). *New industrial society*. Moscow. Progress.

[4] Santo, B. (1990). *Innovation as a means of economic development*. Moscow: Progress.

[5] Tugan-Baranovsky, M.I. (1996). *Industrial crises*. Kyiv: Naukova Dumka.

[6] Krysalnyi, O.V. (2005). Organizational and economic features of innovative activity. *The Economy of Agro-Industrial Complex*, 8, 10-13.

[7] Shebanin V.S. (2014). Scientific support of innovative development of agriculture as a priority area of activity of an agrarian university. *The Economy of Agro-Industrial Complex*, 7, 19-25.

[8] Shpykulyak, O.G. (2012). Development of institutes of innovative activity in the agrarian sphere: theoretical aspect. *The Economy of Agro-Industrial Complex*, 5, 131-138.

[9] Pokotilova, V.I. (2008). *Management of innovative activities in agricultural production*. Kyiv: NSC IAE.

[10] Geets, V.M. (2016). Economy of Ukraine: key problems and prospects. *Economics and Forecasting*, 1, 7-22.

[11] Volodin, S.A. (2014). Model of innovative development of agricultural science on the example of the NAAS system. *Innovative Economy*,. 3, 5-24.

[12] Kurylo, L. (2013). Organizational component of reforming agrarian science and education. *Bulletin of the Sumy National Agrarian University. Finance and Credit*, 1, 218-221.

[13] Khvesyk, M.A., & Obykhod G. O. (2018). The latest dimension of environmental challenges and threats to sustainable development in the era of globalization. *Economics of Nature Use and Sustainable Development*, 3-4 (22-23), 5-18.

[14] Sabluk, P.T. (Ed). (2011). *Organizational and economic modernization of the agricultural sector: scientific report*. Kyiv: NSC IAE.

[15] Lupenko, Yu., Zhuk, V., & Mogylova, M. (2019). *Prospective forms of organization of economic activity in the countryside: scientific report*. Kyiv: NSC IAE.

[16] Lupenko, Yu. (Ed). (2020). *Strategic directions of sustainable development of rural areas until 2030*. Kyiv: NSC IAE.

[17] Malik M.Y., & Khvesyk M.A. (2010). Sustainable development of rural areas on the basis of rational nature management and ecologically safe agro-industrial production. *The Economy of Agro-Industrial Complex*, 5, 3-12.

[18] Malik M.Y., Shpykulyak O.G., & Mamchur V.A. (2020). Realization of the goals of sustainable development of Ukraine in the context of transformation of personal peasant farms into family farms. *Economics of Nature Use and Sustainable Development*, 7(26), 21-31.

[19] Resolution of the UN General Assembly "Transforming our world: Agenda for sustainable development until 2030" No. 70/1 (2015, September). Retrieved from http://21.helsinki.org.ua/files/docs/1549390386.pdf.

[20] Presidential Decree "On the Sustainable Development Goals of Ukraine for the period up to 2030" No. 722/2019. Retrieved from https://zakon.rada.gov.ua/laws/main/722/2019.

[21] Paton, B. (2016). *National paradigm of sustainable development of Ukraine*. Kyiv: State Institution "Institute of Economies of Nature Use and Sustainable Development of the National Academy of Sciences of Ukraine".

[22] Ukraine 2030: Doctrine of balanced development. (2017). Retrieved from http://econom.chnu.edu.ua/wp-content/uploads/2018/03/E-Book-Doctrine-2030.pdf.
[23] Galbraith, J.K. (2018). *Society of abundance* Moscow: Olymp-Business.
[24] Ford, H. (2016). *My life and work*. Kyiv: Our Format, 2016. 344 p.
[25] Rogers, E.M. (2009). *Diffusion of innovations*. Kyiv: Kyiv-Mohyla Academy.
[26] Kaletnik, G.M. (2010). *Biofuel: food, energy and environmental security of Ukraine*. Kyiv: Hi-Tech Press.
[27] Shpykuliak, O., & Bilokinna, I. (2019). "Green" cooperatives in the formation of an institutional mechanism of development of alternative power engineering in the agrarian sector of the economy. *Baltic Journal of Economic Studies*, 5(2), 249-255. doi: 10.30525/2256-0742/2019-5-2-249-255.
[28] Bondar, O.I. (2012). RIO+20 – the way to sustainable development: assessments and perspectives. *Environmental Sciences*, 1, 6-14.
[29] Haidutskyy, I. P. (2014). *Investing in a low-carbon economy: theory, methodology, practice: monograph*. Kyiv: Information systems.
[30] Shpykulyak, O.H. (2004). Personnel potential and its formation in agrarian enterprises. *The Economy of Agro-Industrial Complex,* 1, 155-159.

Теоретико-методологічні оцінки формування інноваційної моделі аграрного сектора на засадах сталого розвитку

В. П. Рибачук

Кандидат економічних наук
https://orcid.org/0000-0001-9153-9674
Миколаївський національний аграрний університет

Анотація. У статті досліджено теоретико-методологічні засади оцінки і проведено концептуальний аналіз основ формування інноваційної моделі аграрного сектора на засадах сталого розвитку. Розкрито методологічний контекст формування інноваційної моделі на засадах сталого розвитку, враховуючи критичну важливість аграрного сектора як системи, у якій реалізуються відносини для гарантування національної продовольчої безпеки. Запропоновано стратегічні пріоритети, ідеологічні орієнтири для реалізації концепції сталості в аграрному секторі економіки в рамках вирішення завдання інноватизації галузі з наступним підвищенням її конкурентоспроможності. Методологічно співставлено й імплементовано в систему наукового дискурсу аспект впровадження заходів реалізації цілей сталого розвитку в рамках формування інноваційної моделі агропромислового сектора

Ключові слова: аграрний сектор, інноваційна модель, сталий розвиток, інноватизація галузі

UDC 633.3/477
DOI: 10.31521/2313-092X/2021-3(111)-4

Ukrainian Black Sea Region Agrarian Science
Vol. 25, No. 3

The influence of changes in the structure of fodder crops on the supply of fodder to livestock

L. Antipova*

Full Doctor in Agricultural Sciences, Professor
https://orcid.org/0000-0003-2609-0801
Mykolayiv National Agrarian University

Abstract. A powerful fodder base should be formed on an innovative basis, with the involvement of all necessary factors. In turn, this determines the proper functioning of the livestock industry. The aspect of forming a fodder base for improving the animal husbandry industry of Southern Ukraine and providing the population with high-quality food should be solved by conducting a study of the state of production of fodder crops, the structure of their crops, the release of nutrients from various types of fodder. The purpose of the article is to study the impact of structural changes in the sown areas of fodder crops in Ukraine and in the arid zones of the Southern Steppe, based on the example of the Mykolaiv region, on the provision of fodder to the cattle industry. To conduct the research, an analysis of data collected by civil servants of the State Statistics Service of Ukraine and the Main Department of Statistics in the Mykolaiv region over the past 20 years was carried out. The analysis of the information of the State Statistics Service of Ukraine for the period from 2000 to 2020 confirms that the highest increase in cultivated area was recorded in the country's farms with technical crops. Their share in the structure of such areas was 15.4% in 2000, and by 2020 it was 17.4%. The article highlights the results of research into the state of production of the main fodder crops in Ukraine and its south (on the example of the Mykolaiv region) for the period 2000-2020. Changes in the structure of cultivated areas, a reduction in cultivated areas, which is due to a decrease in the number of cattle, are noted. The indicator of providing the feed unit with digestible protein has improved, the supply of animals with fodder has improved

Keywords: fodder crops, sown area, structure of sown areas, gross harvest, fodder base

INTRODUCTION

The creation of a strong fodder base should be based on innovative principles, primarily with the use of highly productive mixtures of herbs, the introduction of optimal doses of fertilizers and other agrotechnical measures, especially under conditions of climate warming [1-3]. This is the most important condition for the functioning of the livestock industry, because the state and level of its development determine the possibilities of increasing the number of animals, increasing their productivity, improving the quality of the produced products and reducing their cost price, emphasizes. Stepasiuk L.M. & A.A. Lopanchuk [4].

Environmentalization of agriculture is also an important issue at the current stage of safe food production. A special place in solving this task should belong to the cultivation of such fodder crops as perennial grasses. After all, they, more than others, affect the improvement of soil fertility indicators, besides, they are adapted to arid conditions of fodder production [5].

O.M. Polishchuk [6] notes that the main fodder crops in Ukraine are perennial grasses, which occupy about 50% of the total area of fodder crops. The fodder base is currently formed at the expense of concentrated and juicy fodder, which require the least costs for seeds, fuel, equipment and wages, which, under the conditions of the crisis, allows to reduce the level

Article's History:
Received: 17.03.2021
Revised: 27.06.2021
Accepted: 26.08.2021

Suggested Citation:
Antipova, L. (2021). The influence of changes in the structure of fodder crops on the supply of fodder to livestock. *Ukrainian Black Sea Region Agrarian Science*, 25(3), 29-37.

of unprofitability of an important component of the agrarian sector of the economy – meat cattle breeding. However, this practice significantly worsens the condition of the fodder base as a whole due to an unbalanced fodder ration.The issue of creating a strong fodder base for the development of animal husbandry in the arid zone of the south of Ukraine and providing the population with high-quality food products cannot be solved without an analysis of the state of production of fodder crops, the structure of their sown areas, and the release of nutrients from various types of fodder.

Scientists of the Institute of Irrigated Agriculture of the National Academy of Sciences M.G. Husev & D.P. Voytashenko [7] established that in the Steppe zone of Southern Ukraine, with intensive field fodder production, it deserves attention to restore the area of fodder crops to the level of 27-30%, and 60-70% under irrigation. This will make it possible to solve the problems of producing the required amount of various high-quality feeds. Currently, it is worth giving priority development to intensive-type fodder crops, namely alfalfa, corn, soybeans, root crops, intermediate crops of fodder agrophytocenoses in intensive links of the green conveyor belt.

A significant contribution to the development of the field of fodder production was made by V.F. Petrichenko, O.V. Korniychuk, Yu.A. Veklenkom [8]. They conducted an analysis of the production efficiency of the use of haymakers and pastures in Ukraine. It is proved that as a result of redistribution of land use, as well as the decline of the livestock industry, in the agricultural activity of economic entities, there was a violation of the basic balance between the areas of arable land and natural fodder grounds. This does not allow to effectively combine and use their nature protection and fodder functions.

In Belarus, the soil and climatic conditions determined the spread of natural meadows, which at the beginning of the last century occupied 3.5 million hectares (16.9%) of the territory and were characterized by low biological productivity (1.5-3.0 t/ha of hay of different quality). It was established that their minimum agrobiological potential is 5-6 thousand units. The biological yield of improved meadows during 1986-1990 reached 3.5 t/ha. for applying 190 kg/ha per year of mineral fertilizers. About half as much fertilizer is applied at the time, as a result of which the N:P:K ratio has deteriorated [9]. According to the scientists of this country, up to 60-65% of grass stands should primarily include leguminous grasses. This will reduce plant needs for energy-intensive mineral nitrogen fertilizers. Their high cost prompts the organization of the application of fats to improve the quality of feed from perennial grasses and reduce the energy intensity of their production technologies.

V.S. Tymchuk [10] substantiated that the criterion of the efficiency of the use of feed is the maximum output of animal husbandry products at the optimal cost of feed units for its production. Scientists note that the effectiveness of fodder production in Ukraine is due to inadequate state support, low innovative activity of agro-industrial enterprises.

S.A. Szegeda [11] notes that due to the decline of some branches of animal husbandry, in particular cattle breeding, in Ukraine there is a discrepancy between the levels of consumption of meat and meat products with their rational norm. It has been established that since 2001, a gradual increase in the consumption of cattle meat and meat products by the population of Ukraine began.

At the same time, the level of 1990 (68 kg per person) has not yet been reached.The problem of providing the population with individual food products of animal origin requires the determination of ways to increase the productivity of farm animals, the levels of their feeding and, first of all, the state of production of crops from the forage group.

The purpose of the study is to study the impact of changes in the structure of the sown areas of fodder crops both in Ukraine and in the arid conditions of the Southern Steppe (on the example of the Mykolaiv region) on the provision of fodder to the livestock industry (cattle breeding).

RESULTS AND DISCUSSION

Research and analysis of the structure of cultivated areas

Under modern farming conditions, the development of dairy and meat cattle breeding depends significantly on the state of the fodder base. Therefore, it is important to analyze the structure of sown areas, in particular forage crops, the volume of production of plant fodder, their quality and their provision of existing livestock. For this purpose, data collected by civil servants of the State Statistics Service of Ukraine and the Main Department of Statistics in the Mykolaiv region over the past 20 years were analyzed. It was established that in the period from 2000 to 2020, inclusive, the area under agricultural crops in Ukraine increased from 27,173.3 to 28,147.5 thousand hectares (by 3.6%). A much larger increase in these areas during the analyzed period was recorded in the farms of the southern regions. For example, in the Mykolayiv region, this indicator increased by 23.3%, which indicates greater soil plowing.

The production of fodder crops in Ukraine has undergone significant changes over time, both in terms of the volume of cultivated areas and gross harvests and productivity of crops. In 2000, these crops were planted on an area of 7,063.1 thousand hectares and occupied 26.0% of the structure of cultivated areas.

Over time, as of 2020, these indicators decreased (by 20 percentage points): they were indicated at the level of 1,677.2 thousand hectares and 6.0%, respectively, which significantly affected the state of the fodder base for livestock breeding.

An identical situation was noted in the south of Ukraine. So, for example, in the farms of all categories of the Mykolaiv region in 2000, forage crops occupied 17.1% of the structure of sown areas, and in 2020, this indicator decreased by 14.1% over the studied period. It is worth noting the difference in the production of fodder crops by category of farms.

In 2000, fodder crops occupied 6301.0 thousand ha, or 28.2% in the structure of the total sown areas, in cultural enterprises. As of 2020, this indicator has significantly decreased (by 25.6 percentage points): the sown area is indicated at the level of 508.3 thousand ha or 2.6% in the structure of sown areas. A similar trend is typical for farms. In 2000, fodder crops occupied 155.4 thousand hectares, or 10.5% of the total acreage of this category of farms. In 2020, these indicators also decreased (by 9.4 percentage points): they were recorded at the level of 52.4 thousand hectares or 1.1%, respectively.

In the farms of the population during the analyzed period, the fluctuation of the share of fodder crops in the total sown area of this category of farms was significantly smaller: from 15.8% in 2000 to 13.9% in 2020.

Under today's and current economic conditions, the cultivation of highly liquid crops has become a common practice, so the areas that were previously used for sowing fodder crops are sown with food grain and oil crops, which are in greater demand.

Analysis of the data of the State Statistics Service of Ukraine over the past 20 years shows that the largest increase in cultivated areas was recorded in the country's farms under technical crops. Their share in the structure of the above-mentioned areas was 15.4% in 2000, and by 2020 it had increased by 17.4%. Meanwhile, if we compare the data for this period on the structure of cultivated areas in the farms of the Mykolaiv region, the Southern Steppe region, the growth rate was somewhat lower (16.1 percent). At the same time, it should be noted that technical crops in the south of the country occupied an important place in the structure of total cultivated areas. Thus, in the Mykolaiv region, they occupied 21.8% in 2000 and occupied 37.9% of the area in 2020.

The leading place in the group of industrial crops is occupied by sunflower. Over a twenty-year period, in the south, the area of its cultivation in the Mykolaiv region increased from 235.1 thousand ha to 513.0 thousand ha, i.e. 2.2 times, in the Kherson region – from 177.6 to 335.3 thousand ha. ha, i.e. 1.9 times. The farms of Odesa region are characterized by a somewhat smaller increase in the area of this highly liquid oil crop. The areas under sunflower in this southern region have grown over the past 20 years from 265.8 to 356.6 thousand hectares, i.e. by 34.2%.

Grain and leguminous crops in our country over the studied twenty-year period occupied a space larger by 4.5 cm. p., at the same time in Mykolaiv Oblast, this indicator almost did not change (-0.1 p. p.).

As noted by O.M. Polishchuk [6], the increase in the area of grain due to the decrease in the area of fodder crops indicates that agricultural enterprises under crisis economic conditions grow those crops that are in demand on the market and can be sold better and faster.

According to statistical data, the structure of the sown areas of fodder crops has also changed. In general, in Ukraine, their sown area, as already mentioned, decreased by 76.3%. The largest area reduction (from 1920.3 to 261.7 thousand hectares, or by 86.4%) was recorded under fodder corn and annual grasses (by 82.9%), somewhat less – under perennial grasses (by 70.9%), and under fodder root crops (including fodder sugar beet) – by 32.8% (Table 1).

Table 1. *Sown areas of fodder crops and their structure*

Cultures	2000 y.		2010 y.		2020 y.	
	Thousands ha	%	Thousands ha	%	Thousands ha	%
Ukraine						
Fodder crops (total)	7063.1	100.0	2599.1	100.0	1677.2	100.0
including:						
fodder root crops (including fodder sugar beet)	285.0	4.0	244.3	9.4	191.4	11.4
fodder corn	1920.3	27.2	472.7	18.2	261.7	15.6
annual herbs	1765.1	25.0	582.5	22.4	301.5	18.0
herbs are perennial	2984.5	42.3	1238.3	47.6	868.6	51.8
Others	108.2	1.5	61.3	2.4	54	3.2

Table 1, Continued

Cultures	2000 y.		2010 y.		2020 y.	
	Thousands ha	%	Thousands ha	%	Thousands ha	%
Mykolaiv region						
Fodder crops (total)	216.8	100.0	56.5	100.0	50.7	100.0
including:						
fodder root crops (including fodder sugar beet)	3.2	1.5	3.2	5.7	2.3	4.5
fodder corn	83.1	38.3	13.1	23.2	6.5	12.8
annual herbs	63.4	29.3	19.6	34.7	18.3	36.1
herbs (perennial)	62.3	28.7	18.6	32.9	22.0	43.4
Others	4.8	2.2	2.0	3.5	1.6	3.2

Source: *compiled by the author based on the data of the State Statistics Service of Ukraine [12, 13]*

A similar trend is typical for farms in the south of the country. Thus, in the Mykolaiv region, the greatest reduction in area (from 83.1 to 6.5 thousand hectares, or by 92.2%) was recorded under fodder corn and annual grasses (from 63.4 to 18.3 thousand hectares, or by 71.1%), somewhat less – under perennial grasses (by 64.7%), and under fodder root crops (including fodder sugar beet) – by 28.1%.

It is worth noting that the share of fodder corn crops in the total sown area of fodder crops in Ukraine decreased by 11.6 percent. p., while in the south of the country (in the Mykolaiv region) this indicator reached 25.5%. At the same time, the share of crops of perennial grasses in the total sown area of fodder crops in Ukraine increased by 9.5 percent. p., and in the Mykolayiv region – even by 14.7 centuries. p.

An important role in the gross harvest of forage crops is played by the area from which the crop was harvested. It should be noted that this indicator in Ukraine during the period from 2000 to 2020 decreased under annual grasses for green fodder, hay, silage, grass flour (by 92.8%), under perennial grasses for green fodder, hay, silage, grass flour (by 89.5%), under fodder corn (by 85.5%), under fodder root crops (by 30.9%).

An identical situation was observed in farms of all categories in the south of Ukraine. Thus, in the Mykolayiv region, the largest decrease in the area of fodder crops from which the crop was harvested was recorded under perennial grasses for green fodder, hay, silage, grass flour (by 96.4%), annual grasses for green fodder, hay, silage, grass flour (by 94.6%), fodder corn (by 90.8%).These plants are classified as succulent fodder and they play an important role in creating (organizing) a green conveyor belt for feeding farm animals.

The reduction in the number of cattle (cattle) was largely affected by the amount of fodder crops.

It is generally accepted that in the agrarian sector of Ukraine, the leading branches are plant and animal husbandry, while the decline of the latter continues, as a result of which the balance between the two specified branches of agriculture is disturbed.

Determining the trend in cattle population dynamics

On the basis of statistical information for the period from 2000 to 2020 regarding the livestock population, including cows, graphs were constructed (Fig. 1).

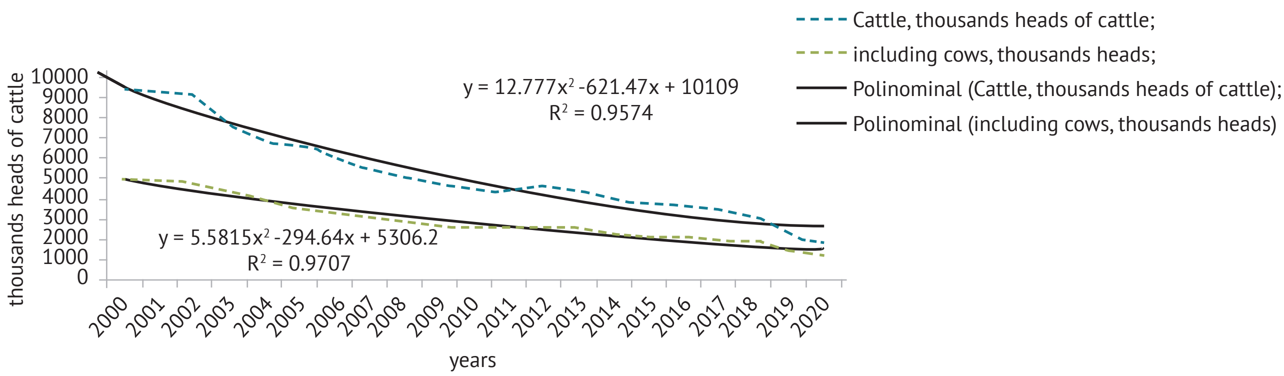

Figure 1. *Dynamics of the cattle population in Ukraine*

Source: *displayed by the author according to the data of the State Statistics Service of Ukraine [14]*

To determine the trend regarding the dynamics of the population, we used the most effective method of analyzing changes in the studied process over time – the method of analytical smoothing of a series of dynamics for the period from 2000 to 2020.

It was established that the process of changing the number of cattle can be characterized by a function represented by a parabola of the 2nd order Y=12.777x2–621.47x+10109 at the level of reliability of approximation R2=0.9574.

To characterize the process of changing the number of cows, a function is defined, which is represented by a parabola of the 2nd order Y=5.5815x2–294.64x+5306.2 at the level of reliability of approximation R2=0.9707.

The analysis of the graph, built for the purpose of leveling a series of dynamics of the cattle population, shows that with a probability of 95.7%, on average during the above-mentioned period, the specified population decreased by 621.5 thousand heads with an annual acceleration of 25.5 thousand heads, which significantly affected the volume of production of livestock products.

With regard to the analysis of the schedule built with the aim of leveling a number of cow herd dynamics, it is worth asserting with a probability of 97.1% that on average during the above-mentioned period the specified herd decreased by 294.6 thousand heads with an annual acceleration of 11.2 thousand heads, which affected the volume of production, primarily of dairy products.

The analysis of the correlations between the areas planted with fodder crops and the cattle population shows that there is a strong dependence between these pairs (correlation coefficient r=0.987).A strong direct correlation (correlation coefficient r=0.979) was noted between the areas of forage crops and the number of cows. Therefore, the allocation of areas for fodder crops directly depends on the number of cattle.

It is known that trend lines are a statistical analysis tool that allows you to predict the future development of events. Based on the array of data that showed changes in the area of forage crops over time (for every 5 years) for the period from 2000 to 2020, a graph was drawn (Fig. 2). Calculations show that the process of area change can be characterized by a function represented by a parabola of the 2nd order Y=468.14x2–4060.9x+10446 at the reliability level of approximation R2=0.9798.

The analysis of the graph, built for the purpose of leveling a series of dynamics of the sown areas of fodder crops, shows that on average during the above-mentioned period the area under their crops decreased by 4060.9 thousand hectares with an acceleration of 936.2 thousand hectares every five years, i.e. annually by 187.2 thousand hectares, which significantly affected the gross harvest and the reduction of production volumes of these crops for fodder purposes.

To calculate the productivity of crops, it was taken into account that in Ukraine, the area of the main fodder crops harvested in 2000 was 5,756.8 thousand hectares, in 2010 it decreased to 2,361.7 hectares, and in 2020 – up to 1,586.3 thousand ha. In the Mykolaiv region, this indicator was noted at the level of 179.3, 51.8 and 44.6 thousand hectares, respectively, by year.

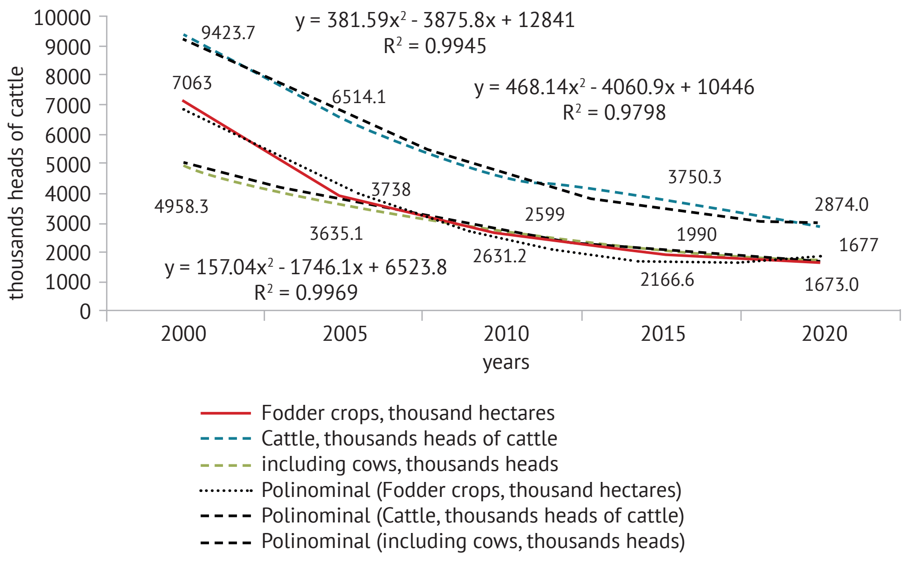

Figure 2. *Dynamics of sown areas of the main fodder crops and cattle population in Ukraine*

Source: *displayed by the author based on the data of the State Statistics Service of Ukraine [12, 14]*

It is generally accepted to calculate the productivity of agrophytocenoses of agricultural crops intended for fodder purposes by collecting fodder (feed unit) and fodder protein units (CPO), digestible protein from their areas (Table 2).

In 2000, 11,314.2 thousand tons of fodder were harvested in Ukraine. units, in 2010 primarily due to a decrease in cultivated areas – 5,801.6, that is, half as much, and in 2020, this indicator was noted within 4,633.7 thousand tons of fodder. unit, which is 41.0% to the level of 2000.

The collection of feed protein units from 1 hectare is calculated according to the formula [15]

$$FPU \ = p \ \frac{(K_o + 10 \ Dp)}{2} \quad (1)$$

where p is productivity, tons/ha; K_o – the content of fodder units in 1 c of fodder, c; D_p – content of digestible protein in 1 t of feed, t.

Calculations show that in 2000, in drier conditions of the Mykolaiv region, products of the main fodder crops were collected 228.8 thousand tons of fodder. unit, in 2010 – 107.3, i.e. 2.1 times less, and in 2020 this indicator was noted at the level of 81.1 thousand tons of fodder. unit, which is 35.4% compared to the level of 2000. Therefore, in the Mykolayiv region, the production volumes of common fodder crops (in fodder units) decreased by 5.6%. p. compared to the state indicator for the studied period. The decrease in indicators of the productivity of fodder crops and the provision of fodder for livestock in the Mykolaiv region compared to the state ones is primarily due to the drier conditions of the Southern Steppe, the lack of irrigation on most of the areas.

Table 2. *Gross harvest of the main fodder crops, thousand tons*

Cultures	Product (physical feed)			Feed. unit			Digestible protein		
	2000 y.	2010 y.	2020 y.	2000 y.	2010 y.	2020 y.	2000 y.	2010 y.	2020 y.
Ukraine									
Fodder roots	6671.9	6770.8	5520.5	934.1	947.9	772.9	59.4	60.3	49.1
Fodder corn	24183.3	7511.0	6620.8	5078.5	1577.3	1390.4	290.2	90.1	79.4
Annual grasses for hay	647.1	953.4	821.1	368.8	543.4	468.0	33.5	49.4	42.5
Annual herbs for green fodder, hay, silage, grass meal	7074.4	1996.1	877.2	1414.9	399.2	175.4	92.0	25.9	11.4
Herbs are perennial for hay	2572.5	3237.7	2983.0	1312.0	1651.2	1521.3	259.8	327.0	301.3
Perennial herbs for green fodder, hay, silage, grass meal	11610.2	3592.5	1609.0	2205.9	682.6	305.7	325.1	100.6	45.1
In total	x	x	x	11314.2	5801.6	4633.7	1060.0	653.3	528.8
Mykolayiv region									
Fodder roots	34.8	62.9	33.8	4.9	8.8	4.7	0.3	0.6	0.3
Fodder corn	533.8	189.3	99.6	112.1	39.8	20.9	6.4	2.3	1.2
Annual grasses for hay	19.7	40.7	39.0	11.2	23.2	22.2	1.0	2.1	2.0
Annual herbs for green fodder, hay, silage, grass meal	174.2	28.1	17.0	34.8	5.6	3.4	2.3	0.4	0.2
Herbs are perennial for hay	38.2	46.0	54.3	19.5	23.5	27.7	3.9	4.7	5.5
Perennial herbs for green fodder, hay, silage, grass meal	243.9	33.9	11.6	46.3	6.4	2.2	6.8	1.0	0.3
In total	x	x	x	228.8	107.3	81.1	20.7	11.1	9.5

Source: *calculated by the author based on the data of the State Statistics Service of Ukraine [12, 13] and elaboration of a literary source [16]*

It is known that an important criterion for assessing the nutritional value of feed is its content of digestible protein, the lack of which in the diet of animals reduces the productive effect of other nutrients. In order to determine the quality of fodder of the group of main fodder crops, the collection of digestible protein from the harvested areas was calculated. According to the estimated data, in 2000, 1,060,000 tons of digestible protein from the main fodder crops were collected in Ukraine, in 2010 – 653,300 tons (30.4% less), and in 2020 this the indicator was noted within 528.8 thousand tons, which is 49.9% to the level of 2000.

It was established that in 2000, in more unfavorable (in terms of moisture and temperature) conditions of the Mykolaiv region, 20.7 thousand tons of digestible protein were collected from the products of common fodder crops, in 2010 – 11.1, that is, in 1.9 times less, and in 2020 this indicator was noted at the level of 9.5 thousand tons of fodder. units, which is 45.9% compared to the level of 2000. Therefore, in the conditions of a lack (insufficient amount) of moisture during the studied period, the amount of collection of digestible protein from common fodder crops decreased by 4.0% compared to the indicator for the entire country. In order to form an appropriate fodder base, it is necessary to take into account both the total volume of fodder, which should ensure the production of the planned amount of products, and their quality composition, especially the balance in terms of nutrients [17].

It should be emphasized that due to changes in the structure of forage crops, productivity indicators of the fodder wedge improved for the period from 2000 to 2020. The advantages of growing annual and perennial grasses for hay played a special role. Thus, in Ukraine in 2000, 1.97 tons of fodder was collected from 1 ha. unit As of 2010, this indicator increased to the level of 2.46 tons of fodder. unit, which is more than 1.2 times higher than the level of 2000, and in 2020 – up to 2.92 tons of fodder. units, that is, by 48.2% compared to 2000 (Table 3).

Table 3. *Productivity of agrophytocenoses of the main fodder crops and provision of animal fodder from them*

Indicators	Years			2020 у. до 2000 у, %
	2000	2010	2020	
Ukraine				
Collection from 1 ha/t				
feed units	1.97	2.46	2.92	148.2
digestible protein	0.184	0.277	0.333	181.0
food protein units	1.91	2.62	3.13	163.9
Digestible protein per 1 unit, g	93.4	112.6	114.0	122.1
Produced for 1 head: - cattle, t/unit.	1.20	1.29	1.61	134.2
- cows, t/unit.	2.28	2.21	2.77	121.5
Produced per 1 head/ t of FPU: - cattle, t FPU	1.16	1.37	1.73	149.1
- cows, t FPU	2.21	2.34	2.97	134.4
Mykolaiv region				
Collection from 1 ha/t				
feed units	1.28	2.07	1.82	142.2
digestible protein	0.115	0.214	0.213	185.2
food protein units	1.22	2.11	1.98	162.3
Digestible protein per 1 unit, g	89.8	103.4	117.0	130.3
Produced for 1 head: - cattle, t/unit..	0.92	0.65	1.09	118.5
- cows, t/unit.	1.58	1.00	1.72	108.9
Produced per 1 head/ t of FPU: - cattle, t FPU	0.88	0.77	1.19	135.2
- cows, t FPU	1.50	1.18	1.87	124.7

Source: *calculated by the author based on the data of the State Statistics Service of Ukraine [12, 13] and elaboration of a literary source [16]*

Productivity of agrophytocenosis of the main fodder crops in the south of the country (in the Mykolaiv region) was lower by 15.8-37.7% in terms of collection of fodder units compared to the average for Ukraine. At the same time, it increased by 42.2% during the studied period, which is 6%. less than in Ukraine.

More important is the determination of the productivity of the fodder wedge based on the collection of fodder protein units (FPU). This indicator in Ukraine ranged from 1.91 (2000) to 3.13 t KPO (2020), i.e. it increased by 63.9%. In the conditions of the Mykolaiv region, the amplitude of fluctuation was noted at the level of 1.22 (2000) – 2.11 tons of FPU (2010), and during the studied period, the collection of FPU per unit area increased by 62.3%.

The indicator of providing a feed unit with digestible protein also improved during the analyzed period: in Ukraine – by 22.1%, slightly more in the Mykolaiv region (by 30.3%).

The level of providing agricultural animals, particularly cattle, with fodder from forage crops reflects the state of development of the livestock industry. As already noted above (see Fig. 1 and Fig. 2), a significant reduction in the number of cattle in Ukraine during the studied period (69.5%) affected the area of fodder crops and led to a decrease in the gross collection of fodder. Their volume in 2020 was only 41% in fodder units and 45.3% in FPU to the level of 2000 (Table 3).

An identical situation is observed in the farms of the Mykolaiv region. When calculating the rate of change in the number of animals, it was determined that in 2020 their total number (74,000 cattle) decreased by 70.3% compared to 2000, and the volume of gross forage collection in 2020 was only 35.4% in fodder units and 40.4% in FPU before the level of 2000.

A significant decrease in livestock also caused changes in providing animals with fodder from the group of fodder crops. Thus, in 2020, Ukraine produced 1.61 tons of fuel, while Mykolaiv Region produced only 1.09 tons of fuel. per head of cattle, which is 34.2 and 18.5% more, respectively, compared to 2000. This indicator also improved for cows: by 21.5% in Ukraine and slightly less – by 8.9% in the Mykolaiv region (Table 3).

A similar (improved) situation is observed in the provision of cattle fodder under the FPU. At the same time, it should be emphasized that in 2020, 1.73 tons of FPU were produced in Ukraine, and in Mykolaiv Region – 1.19 tons of FPU per 1 head of cattle, which is 49.1 and 35.2% more, respectively, compared to 2000 This indicator also improved for cows: by 34.4% in Ukraine and slightly less – by 24.7% in the Mykolaiv region.

N.O. Avercheva [18] claims that the level of feed costs during the planning of the feed base is set at the level of 40 tons of feed units per one conditional head, while their actual costs in Ukraine amount to no more than 29 tons of feed in the last three years. According to the State Statistics Service, the specific weight of feed in the structure of production costs for milk production reached 53.9-62.6% in the period 2017-2019.

In view of the above, most agricultural enterprises are reorienting to feeding animals with combined feed [18-20].

CONCLUSIONS

Significant changes in the structure of cultivated areas for the period from 2000 to 2020 inclusive, both in Ukraine and in its southern region, Mykolaiv Region, have been established. As a result of a decrease in the number of cattle, an increase in the area under technical crops, the area under fodder crops decreased.

The greatest decrease in area in Ukraine (by 86.4%) was recorded under fodder corn and annual grasses (by 82.9%), somewhat less under perennial grasses (by 70.9%), and under fodder root crops (including fodder sugar beet) – by 32.8%.

The situation in the south is almost identical, due to a significant reduction in the number of cattle. At the same time, the share of crops of perennial grasses in the total sown area of fodder crops in Ukraine increased by 9.5 percent. p., and in the Mykolayiv region – even by 14.7 centuries. p.

The productivity of agrophytocenoses of the main fodder crops in the Mykolaiv region was lower by 15.8-37.7% compared to the average for Ukraine, which is explained primarily by drier weather conditions and insufficient amount of irrigated land. Due to changes in the structure of sown areas of fodder crops, the index of providing a fodder unit with digestible protein has improved: in Ukraine – by 22.1%, slightly more in the Mykolayiv region – by 30.3%. An increase in the quality of fodder has been established, which is evidenced by an increase in the production of FPU per 1 head of cattle in 2020 compared to 2000 in Ukraine by 49.1%, in the Mykolaiv region by 35.2%.

In Ukraine, there are appropriate conditions for reproducing the cattle herd to provide the population with quality food products, reviving the fodder production industry by increasing the production of cheap fodder in field and forage crop rotations, and restoring the disturbed balance between the areas of arable land and natural fodder areas.

REFERENCE:

[1] Misiuk, M.V. (2013). Increasing the efficiency of fodder production based on innovative principles. *The Economy of Agro-Industrial Complex*, 3, 81-87.

[2] Petrychenko, V.F., Korniychuk, O.V., & Veklenko, Yu.A. (2018). Sustainable development of onion pasture fodder production in conditions of climate change. *Herald of Agrarian Science*, 6, 25-32.
[3] Goloborodko, S.P., & Dymov O. M. (2019). Global climate change: causes of occurrence and consequences for agricultural production in the Southern Steppe. *Land Reclamation and Water Management*, 1, 88-98.
[4] Stepasyuk, L.M., & Lopanchuk, A.A. (2016). Fodder production as the main factor in the effective development of the livestock industry. *The Economy of Agro-Industrial Complex*, 4, 28-33.
[5] Petrychenko, V.F., & Antipova, L.K. (2019). The influence of hydrothermal conditions on the productivity of perennial grasses in the southern Steppe of Ukraine. *Fodder and Fodder Production*, 88, 3-10.
[6] Polishchuk, O.M. (2013). Fodder base is one of the factors in the formation of competitiveness of meat cattle breeding. *Effective Economy*, 1. Retrieved from http://www.economy.nayka.com.ua/?op=1&z=1914.
[7] Gusev, M.G., & Voytashenko D.P. (2010). Agrotechnological measures to increase the productivity of fodder agrocenoses on irrigated lands of the southern region of Ukraine. *Fodder and Fodder Production*, 67, 159-165.
[8] Petrychenko, V.F., Korniychuk, O.V., & Veklenko, Yu.A. (2020). Scientific basis of intensification of fodder production in meadows and pastures of Ukraine. *Fodder and Fodder Production*, 89, 10-22. doi: 10.31073/kormovyrobnytstvo202089-01.
[9] Biryukovich, A.L., Meerovsky, A.S., & Pastushok, R.T. (2010). Main directions of development of grassland fodder production in Belarus. *Fodder and Fodder Production*, 67, 128-134.
[10] Tymchak, V.S. (2014). Interpretation of the category “effectiveness of innovations” in fodder production. *Bulletin of ZhNAEU*, 1-2(43), 39-49.
[11] Szegeda, S.A. (2020). Statistical analysis of consumption of meat and meat products in Ukraine. *The Economy of Agro-Industrial Complex*, 3, 36. doi: 10.32317/2221-1055.202003036
[12] Vegetation of Ukraine: statistical collection. Retrieved from www.ukrstat.gov.ua
[13] Areas, gross harvests and productivity of agricultural crops, fruits, berries and grapes in 2020 in the Mykolayiv region: statistical bulletin. (2020). Retrieved from https://ukrstat.gov.ua/operativ/operativ2022/sg/pvzu/arch_pvxu_reg.htm.
[14] Animal husbandry of Ukraine: statistical collection. Retrieved from www.ukrstat.gov.ua.
[15] Zbarskyi, V.K., Matsybora, V.I., & Chalyi A.A. (2018). *Economics of agriculture: training. manual*. Kyiv: Caravela.
[16] Provatorov, G.V. (Ed.). (2019). Feeding norms, rations and nutrition of fodder for different types of farm animals: a guide. *Sumy: University Book*.
[17] Korniychuk, O.V., Antipova, L.K., & Manushkina, T.M. (2021). Analysis of the state of fodder crop production in the south of Ukraine. *Fodder and Fodder Production*, 91, 20-32. doi: 10.31073/kormovyrobnytstvo202191-02.
[18] Avercheva, N.O. (2021). Organizational aspects of the formation of the fodder base of animal husbandry. *Investments: Practice and Experience*, 10, 55-63. doi: 10.32702/2306-6814.2021.10.55
[19] Lavruk, V.V. (2017). Fodder production as a component of the mechanism of economic modernization of animal husbandry. *Scientific Bulletin of the Uzhhorod National University*, 14. Retrieved from http://www.visnyk-econom.uzhnu.uz.ua/archive/14_1_2017ua/38.pdf
[20] Yatsiv, I.B., & Temnenko, S.M. (2020). Formation of the fodder base as a factor in the development of animal husbandry in agricultural enterprises. *Agroworld*, 16, 24-31. doi: 10.32702/2306-6792.2020.16.24.

Вплив зміни структури посівних площ кормових культур на забезпечення скотарства кормами

Л. К. Антипова

доктор сільськогосподарських наук, професор
https://orcid.org/0000-0003-2609-0801
Миколаївський національний аграрний університет

Анотація. У статті висвітлено результати досліджень стану виробництва основних кормових культур в Україні та на її півдні (на прикладі Миколаївської області) за період 2000-2020 рр. Відзначено зміни структури посівних площ, скорочення площ посівів, що обумовлено зменшенням поголів’я великої рогатої худоби. Поліпшено показник забезпечення кормової одиниці перетравним протеїном, покращилося забезпечення тварин кормами

Ключові слова: кормові культури, площа посівів, структура посівних площ, валовий збір, кормова база

UDC «324».003.13:631.51:633.85(477.4)
DOI: 10.31521/2313-092X/2021-3(111)-5

Ukrainian Black Sea Region Agrarian Science
Vol. 25, No. 3

Economic efficiency of winter rapeseed cultivation depending on the influence of technology elements in the forest-steppe of Ukraine

V. Gamayunova*
Full Doctor in Agrosciences, Professor
https://orcid.org/0000-0002-4151-0299

I. Garo
Getter
https://orcid.org/0000-0003-1846-9483

Mykolaiv National Agrarian University

Abstract. The paper presents the results of the studies conducted during 2012-2015 on common chernozem in the Forest-Steppe zone of Ukraine with winter rapeseed of the Chempion Ukrainy variety. The influence of the terms and methods of sowing and main tillage on seed yield was determined, which affected the indicators of the economic efficiency of crop production. Their determination justifies the expediency of combining the following elements: sowing in the first decade of September in rows (row spacing width 15 cm) on the background of ploughing by 25-27 cm (as the main tillage). This technology on average for 2013-2015 provided the highest level of yield – 4.54 t/ha and the following economic indicators: conditional net profit of 18.8 thousand UAH/ha, profitability – 113.6%, cost of 1 tonne of seeds – 4.5 thousand UAH

Keywords: winter rapeseed, main tillage, sowing period, sowing method, profitability, conditional net profit, prime cost

INTRODUCTION

According to these market relations, the cultivation of all agricultural crops should be accompanied by the determination of the main economic indicators. This is especially important for the introduction of new technology elements that are poorly researched for the area. Each of them, in addition to their impact on crop productivity, is characterised and differs in certain costs. It is most effective to make a profit that will indicate the feasibility of implementing this element of the technological process. Ultimately, without sufficient crop growth, it will not be profitable.

The technology of growing winter rapeseed has its own characteristics, it depends and changes on the growing area, the economic viability of the farm, the conditions of autumn vegetation, overwintering of plants, etc. The goal is to get both a high level of yield and high-quality seeds at favourable economic indicators.

LITERATURE REVIEW

The efficiency of winter rapeseed production depends on the level of crop productivity and the area of use of green mass or seeds. It is a valuable fodder and oilseed crop. In terms of food and feed qualities, it surpasses a number of agricultural

crops, including legumes. Due to the low content of erucic acid and glucosinolates in seeds, oil is produced from it, and cake and meal are used in animal husbandry [1]. In recent years, biodiesel has been produced from rapeseed seeds. This method of use

Article's History:
Received: 9.01.2021
Revised: 24.06.2021
Accepted: 26.08.2021

Suggested Citation:
Gamayunova, V., & Garo, I. (2021). Economic efficiency of winter rapeseed cultivation depending on the influence of technology elements in the forest-steppe of Ukraine. *Ukrainian Black Sea Region Agrarian Science*, 25(3), 38-45.

caused a substantial increase in demand on the world market and an increase in seed prices [2]. Therefore, the task of any agricultural technology in the modern period of management is to determine by research and select the most effective elements of technology, test them in zonal technologies for growing crops.

Any element of the improved technology should not only help to increase the level of yield, but also ensure, accordingly, optimal quality of grown products and high economic indicators. In the cultivation of agricultural crops, including winter rapeseed, the components of economic efficiency substantially depend and change under the influence of the background of nutrition, the characteristics of the variety or hybrid, the time and method of sowing, the seeding rate, and other factors [3-5]. Thus, after conducting a study with three varieties of winter rapeseed in the conditions of the Southern Steppe of Ukraine, it was determined that the use of mineral fertilisers affects the growth of conditional net profit and the level of profitability of production of this crop. In particular, due to their influence, the profitability of cultivation in the context of three hybrids increased by 1.9-4.1 times [6]. The author justifies such results by a substantial increase in both seed yield and conditional fat yield per unit area on the background of fertiliser application with the maximum efficiency of their calculated dose. The greatest influence on the indicators of economic efficiency of the fertiliser background, including their dose calculated for the programmable level of yield, was also determined for the cultivation of winter wheat varieties in the conditions of the NSPC MNAU in the Southern Steppe zone of Ukraine [7].

In addition to optimising nutrition in the cultivation of agricultural plants, it is advisable to investigate other measures and elements of technology that are low-cost and can substantially increase the productivity and quality of the crop [8-10]. The resource-saving elements of technology and measures to avoid or mitigate stressful situations, in particular, the use of biologics, should also be investigated, especially in recent years, when climate change occurs [11,12]. The high efficiency of using biologics to optimise the nutrition of plants of two varieties of spring barley was also established when determining the main indicators of economic efficiency of growing this crop on southern chernozem in the conditions of the NSPC MNAU [13].

The effectiveness of economic indicators is largely determined by the weather and climatic conditions of the year of crop cultivation, because the more favourable the year for moisture content, the higher the yield level is formed and, accordingly, the components of economic efficiency. This postulate is relevant even when growing plants on irrigation (in the studies on millet), since the amount of irrigation is reduced with optimal natural moisture [14]. This pattern is confirmed by the results of studies of growing oilseeds under irrigation and without irrigation, namely oils flax [15]. In addition to the water supply regime, the study considered plant nutrition, row spacing, and seeding rate.

The authors attribute a substantial increase in the productivity of the white mustard oil crop primarily to the effective use of moisture by plants, which is largely determined and varies depending on the amount of precipitation during the growing season, the content and accumulation of which depend on tillage [16]. In addition, the paper justifies obtaining the highest conditional net profit when using white mustard for culture by combining ploughing as the main tillage and using organic-mineral fertiliser. The profitability of growing white mustard in the context of tillage systems ranged between 93-123%.

A number of studies conducted with various agricultural crops have determined the impact of both productivity and economic efficiency of such a factor as tillage. In cultivation technologies, this element, as a rule, is the most expensive compared to other measures. In particular, tillage and other elements of the technology were investigated on rapeseed and spring wheat [17, 18]. In general, the factor of tillage, the efficiency of measure selection and depth for a particular agricultural crop substantially affects the efficiency of its cultivation [19]. In addition, the authors point to the prospect of research with methods of tillage since they are the most expensive. In recent years, due to climate change and the energy equipment of farms, it is necessary to select the most rational measures of tillage, considering resource and energy preservation, since they are among the main links of agriculture.

In addition, for researchers and producers, the question of the most correct selection of the method of tillage and its measures, which are developed and compiled for all crops of crop rotation, is indisputable. Under such conditions, as a rule, differentiated (combined) approaches to the depth and method of tillage are recommended. In the same way, fertiliser systems are determined and developed for the crop rotation crops, while considering their effect and aftereffect for subsequent crops that will be placed in the order of their alternation.

Winter rapeseed, as was already noted in this and many papers, reacts quite strongly to the background of fertiliser. The latter substantially affects the levels of seed yield and its main quality indicators [20, 21]. Issues related to plant nutrition and main tillage measures for winter rapeseed are insufficiently investigated. In particular, in recent decades, the surface resource-saving methods of tillage using the Till and No-Till systems have become widespread. It is their application that is considered low-cost and cost-effective [22].

The purpose of the study is to determine the influence of the main elements of winter rapeseed cultivation technology, in particular, the method and depth of tillage, the time and method of sowing on seed yield, economic efficiency, and changes in its indicators due to these factors.

MATERIALS AND METHODS

Elements of the technology for growing winter rapeseed were investigated during 2012-2015 on ordinary chernozem in the conditions of agricultural LLC "Zoria" of the Cherkasy district of the Cherkasy region. The experiment is three-factor: factor A – main tillage – ploughing by 25-27 cm and disking by 12-14 cm; Factor B – sowing period – 1st – in the first decade of September, 2nd – in the second decade of September, 3rd – in the third decade of September; factor C – sowing method with row spacing of 15 cm, 30 cm, and 60 cm. The study was conducted with the Ukrainian variety of winter rapeseed Chempion Ukrainy.

Indicators of economic efficiency were determined by the factual cost of material resources for growing products at prices at the beginning of 2016. The cost of 1 tonne of seeds for the billing period was 9550 UAH.

RESULTS AND DISCUSSION

Certain elements of the technology of growing winter rapeseed plants and their combination primarily affected seed yield. During the years of research, crop levels varied substantially depending on the weather conditions of the growing season of the crop. In the most optimal version of the experiment for the combination of the sowing period (I decade of September) using the rows method (15 cm) on the background of ploughing to a depth of 25-27 cm, it was the highest and ranged from 3.86 to 5.02 t/ha. The average yield of winter rapeseed for three years of cultivation is shown in Figure 1.

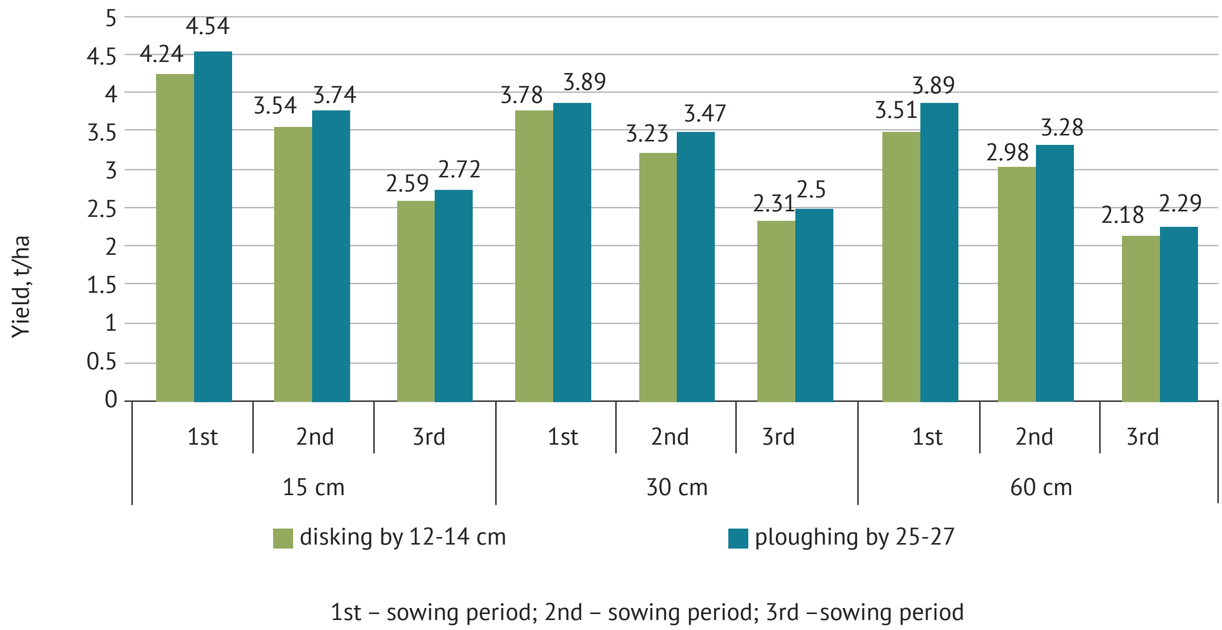

Figure 1. *Yield of winter rapeseed depending on the time and method of sowing, type, and depth of tillage (average for 2013-2015)*

The studies determined that the yield of seeds and technology elements adopted in the cultivation of winter rapeseed had different effects on the main indicators of economic efficiency. Thus, the calculation of the cost of gross output justifies a substantial impact on this indicator of the sowing period and row spacing width, and a slight change depending on the type of the main tillage (Table 1). On average, according to factor A, ploughing to a depth of 25-27 cm contributed to an insubstantial increase in the cost of gross output by 1.7% compared with disking to a depth of 12-14 cm – from 24.8 to 25.3 thousand UAH/ha. A substantial decrease in the cost of gross output (winter rapeseed) was determined for the transfer of sowing from the first decade of September to the second and third decades of this month. Thus, for disking to a depth of 12-14 cm, this indicator was for sowing in the first decade of September, on average by factor, 30.9 thousand UAH/ha, for sowing in the second decade it decreased to 24.8 thousand UAH/ha (by 24.4%), and in the third decade – to 18.8 thousand UAH/ha (or by 64.4%). When ploughing to a depth of 25-27 cm, this decrease was 21.9 and 78.6%, respectively.

Table 1. *Cost of gross output of winter rapeseed depending on tillage, sowing period, and row spacing width, thousand UAH/ha*

Tillage (factor A)	Sowing period (Factor B)	Row spacing width, cm (factor C)			Average by factors	
		15	30	60	B	A
Disking by 12-14 cm	1st decade of September	33.4	30.6	28.7	30.9	24.8
	2nd decade of September	26.7	24.8	22.9	24.8	
	3rd decade of September	20.1	19.1	17.2	18.8	
Ploughing by 25-27 cm	1st decade of September	35.3	31.5	28.7	31.8	25.3
	2nd decade of September	28.7	26.7	22.9	26.1	
	3rd decade of September	20.1	18.1	15.3	17.8	
Average for factor C		27.4	25.1	22.6		

The row spacing width of 15 cm provided the maximum cost of gross output, which averaged 27.4 thousand UAH/ha. For the expansion of row spacing to 30 and 60 cm, a substantial decrease in this indicator was determined – 25.1 and 22.6 thousand UAH/ha, or by 8.9 and 21.1%. A substantial reduction in the cost of the grown products indicates the expediency of increasing the width of row spacing. Production costs, in contrast to the cost of gross output, were characterised by a substantial difference in tillage options and minimal differences in the second and third factors under study (Table 2). For disking to a depth of 12-14 cm, this economic indicator averaged 15.1 thousand UAH/ha. Ploughing to a depth of 25-27 cm in experimental areas due to an increase in the cost of diesel fuel and other agricultural resources led to their increase to 16.2 thousand UAH/ha, or by 7.5%.

Table 2. *Production costs for growing winter rapeseed depending on the tillage, sowing period, and row spacing width, thousand UAH/ha*

Tillage (factor A)	Sowing period (Factor B)	Row spacing width, cm (factor C)			Average by factors	
		15	30	60	B	A
Disking by 12-14 cm	1st decade of September	15.4	15.3	15.2	15.3	15.1
	2nd decade of September	15.1	15.1	15.0	15.1	
	3rd decade of September	14.9	14.9	14.8	14.9	
Ploughing by 25-27 cm	1st decade of September	16.5	16.4	16.3	16.4	16.2
	2nd decade of September	16.3	16.2	16.1	16.2	
	3rd decade of September	16.0	15.9	15.8	15.9	
Average for factor C		15.7	15.6	15.5		

According to the variants of sowing dates, there was little difference between certain indicators of production costs. Thus, during the first sowing period, an increase in this indicator was identified for disking up to 15.3, and for ploughing – up to 16.4 thousand UAH/ha. During sowing in the second and third decades of September, this indicator slightly decreased, respectively, to 15.1 and 14.9, 15.9 and 16.2 thousand UAH/ha, or by 1.4-2.8 and 1.25-3.1%.

The width of row spacing practically did not affect production costs, since the difference between the variants under study (15; 30; 60 cm) was only 0.5-1.1%. The cost of production of 1 tonne of winter rapeseed had a clear trend towards its growth during ploughing, sowing in the 2nd and 3rd decades of September and sowing with row spacing of 30 and 60 cm (Table 3). The increase in this indicator was manifested during ploughing to a depth of 25-27 cm, at which the cost price increased, on average, to 6.5 thousand UAH/tonne. Disking to a depth of 12-14 cm caused its decrease to 6.0 thousand UAH/tonne, or by 8.0%.

According to factor B (sowing period), the minimum cost level of 1 tonne of winter rapeseed is determined for sowing in the first decade of September – 4.7-5.0 thousand UAH. The postponement of sowing to the second and third decades of September led to an increase in this indicator by 18.5- 42.6%.

Options with row spacing of 15 cm provided the lowest cost – an average of 5.7 thousand UAH/tonne. The expansion of row spacing to 30 and 60 cm led to an increase in this indicator to 6.2 and 6.9 thousand UAH/tonne, or by 7.3 and 17.2%, respectively.

Table 3. *Cost of growing 1 tonne of winter rapeseed depending on the tillage, sowing period, and row spacing width, thousand UAH*

Tillage (factor A)	Sowing period (Factor B)	Row spacing width, cm (factor C)			Average by factors	
		15	30	60	B	A
Disking by 12-14 cm	1st decade of September	4.4	4.8	5.1	4.7	6.0
	2nd decade of September	5.4	5.8	6.3	5.8	
	3rd decade of September	7.1	7.4	8.2	7.6	
Ploughing by 25-27 cm	1st decade of September	4.5	5.0	5.4	5.0	6.5
	2nd decade of September	5.4	5.8	6.7	6.0	
	3rd decade of September	7.6	8.4	9.9	8.6	
Average for factor C		5.7	6.2	6.9		

Conditional net profit in the field experiment with winter rapeseed ranged in a very wide range – from 18.8 thousand UAH/ha for a combination of factors: ploughing to a depth of 25-27 cm; sowing in the first decade of September; row spacing of 15 cm, to a loss of 0.6 thousand UAH/ha - ploughing to a depth of 25-27 cm; sowing in the third decade; row spacing of 60 cm (Table 4).

Table 4. *Conditional net profit for growing winter rapeseed depending on the tillage, sowing period, and row spacing width, thousand UAH/ha*

Tillage (factor A)	Sowing period (Factor B)	Row spacing width, cm (factor C)			Average by factors	
		15	30	60	B	A
Disking by 12-14 cm	1st decade of September	18.1	15.3	13.5	15.6	9.8
	2nd decade of September	11.6	9.8	7.9	9.8	
	3rd decade of September	5.2	4.2	2.4	3.9	
Ploughing by 25-27 cm	1st decade of September	18.8	15.1	12.3	15.4	9.1
	2nd decade of September	12.3	10.5	6.8	9.9	
	3rd decade of September	4.0	2.2	-0.6	1.9	
Average for factor C		11.7	9.5	7.1		

Disking to a depth of 12-14 cm contributed to the growth of this indicator, on average, 9.8 thousand UAH/ha. For ploughing to a depth of 25-27 cm, the conditional net profit decreased to UAH 9.1 thousand/ha, or by 7.2%.

A substantial increase in profitability was provided by the first sowing period, which averaged 15.4-15.6 thousand UAH/ha. During sowing in the second decade of September, there was a substantial decrease in conditional net profit by 55.9-59.7%, and during the third sowing period – by 3.9-8.1 times. The most substantial decrease in profit was manifested in all variants of the experiment with ploughing to a depth of 25-27 cm.

The formation of a row spacing of 15 cm provided the maximum conditional net profit at the level of 11.7 thousand UAH/ha. With wider row spacing – 30 and 60 cm, this indicator decreased to 9.5 in 7.1 thousand UAH/ha, or by 22.7 and 65.2%, respectively.

The level of profitability of the developed elements of the cultivation technology of the crop under study – winter rapeseed reflected the trends that were identified regarding the formation of indicators of conditional net profit (Fig. 2). For disking to a depth of 12-14 cm, higher profitability was obtained – 64.4%, compared with ploughing to 25-7 cm – 55.5%.

The trend of a substantial decrease in the level of profitability from the first sowing period (93.8-102.1%) to the second (60.9-64.8%), and especially the third (11.8-26.4%) was clearly traced. Thus, the difference between sowing in the first and second decades of September was, on average, 54.9-57.6 relative per cent, and between the first and third terms – 3.9-7.9 times.

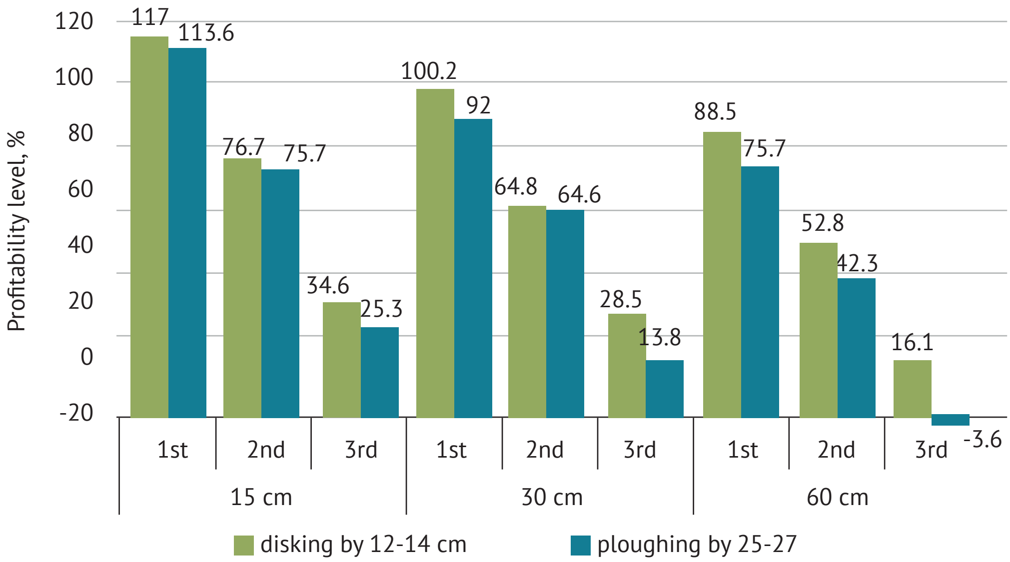

Figure 2. *The level of profitability of growing winter rapeseed depending on the tillage, sowing period, and row spacing width*

The lowest profitability (45.3%) was determined for sowing with row spacing of 60 cm. In the variants with row spacing of 15 and 30 cm, this indicator increased substantially and averaged 73.9 and 60.7% for this factor, or increased by 21.8-63.1 relative per cent.

CONCLUSIONS

The examined factors in the cultivation of winter rapeseed of the Chempion Ukrainy variety during 2012-2015 substantially affected the level of seed yield. The maximum yield – 4.54 t/ha on average for 2013-2015 was formed by combining the following elements of the technology: sowing in the first decade of September in the usual rows method (15 cm) on the background of ploughing by 25-27 cm as the main tillage. Shifting the sowing dates to the second and third decades of September, increasing the width of row spacing to 30 and 60 cm, and disking by 12-14 cm led to a decrease in the yield of winter rapeseed grain.

The determination of components of economic efficiency showed that the cost of gross output of winter rapeseed during ploughing increased, but the cost of its cultivation caused a slight decrease in conditional net profit, which on average for factors on the background of disking was 9.8, and ploughing – 9.1 thousand UAH/ha.

Regarding the optimisation and selection of the sowing period, the highest profit was for its implementation in the first decade of September – for disking – 15.6 thousand UAH/ha, and ploughing – 15.4 thousand UAH/ha on average for all row spacing. According to the latter factor, the highest yield was provided by rows sowing with row spacing of 15 cm, with an increase to 30 and 60 cm, this indicator decreases.

The level of profitability is closely correlated with the value of net profit and changes. On average, for disking options by 12-14 cm, it was 64.4%, and ploughing – 55.5%. For the first period of sowing according to these methods of tillage, the profitability was the highest – 102.1 and 93.8%, respectively, for all methods of sowing, and for row spacing of 15 cm – 117.5 and 113.6%. With later sowing and expansion of row spacing, this indicator decreased.

Thus, the highest yield of seeds and the most favourable indicators of economic efficiency for growing winter rapeseed in the conditions of the Forest-Steppe of Ukraine provides the use of such elements: sowing in the first decade of September in the usual rows way (15 cm), and as the main tillage - ploughing to a depth of 25-27 cm. This combination of factors prevails over other measures and options under study. It is advisable to recommend it for production for growing winter rapeseed.

REFERENCES

[1] Kokovikhin, S.V., Donets, A.O., Husiev, M.H., Fedorchuk, M.I., & Mrynskyj, I.M. (2012). *Agrotechnical and organizational and economic aspects of rapeseed production in southern Ukraine* (176). Kherson: Ailant.

[2] Tokarchuk, D.M. (2018). Management measures to improve the efficiency of rapeseed production. *Herald of Socio-Economic Research*, 1(65), 125-133.

[3] Takalić, M., & Blažičević, S. (2014). Economic analysis of rape production. *Agricultura* – Ştiinţă şi *practică*, 3-4(91-92), 5-12.

[4] Pasichnyk, N.A., Lysenko, V.P., Bykin, A.V., & Opryshko, O.O. (2020). Indicative stress indices of a technological nature for winter rapeseed. *Scientific Reports of NULES of Ukraine*, 3(85). doi: 10.31548/dopovidi2020.03.007.

[5] Pasichnyk, N.A., Opryshko, O.O., Lysenko, V.P., & Komarchuk, D.S. (2021). Information technologies for remote assessment of the aftereffect of herbicides on winter rapeseed crops. *Scientific Reports of NULES of Ukraine*, 2(90). doi: 10.31548/dopovidi2021.02.008.

[6] Vlashchuk, A.M., Kokovikhin, S.V., & Donets, A.O. (2012). Modeling the costs of agricultural resources in the technological process of winter rape seed production in the conditions of southern Ukraine. *Irrigated Agriculture*, 58, 159-163.

[7] Gamayunova, V.V., & Smirnova, *I*.V. (2018). Economic efficiency of growing winter wheat varieties depending on nutrition optimization. *Scientific Horizons*, 1(64), 10-14.

[8] Antonenko, O.F., & Savchuk, Yu.M. (2016). The influence of sowing dates and microfertilizers on the development of winter rapeseed plants in the conditions of the Right Bank Forest Steppe of Ukraine. *Scientific Horizons*, 1(53), 87–94.

[9] Pekhov, V.A. (2016). Grain production and formation of efficiency of agricultural enterprises. *Economy of ACC,* 8, 110-120.

[10] Kvasnitska, L.S. (2020). Comprehensive assessment of crop rotations with different saturation of oil crops in the conditions of the Right Bank Forest Steppe. *Scientific Horizons*, 7(92), 40-44. doi: 10.33249/2663-2144-2020-92-7-40-44.

[11] Huang, H., Ullah, F., Zhou, D.-X., Yi, M., & Zhao, Y. (2019). Mechanisms of ROS regulation of plant development and stress responses. *Front Plant Sci*, 10, 800. doi: 10.3389/fpls.2019.00800.

[12] Vozhegova, R.A., & Kryvenko, A.I. (2019). The influence of biological preparations on the productivity of winter wheat and the economic and energy efficiency of its cultivation technology in the conditions of Southern Ukraine. *Ukrainian Black Sea Region Agrarian Science*, 1(101), 39-46. doi: 10.31521/2313-092X/2019-1(101)-6.

[13] Gamayunova, V.V., Kasatkina, T.O., & Baklanova, T.O. (2021). Agro-economic evaluation of the effectiveness of the use of biological preparations in the cultivation of spring barley in the conditions of the Southern Steppe of Ukraine. *Agrology*, 4(2), 65-70. doi: 10.32819/021008.

[14] Averchev, O.V., & Hubenia, Yu.E. (2012). Economic efficiency of growing millet in the conditions of irrigation in the south of Ukraine. *Taurian Scientific Bulletin*, 80(2), 183-186.

[15] Ushkarenko, V.O., Lazer, P.N., & Rudik, *O*.L. (2012). Features of the elements of the technology of growing oil flax in the conditions of the South of Ukraine. *Taurian Scientific Bulletin*, 80(2), 198-202.

[16] Kyrykiuk, V.P., Tymoshchuk, T.M., & Kalchuk, M.M. (2019). The yield of white mustard depends on the systems of the main tillage and fertilization. *Scientific Horizons*, 2(75), 27-33. doi: 10.332491/2663-2144-2019-75-2-27-33.

[17] Snizhok, O.V., & Yuvchyk, N.O. (2021). Species composition of harmful organisms in winter rapeseed crops depending on soil cultivation and protection system. *Cereal Crops: Scientific Journal*, 5(1), 145-152. doi: 10.31867/2523-4544/0171.

[18] Hrynyk, S.I. (2018). Efficiency of spring wheat cultivation depending on soil cultivation and nutrition system in the conditions of Precarpathia. *Taurian Scientific Bulletin*, 104, 40-46.

[19] Kyryliuk, V.P., Krychkivskyj, V.M., & Kovalchuk, N.V. (2020). The effect of long-term use of tillage and fertilization systems on the soil structure. *Scientific Horizons*, 8(93), 119-124.

[20] Poliovyk, V.M., Lukashuk, L.Ya., Rovna, H.F., & Huk, B.V. (2020). Productivity of winter rape depending on fertilization and liming in the conditions of Western Polissia. *Cereal Crops*, 4(1), 108-115. doi: 10.31867/2523-4544/0113.

[21] Kurach, O.V. (2021). The effect of fertilizer on the productivity of winter rape in the conditions of the western forest-steppe. *Cereal Crops*, 5(1), 92-98.

[22] Nadykto, V., Rohach, Yu., Kovbasa, V. (2009). One more time about Till and No-Till. *Ukrainian Magazine on Agribusiness,* 5, 96-9.

Економічна ефективність вирощування ріпаку озимого залежно від впливу елементів технології в умовах лісостепу України

В. В. Гамаюнова

Доктор сільськогосподарських наук, професор
https://orcid.org/0000-0002-4151-0299

І. М. Гаро

Здобувач
https://orcid.org/0000-0003-1846-9483

Миколаївський національний аграрний університет

Анотація. У статті наведено результати досліджень, проведених упродовж 2012-2015 рр. на чорноземі звичайному в зоні Лісостепу України з ріпаком озимим сорту Чемпіон України. Визначено вплив строків і способів сівби та основного обробітку ґрунту на врожайність насіння, що позначилося на показниках економічної ефективності виробництва культури. Їх визначенням обґрунтовано доцільність поєднання наступних елементів: сівба у І декаду вересня рядковим способом (ширина міжрядь 15 см) по фону оранки на 25-27 см (у якості основного обробітку ґрунту). Така технологія у середньому за 2013-2015 рр. забезпечила отримання найвищого рівня врожаю – 4,54 т/га і наступні економічні показники: умовно чистий прибуток 18,8 тис. грн/га, рівень рентабельності – 113,6 %, собівартість 1 т насіння – 4,5 тис. грн.

Ключові слова: ріпак озимий, захід основного обробітку ґрунту, строк сівби, спосіб сівби, рентабельність, умовно чистий прибуток, собівартість

UDC 633.11:631.526.3]:631.147(477.7)
DOI: 10.31521/2313-092X/2021-3(111)-6

Ukrainian Black Sea Region Agrarian Science
Vol. 25, No. 3

Allelopathic properties of winter wheat varieties in the phase of full maturity in the steppe zone of Ukraine

M. Korkhova*

PhD in Agricultural Sciences, Associate Professor
https://orcid.org/0000-0001-6713-5098

V. Mikolaichuk

PhD in Biological Sciences, Associate Professor
https://orcid.org/0000-0003-0110-6539

Mykolayiv National Agrarian University

Abstract. The direction of organic farming is one of the most promising and relevant in the field of agriculture. Organic agriculture assumes the priority role of grain production, for which a significant share of organic land is allocated from the total area, but compared to other European countries, it is a much smaller indicator. One of the reasons for this is the low yield of crops, which is due to the cessation of the use of chemical plant protection agents and mineral fertilizers. The phenomenon of allelopathy is taken into account when developing the structure of crop rotation and mixed crops in order to avoid soil fatigue in monocultures and weed control. Accordingly, it is appropriate to research and study the allelopathic properties of new varieties of winter wheat from different breeding centers of Ukraine. Therefore, the purpose of this work is to establish the allelopathic activity of various types of winter wheat, which will make it possible to identify varieties relevant for organic farming. To confirm the allelopathic activity of various types of winter wheat in 2019-2020, field research was carried out in the field of the Educational-Scientific-Practical Center of Mykolaiv National Agrarian University. The article presents the results of research into the allelopathic activity of water-soluble secretions from the soil rhizosphere and vegetative organs of winter wheat plants of new varieties of domestic breeding. It was established that water extracts from the organs of winter wheat plants of Koshova and Garantiya Odeska varieties inhibited the germination of watercress seeds more than other studied varieties. The variety Shchedrivka Kyivska has high allelopathic activity, and the varieties Vidrada and MIP Assol are neutral to the germination of watercress seeds

Keywords: winter wheat, allelopathic activity, varieties, water extracts, rhizosphere zone

INTRODUCTION

Organic farming is one of the priority areas of agriculture in the world. Organic agriculture in Ukraine is dominated by grain production, for which 43.2% of organic land (133,440 thousand ha) is allocated, but this is about 0.9% of the total area allocated for these crops in the country, which is significantly less than in Austria – 15.6%, Italy – 10.4%, Germany – 4.8%, Belgium – 3.8% [1]. It is believed that the main reason for the slow expansion of organic cultivated areas is the low yield of crops, which is due to the cessation of the use of mineral fertilizers and chemical plant protection agents.

One of the most important tasks of modern agricultural science is solving the problem of biologicalization of agriculture, increasing the profitability and

Article's History:
Received: 11.03.2021
Revised: 25.06.2021
Accepted: 26.08.2021

Suggested Citation:
Korkhova, M., & Mikolaichuk, V. (2021). Allelopathic properties of winter wheat varieties in the phase of full maturity in the steppe zone of Ukraine. *Ukrainian Black Sea Region Agrarian Science*, 25(3), 46-53.

stability of agrophytocenoses, obtaining stable harvests of high-quality products [2; 3].

When developing the structure of crop rotations and mixed crops in order to prevent soil fatigue in monoculture, fight against weeds and phytopathogenic organisms, etc., the phenomenon of allelopathy or chemical interaction of plants, which was first discovered by the Australian scientist H. Molish in 1937, is taken into account [4]. Allelopathy, as a scientific direction, due to the multifaceted nature of its approaches to the study of various biological phenomena, is intensively developing all over the world, including in Ukraine [5-10].

Currently, the need for alternative methods of weed control and the search for biological plant growth regulators is becoming increasingly urgent [11-14].It has been established that an allelopathically active culture can potentially be used for weed control by sowing a variety with allelopathic properties, thus reducing the rates of synthetic herbicides [15-17]. Many crops have been identified that produce substances poisonous to weeds.

Soft winter wheat is one of the most common agricultural crops in the world and has an allelopathic potential for fighting weeds, pests and diseases, which contributes to its cultivation according to organic technologies [18; 19].

According to V.A. Derevyanka, L.D. Yurchak, B.O. Ivanytska, A.K.M.S. Kabir and others. [19-21; 22], the phytoimmunity of wheat plants and other crops largely depends on the allelopathic regime of the soil, and the constant cultivation of cultivated plants in one place leads to inhibition of growth and a decrease in resistance to damage by diseases and pests.

Based on the results of the research, it was established that there is a difference in the allelopathic activity of soft winter wheat varieties when grown in the Steppe zone of Ukraine [23; 24].

Currently, research, testing and selection of winter wheat varieties with high potential for organic cultivation are important, but their allelopathic properties are not always taken into account.

Therefore, the study of allelopathic properties of eight new varieties of winter wheat from different breeding centers of Ukraine is relevant.

V.A. Derevyanko (2003) believes that allelopathic parameters should also be taken into account in the characteristics of a wheat variety as an integral part of the variety's passport, since plants show different tolerance to allelopathically active substances [19]. Therefore, one of the promising directions for the development of allelopathy is the screening test of various varieties and varieties of cultivated plants in order to study their allelopathic potential or resistance to allelopathically active substances [9; 19-24].

It is known that varieties of extensive use must have high allelopathic activity in order to create their own allelopathic regime in the crop and to counteract the penetration of weeds. Varieties of intensive use should have a low allelopathic activity [20].

As a result of numerous studies [18; 23; 24; 26] it was established that winter wheat varieties have different allelopathic properties against weeds, therefore, when they are alternated in crop rotation, the yield reduction in monoculture will be significantly less than when one variety is grown for a long time.

Research on genetic markers associated with wheat allelopathy and gene transfer into modern varieties for resistance to weeds is currently being conducted [25; 26].

It is known that the allelopathic effect of root secretions increases during plant aging [20]. According to B.O. Ivanytska [21], plant leaves and their secretions are more toxic; less – roots and root extracts; stems occupy an intermediate position. Other scientists [27] claim that aqueous extracts from leaves and stems have a higher inhibitory effect on rice seed germination than root extracts because they contain more phenolic compounds. Taking into account the spread of winter wheat and insufficient study of its allelopathic properties, the research topic is relevant.

The purpose of the article is to establish the allelopathic activity of various varieties of winter wheat, which will allow identifying varieties suitable for organic farming.

MATERIALS AND METHODS

In order to establish the allelopathic activity of various varieties of winter wheat in 2019-2020, field research was conducted in the field of the Educational, Scientific and Practical Center of the Mykolaiv National Agrarian University. The technology of growing winter wheat was generally accepted for the Southern Steppe zone of Ukraine. The predecessor is field peas. The research material was eight varieties of winter wheat recommended for cultivation in the conditions of the Steppe of Ukraine (Table 1).

Table 1. Characteristics of winter wheat varieties

Varieties	Type	By height	Resistance to disease	Grain quality
Vidrada	*erithrospermum*	medium growth	average	strong
Koshova	*erithrospermum*	medium growth	above average	strong
Shchedrivka Kyivska	*lutescense*	medium growth	above average	valuable
Krasa Ianiv	*erithrospermum*	medium growth	above average	strong
Kvitka poliv	*lutescense*	medium growth	above average	valuable
MEP Assol	*lutescense*	medium growth	high	filler
Guarantia Odesa	*erithrospermum*	medium growth	high	strong
Shedrist Odeska	*erithrospermum*	a half-dwarf	high	valuable

Variants in the experiment were placed by the method of split plots, repetition four times. The area of the accounting plot is 25 m². The soil of the experimental sites is low-humus, light-loam southern chernozem on the loess of wide poorly drained watershed plateaus, which is typical for the Southern Steppe zone of Ukraine. The content of humus in the arable layer of the soil is 2.4%, easily hydrolyzed nitrogen is 16 mg/kg, mobile phosphorus is 160 mg/kg, and exchangeable potassium is 187 mg/kg of soil.

To determine the allelopathic properties of winter wheat varieties suitable for distribution in the Steppe zone of Ukraine, the bioassay method of A.M. Grodzynskiy [28] was used. Watercress (*Lepidium sativum* L.) was taken as the test object, as it is highly sensitive to allelopathic substances. The growth of the roots of the test object in distilled water was taken as the control (100%).

Laboratory research was carried out in 2020 in the laboratories of the department of plant breeding and horticulture of the Mykolaiv National Agrarian University.

The effect of aqueous extracts of the basal soil layer, roots, leaves and stems of winter wheat plants of different varieties on the growth of seedling roots and the germination of watercress seeds was evaluated.

Since the largest amount of growth inhibitors accumulates in the phase of full grain maturity of winter wheat plants, soil and plant samples of each of the investigated varieties were taken precisely in this phase of development.

Vegetative organs of winter wheat plants (roots, stems, leaves) were separated in laboratory conditions. The selected samples were dried at a temperature of +65°C to a constant mass and ground. An average weight of 1 g was taken, which was extracted in 100 ml of distilled water in a thermostat during the day at a temperature of +25°C.

One-day-old seedlings were placed in sterile Petri dishes with a diameter of 9 cm on sterile filter paper soaked in 3 ml of filtrate watercress seeds (seeds were considered germinated if the root length was 1 mm). In the control variant, seedlings were grown on distilled water. Petri dishes with watercress seedlings were placed in a thermostat at a temperature of +25°C for one day. The length of the roots was measured using a digital caliper DIGITAL CALIPER 391110 with an accuracy of 0.02 mm. The experiment was completely randomized, four-fold repetition of studies with 100 seeds each was used.

RESULTS AND DISCUSSION

As a result of the conducted research, it was established that water-soluble secretions from the rhizosphere of winter wheat plants of the majority of studied varieties had a stimulating effect on the growth of watercress roots, except for the varieties Shchedrivka Kyivska, Garantia Odeska and Shchedrist Odeska. A longer root length was established in the seedlings of the test culture in the version with water extraction of the soil of the rhizosphere of the Kvitka poliv (14.27 mm) and Koshova (11.22 mm) varieties, which is 5.72 mm and 2.67 mm more than in control A smaller stimulating effect was observed in varieties Krasa Laniv (9.37 mm), MIP Assol (9.69 mm) and Vidrada (8.77 mm), which by 9.6; 13.3; 2.6% more than in the control (Table 2).

Table 2. *Effect of water extracts from the rhizosphere zone and vegetative organs of plants of winter wheat varieties on the root length of watercress seedlings, mm*

Type (factor A)	Water extraction (factor B)				Average by factor B
	soil	roots	stems	leaves	
Distilled water (control)	8.55	8.55	8.55	8.55	8.55
Krasa Laniv	9.37	4.55	7.30	7.43	7.16
Vidrada	8.77	7.21	8.47	8.01	8.12
Kvitka poliv	14.27	4.45	7.43	7.71	8.47
Koshova	11.22	2.60	10.41	6.64	7.72
Shchedrivka Kyivska	7.44	4.87	3.83	7.88	6.02
MIP Assol	9.69	9.49	7.43	9.92	9.13
Garantia Odeska	7.10	3.20	6.21	8.32	6.21
Shchedrist Odeska	6.05	3.55	7.43	8.86	6.47
Average by factor A	9.55	4.99	7.31	8.10	7.41

Research has established that water extracts from the roots of plants of most studied varieties inhibited the growth of watercress roots by 15.7-69.6%, the length of the roots of the seedlings ranged from 2.60 mm (Koshova) to 7.21 mm (Vidrada). Stimulation of the growth of watercress roots was detected using water extract from the roots of winter wheat plants of only one studied variety – MIP Assol (9.49 mm), which exceeded the control by 11.0%.

It was determined that the water extract from the stems of plants of most winter wheat varieties studied had an inhibitory effect on the germination of the seeds of the test culture, while the length of the roots of the seedlings ranged from 3.83 mm for the Shchedrivka Kyivska variety to 8.47 mm for the Vidrada variety, which by 1.0-55.2% less than the control. A water extract from the stems of plants of the Koshova variety had a stimulating effect on the germination of watercress seeds. The length of the roots was 10.41 mm, which is 1.86 mm or 21.8% more than in the control.

A more inhibitory effect of water-soluble extracts from the leaves of winter wheat plants of the Koshova variety on the growth of watercress roots was revealed, which is 22.3% lower than the control. A slight stimulating effect on root growth was exerted by water extractions of the varieties Shchedrist Odeska (8.86 mm) and MIP Assol (9.92 mm), which was 16.0 and 3.6% higher, respectively, than in the control variant.

Thus, the average length of watercress roots by varieties (factor A) was the smallest (4.99 mm) under the action of water extraction from the roots, and the largest – 9.55 mm under the action of water extraction from the basal layer of the soil of winter wheat plants. On average, according to factor B (water extract), the MIP Assol variety had a slight stimulating effect on the growth of watercress roots, and all other varieties had an inhibitory effect.

It was established that the greater growth of the roots of the test culture was under the influence of water extraction from the basal layer of the soil of plants of the Kvitka poliv variety, which is 166.9% compared to the control. Watercress seed treatment

extracts from the vegetative organs of winter wheat plants of the same variety inhibited the growth of the primary root, which amounted to 52.1 (roots); 86.9 (stems) and 90.2% (leaves) relative to the control (Fig. 1).

A similar pattern was observed in the varieties Krasa Laniv and Vidrada, that in the version with water extraction from the soil of the rhizosphere of plants, the growth of roots was 109.6 and 102.6%, respectively, relative to the control, while in the variants with water extraction from the roots – 53.2 and 84.3%; from stems – 85.4 and 99.1 and water extract from leaves – 86.9 and 93.4% relative to the control.

Water extracts from the soil of the rhizosphere and from the stems of winter wheat plants of the Koshova variety had a stimulating effect on the growth of the roots of the studied test crop – 131.2 and 121.8% relative to the control, respectively.

It was determined that the water extract from the leaves of winter wheat plants of the Odesa Generosity variety insignificantly stimulated the growth of the roots of watercress seedlings – 103.6% compared to the control, while the extracts from the basal layer of the soil, roots and stems, on the contrary, inhibited it (70.8; 41.5 and 86.9% relative to the control).

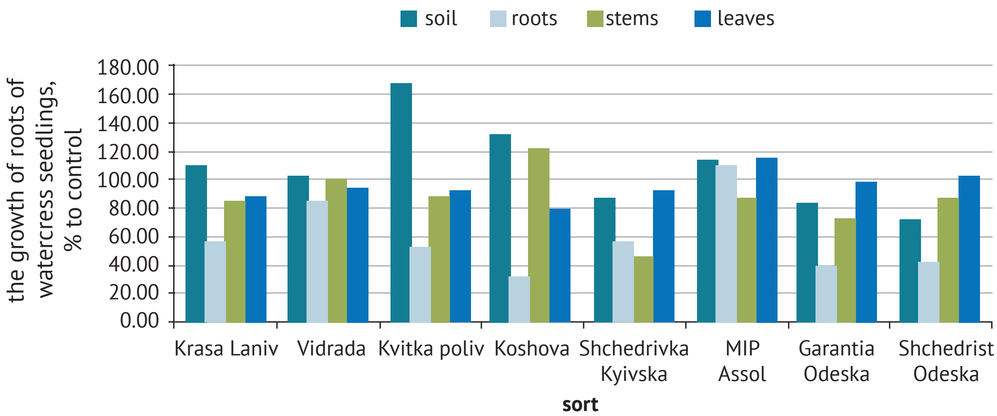

Figure 1. *The influence of water extracts from the soil of the rhizosphere and vegetative organs of plants of winter wheat varieties on the growth of roots of watercress seedlings, % to control*

It was established that all investigated variants of water extracts from plants of the Garantia Odeska and Shchedrivka Kyivska varieties had an inhibitory effect on the growth of the roots of seedlings of the test culture, which is from 37.4 to 97.3% relative to the control. The water extract from the leaves of both studied varieties had less inhibition of root growth – 92.2% (Schedrivka Kyivska) and 97.3% (Odesa Guarantee). The results of our research showed that allelopathic activity towards watercress seedlings was revealed by the water-soluble secretions of plant roots of the majority of winter wheat varieties studied. The greatest inhibitory effect is characteristic of the varieties Koshova (-69.59%) and Garantia Odesa (-62.57%) (Table 3).

Table 3. *Allelopathic activity of water-soluble secretions in the rhizosphere zone and vegetative organs of plants of different varieties of winter wheat, % to control*

Type(factor A)	Water Extractor (Factor B)			
	soil	roots	stems	leaves
Krasa Laniv	9.57	-46.78	-14.62	-13.10
Vidrada	2.56	-15.67	-0.94	-6.32
Kvitka poliv	66.87	-47.95	-13.10	-9.82
Koshova	31.23	-69.59	21.75	-22.34
Shchedrivka Kyivska	-12.99	-40.04	-55.20	-7.84
MIP Assol	13.33	10.99	-13.10	16.02
Garantia Odeska	-16.60	-62.57	-27.37	-2.69
Shchedrist Odeska	-29.25	-54.48	-13.10	3.63

A significant inhibitory allelopathic effect of the water extract from the stems of winter wheat plants of the Shchedrivka Kyivska variety was observed (-55.20%), while in the Koshova variety of this extract, it was stimulating (21.75%).

Thus, it was determined that high allelopathic activity in the phase of full ripeness of the grain had a high allelopathic activity in the studied water extracts of soil and plant organs of winter wheat of the Shchedrivka Kyivska variety (from -7.84 to -55.2%), and the lowest – Vidrada varieties (from -0.94 to -15.62%) and MIP Assol (+16.02 to -13.10%).

It was established that among all studied varieties of winter wheat, the water extract from the leaves of plants of the Koshova variety had the greatest allelopathic activity (-22.34%); from stems – Shchedrivka Kyivska variety (-55.2%); from the roots – the Koshova variety (-69.59%) and from the soil – the Odesa Generosity variety (-29.25%).

The winter wheat variety Shchedrivka Kyivska has a high allelopathic activity in the phase of full grain ripeness (from -7.84 to -55.2%), and the lowest is the Vidrada variety (from -0.94 to -13.50%) and MIP Assol (+16.02 to -27.95%).

It was determined that different parts of the plants of each of the researched varieties exert different inhibitory or stimulating effects on the germination of watercress seeds. As a result of the research, it was established that the water extract from the leaves of winter wheat plants had a greater negative effect on the germination of watercress seeds, which on average was 74.4% (80.9% of the control) by variety. This is 5.6% less than in the option with water extraction from leaves and 11.8% less than in the option using water extraction from stems (Table. 4) It was determined that the water extract from the roots of winter wheat plants of the Koshova variety had a more inhibitory effect on the germination of watercress seeds (54.8%), which is 94.3% compared to the control. The germination of the seeds of the studied test crop was reduced less by the varieties Krasa Laniv - 88.3% (96.0% to the control), MIP Assol – 88.8% (96.5% to the control), Vidrada – 86.8% (94.3% before the control), Shchedrivka Kyiv – 85.8% (93.3% before the control) and Shchedrist Odesa – 84.3% (91.6% before the control).

Water extracts from the leaves of plants of the Koshova variety had a more negative effect (68.3%) on the seed germination of the test culture, while the extract from the leaves of plants of the MIP Assol variety had a positive effect (105.2%). Aqueous extracts from the stems of winter wheat plants reduced the germination of watercress seeds less compared to extracts from roots and leaves, which is an average of 92.7% for the varieties compared to the control. The lower seed germination (68.3%) was obtained after processing with its extraction from the stems of winter wheat of the Shchedrivka Kyivska variety – 74.2% before the control. Water extracts from the stems of plants of the varieties Vidrada and Kvitka of the fields had a slight stimulating effect on the germination of the seeds of the test culture, which was 104.1 and 107.4%, respectively, of the control.

Table 4. *The effect of water-soluble secretions in the rhizosphere zone and vegetative organs of winter wheat plants of different varieties on the germination of watercress seeds, %*

Type (Factor A)	Water Extractor (Factor B)							
	Soil	%. To control	roots	%. To control	stems	%. To control	leaves	%. To control
Distilled water (control)	92.0	100.0	92.0	100.0	92.0	100.0	92.0	100.0
Krasa Laniv	83.3	90.5	88.3	96.0	74.3	80.8	90.3	98.2
Vidrada	66.7	72.5	86.8	94.3	95.8	104.1	66.0	71.7
Kvitka poliv	59.7	64.9	67.8	73.7	98.8	107.4	70.3	76.4
Koshova	77.8	84.6	54.8	59.6	88.0	95.7	62.8	68.3
Shchedrivka Kyivska	66.7	72.5	85.8	93.3	68.3	74.2	70.3	76.4
MIP Assol	79.0	85.9	88.8	96.5	83.3	90.5	96.8	105.2
Garantia Odeska	66.7	72.5	71.5	77.7	76.3	82.9	72.0	78.3
Shchedrist Odeska	66.1	71.8	84.3	91.6	82.0	89.1	73.0	79.3
Average on types	**70.8**	**77.0**	**79.6**	**86.5**	**85.3**	**92.7**	**74.4**	**80.9**

Analyzing the amplitude of the allelopathic activity of water-soluble secretions of plants of domestic varieties of winter wheat from the rhizosphere zone and vegetative organs, we found that a higher indicator is characteristic of the Kvitka poliov variety – 114.82% (soil) (Fig. 2).

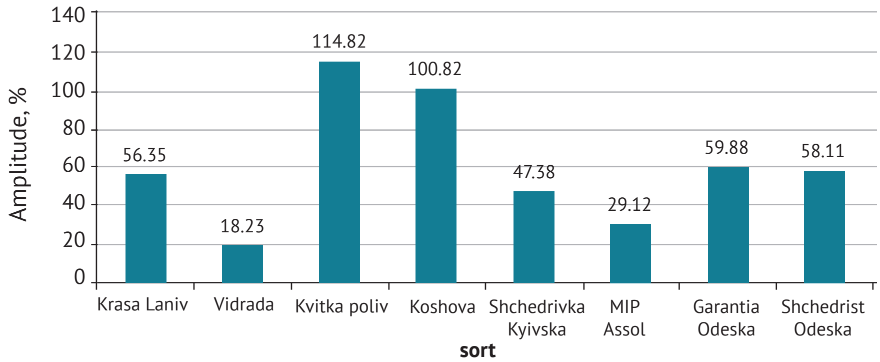

Figure 2. *Amplitude of allelopathic activity of water-soluble secretions of water extracts from rhizosphere soil and vegetative organs of winter wheat plants*

The average indicators of the amplitude of allelopathic activity are typical for Shchedrivka Kyivska varieties (47.38%), water-soluble secretions in the rhizosphere zone and all vegetative organs of which had inhibitory properties of varying intensity. The amplitude of allocation of plants of the Krasa Laniv variety is 56.35% and ranges from intense inhibitory (water extract from the roots) to slight stimulating (water extract from the rhizosphere soil). The varieties Shchedrist Odeska and Garantiya Odeska are also characterized by average indicators of the amplitude of allelopathic activity (58.11 and 59.88%, respectively), a significant share of which is contributed by the release of roots that have a high inhibitory effect. Plants of Vidrada and MIP Assol varieties are characterized by the smallest amplitude of allelopathic activity (18.23 and 29.12%, respectively), that is, it is close to neutral. However, there is a difference, which is manifested in the fact that in the latter variety, only the release of leaves has a slight inhibitory effect, and for the Vidrada variety, the inhibitory effect of different activity is characteristic of the water-soluble secretions of all vegetative organs, and only the release into the soil of the rhizosphere has a slight stimulating effect.

Due to the fact that Vidrada and MIP Assol varieties show tolerance, we consider it important to analyze the change in allelopathic activity from inhibitory to stimulating.It was established that the change in the allelopathic activity of water-soluble secretions for the Vidrada variety has the following form: "water-soluble secretions of roots < leaves < stems < secretion into the rhizosphere"; for the MIP Assol variety – "water-soluble secretions of stems < roots < secretion into the rhizosphere < leaves". It can be assumed that this phenomenon is associated with the accumulation of a greater amount of phenolic compounds in the roots of plants of the Vidrada variety and the stems of plants of the MIP Assol variety.

As a result of the conducted correlation-regression analysis, it was established that there is a very weak inverse relationship between seed germination and cress root growth under the influence of water extracts of vegetative organs of plants of different varieties of winter wheat – in the varieties Krasa laniv and Shchedrist Odeska (-0.0349 and -0.2469, respectively) to a weak straight line – in Shchedrivka Kyivska (0.1450), MIP Assol (0.2217) and Kvitka Poliv (0.4555) varieties. A moderate dependence is observed in winter wheat plants of Garantia Odeska and Koshova varieties (0.6445 and 0.7631, respectively). Only the Vidrada variety is characterized by a high correlation between seed germination and watercress root growth – 0.9069.

CONCLUSIONS

As a result of the conducted research, it was established that the character of the metabolites of the studied varieties of winter wheat, which are released into the rhizosphere zone, have stimulating and inhibitory effects on seed germination and the growth of watercress seedlings.

It was determined that water extracts from the organs of winter wheat plants of the Koshova and Garantiya Odeska varieties suppress the germination of the seeds of the test crop more than the other studied varieties. The water extract from the roots of plants of the Koshova variety had the most inhibitory effect on the growth of watercress roots. It was established that the Shchedrivka Kyivska winter wheat variety has high allelopathic activity, while the Vidrada and MIP Assol varieties are neutral to the germination of watercress seeds. A high correlation (0.9069) was determined between seed germination and cress root growth under the action of water extraction from the rhizosphere soil and vegetative organs of Vidrada variety plants. We assume that with a smaller amplitude of allelopathic activity of water-soluble secretions of winter wheat plants of the Vidrada and MIP Assol varieties, they are tolerant to the reduction of the aftereffects of the cultivation of these varieties and soil fatigue. In the future, the researched varieties will be subjected to a more detailed check at different stages of development and with other test cultures.

REFERENCES:

[1] Willer, H., Trávníček, J., Meier, C., Schlatter, B. (Eds.). (2020). *The world of organic agriculture statistics and emerging trends*. Retrieved from https://www.fibl.org/fileadmin/documents/shop/1150-organic-world-2021.pdf.

[2] Ivanyshyn, V., & Shuvar, I. (Eds.). (2016). *Biologization of agriculture in Ukraine: realities and prospects: scientific and industrial. view*. Ivano-Frankivsk: Symphony Forte.

[3] Korkhova, M., Panfilova, A., Chernova, A., & Rozhok, O. (2019). The effect of pre-sowing seed treatment with biopreparations on productivity of cultivars of Triticum spelta L. *Agrolife Scientific Journal*, 8(1), 120-127.

[4] Yurchak, E. (2018). History of allelopathy: past and present. *Outlook*, 2(70), 16-20.

[5] Vergunov, V.A., & Yurchak, E.V. (2017). Allelopathic bases of highly productive agrophytocenoses of introduced aromatic plants in creative heritage. *Agricultural Microbiology*, 26, 68-75.

[6] Shao, G.G. (2019). Allelopathic effects of different weed extracts on seed germination and seedling growth of wheat. *Pakistan Journal of Botany*, 51(6), 2159-2167.

[7] Andrianandrasana, M.D. (2020). Allelopathic effects of Grevillea banksii R. BR. Leaf extracts and its rhizospheric soil on germination and initial growth of three agricultural crops in Madagascar. *AgroLife Scientific Journal*. 9(1), 23-30.

[8] Saracin, V.-C., & Vasile, A. (2015). An exploratory research regarding Romanian organic farming sector. *AgroLife Scientific Journal*, 4(2), 119-123.

[9] Mykolaychuk, V.G., Koroleva, O.V., & Korkhova, M.M. (2021). Allelopathic activity of water-soluble secretions of Crocus sativus L. (Iridaceae) flowers upon introduction in the Northern Black Sea region. Ukrainian *Journal of Medicine, Biology and Sports*, 6, 3(31), 340-346. doi: 10.26693/jmbs06.03.340.

[10] Tahir, H.A. (2019). Antibacterial activity and allelopathic effects of extracts from leaf, stem and bark of Mt. Atlas mastic tree (Pistacia atlantica subsp. kurdica) on crops and weed. *Allelopathy Journal*, 46(1), 121-132.

[11] Franca Teixeira, M.F. (2018). Allelopathic influence of some fruit tree leaf extracts on germination and seedling development of different weeds and vegetable crops. *Australian Journal of Crop Science*, 4(2), 726-730.

[12] Kyrychenko, E.V. (2014). Phytolectins and diazotrophs are the polyfunctional components of the complex biological compositions. *Biotechnologia Acta*, 7(1), 40-53.

[13] Stephen, O.D. (2015). Proving allelopathy in crop-weed interactions. *Weed Science*, 63(1) 121-132. doi: 10.1614/WS-D-13-00130.1.

[14] Iqbal, J. (2020). Herbicidal potential of some dry land plants against Lathyrus aphaca (L.), winter season weed. *Planta Daninha*, 38, 1-7.

[15] Storchous, I. (2017). Biological method of weed control – foreign and domestic experience. *Offer. Bioprotection and Biological Preparations are an Actual Perspective*, 16-20.

[16] Sangeetha, C., & Baskar, P. (2015). Allelopathy in weed management: A critical review. *African Journal of Agricultural research*, 10(9), 1004-1015.

[17] Ming, Y., Hu, G.-X., Li, J., Zhu, Zh.-J., Fan, X.-M., Yuan, D.-Y. (2020). Allelopathic effects of Castaneahenryi aqueous extract sonthegrowth and physiology of brassica pekinensis and zea mays. *Chemistry & Biodiversity*, 17(6). doi: 10.1002/cbdv.202000438.

[18] Derevyanko, V.A. (2007). Allelopathic activity of species and varieties of the genus Triticum L. *Introduction of Plants*, 4, 112-116.

[19] Derevyanko, V.A. (2003). Variety through the prism of allelopathic parameters. *Introduction of Plants*, 4, 129-133.

[20] Yurchak, L.D. (2000). Modern criteria for allelopathic evaluation of extracts of mint. *Introduction of Plants*, 3-4, 140-146.

[21] Ivanytska, B.O. (2008). Allelopathic activity of some species of the family Araceae Juss. *Introduction of Plants*, 101-105.

[22] Kabir, A.K.M.S. (2001). Allelopathic potential of rice varieties against Spinach *(Spinacia oleracea)*. *International Journal of Agriculture & Biology*, 12(6), 809-815.

[23] Wu, B.H. (2001). Allelopathy in wheat (*Triticum aestivum*). *Association of Applied Biologists*, 139, 1-9.

[24] Korkhova, M., & Mykolaichuk, V. (2021). Allelopathic properties of winter wheat varieties of various breeding institutions of Ukraine. *AgroLife Scientific Journal*, 10(1), 116-120.

[25] Korkhova, M. (2021). Evaluation of allelopathic activity of extracts of plantorgans of various varieties of winterwheat. *Scientific Papers. Series A. Agronomy*, 64(1), 417-422.

[26] Zuo, S.P., Ye, L.T., Mei, H. (2011). Physiological basis for allelopathic potential of different wheat cultivars in heading period on the Loess Plateau of China. *African Journal of Biotechnology*, 10(48), 9786-9795.

[27] Wu, B.H., & Pratley, J.E. (2001). Allelopathy in wheat (Triticum aestivum). *Association of Applied Biologists*, 139, 1-9.

[28] Krumsri, R., Kato-Noguchi, H., & Poonpaiboonpipat, T. (2020). Allelopathic effect of Sphenoclea zeylanica Gaertn. on rice (*Oryza sativa* L.) germination and seedling growth. *Australian Journal of Crop Science*, 14(09), 1450-1455.

[29] Grodzinskyi, A.M., Bohdan, H.P., & Golovko, E.A. (1979). *Allelopathic soil fatigue*. Kyiv: Scientific opinion.

Алелопатичні властивості сортів пшениці озимої у фазі повної стиглості в зоні степу України

М. М. Корхова

Кандидат сільськогосподарських наук, доцент
https://orcid.org/0000-0001-6713-5098

В. Г. Миколайчук

Кандидат біологічних наук, доцент
https://orcid.org/0000-0003-0110-6539

Миколаївський національний аграрний університет

Анотація. У статті представлено результати досліджень алелопатичної активності водорозчинних виділень з ризосфери ґрунту та вегетативних органів рослин пшениці озимої нових сортів вітчизняної селекції. Встановлено, що водні витяжки з органів рослин пшениці озимої сортів Кошова та Гарантія одеська більше пригнічували схожість насіння крес-салату, ніж інші досліджувані сорти. Високу алелопатичну активність має сорт Щедрівка київська, а сорти Відрада та МІП Ассоль є нейтральними до проростання насіння крес-салату

Ключові слова: пшениця озима, алелопатична активність, сорти, водні витяжки, зона ризосфери

UDC 606.628.3:663.18
DOI: 10.31521/2313-092X/2021-3(111)-7

Ukrainian Black Sea Region Agrarian Science
Vol. 25, No. 3

Bioconversion of the fat-containing phase of effluents of fish processing enterprises into a feed additive

M. Madani
PhD in Technical Science, Associate Professor
https://orcid.org/0000-0001-9386-7364

R. Shevchenko*
PhD in Technical Science, Associate Professor
https://orcid.org/0000-0002-7924-1987

O. Hankonjich
PhD in Technical Science, Associate Professor
https://orcid.org/0000-0002-7622-521X

Odesa National Academy of Food Technologies

Abstract. Currently, the branch of the Ukrainian food industry occupies a priority place among other spheres of the economy. However, the field of food production faces the problem of non-compliance with current requirements in the context of the environmental aspect. Among them is the aspect of waste processing, which is generated during the processing of fish raw materials, cleaning of sewage wells. A typical situation for fish processing enterprises is the disposal of waste and fatty effluents. Actual economic needs include the need for the production of protein feed additives, as well as solving environmental issues for the processing of fat-containing effluents from fish processing enterprises. Thus, the purpose of the article is to develop the technological basis of the aerobic bioconversion of the fat component of the effluents of fish processing enterprises into a protein feed additive. Therefore, a technology for utilization of the fat-containing phase of fish processing effluents based on a combination of physical and chemical effects and biological oxidation is proposed. It was established that the predominant organism of the autochthonous microflora of the waste is the fungus *Geotrichum sp.*, and also that the yeast *Yarrowia lipolytica*, selected for the substrate, is the most promising biodecomposer of fats. A basic technological scheme of bioconversion of the fat-containing phase of effluents of fish processing enterprises into yeast biomass for fodder purposes has been developed. The main chemical and microbiological indicators of the fat-containing phase of the effluents of fish processing enterprises were determined. It has been established that for the biodestruction of fatty effluents, it is appropriate to use both top-up and continuous methods of cultivation, which do not lead to radical changes in the quality of the obtained biomass. It was established that in the process of holding waste in a sludge collector (1-13 days) as a result of the vital activity of autochthonous microorganisms, the fat content decreases from 87 to 58

Keywords: technical ecology, protection technologies, waste management, normalization of the load on the environment, feed additive

Article's History:
Received: 4.03.2021
Revised: 20.07.2021
Accepted: 26.08.2021

Suggested Citation:
Madani, M., Shevchenko, R., & Hankonjich, O. (2021). Bioconversion of the fat-containing phase of effluents of fish processing enterprises into a feed additive. *Ukrainian Black Sea Region Agrarian Science*, 25(3), 54-65.

INTRODUCTION

Currently, the food industry in terms of production occupies a leading position among the branches of the national economy. One of the main problems of food production is their non-compliance with modern environmental requirements, which can be solved by introducing low-waste technologies. For example, there is an urgent issue of processing waste from the fish processing complex, which is generated during the processing of fish raw materials, clarification of waste water in the grease trap and flotation device, and cleaning of sewage wells.

For fish processing enterprises, the main problems are the disposal of organic waste (blood, guts, scales, fish trimmings) and fatty effluents. Special attention should be paid to the fat component, since it accounts for the main share of the total amount of waste. Thus, the solid fish mass collected in sedimentation tanks contains at least 25-35% crude fat [1]. Thus, during the operation of fish processing enterprises, large amounts of fatty waste are inevitably generated, and their contamination with microflora leads to rapid decay with the formation of unpleasant odors. In addition, the high content of fats in wastewater complicates the functioning of treatment facilities of fish processing plants, as it contributes to the formation of deposits on the walls of pipes and tanks.

It should be noted that fat-containing waste varies in composition, which varies depending on the mode of operation of the fish processing enterprise, therefore most of the existing technologies can be applied only with a number of restrictions.

Existing technologies for the processing of fat waste can be divided into two types: physico-chemical and microbiological. The former require specific conditions, significant capital expenditures, are inefficient, and the demand for waste processing products is not high enough. Microbiological methods are characterized by high efficiency, but their significant drawback is that they do not obtain a final product, but only involve the disposal of waste. This significantly reduces their value from the point of view of increasing the profitability of the main production.

The microbial biomass produced as a result of the application of microbiological methods can be used as a valuable feed additive for farm animals and poultry. The latter is especially relevant for modern fodder production, as it allows more efficient use of raw materials and maximum productivity of livestock and poultry farming with the lowest costs.

Thus, modern economic needs include the need for the production of protein feed additives and the solution of environmental issues in the processing of fat-containing effluents of fish processing enterprises. This allows us to consider research aimed at solving these problems as having great practical and social significance. Fish processing enterprises are faced with the problems of disposal of a number of different organic wastes. Among them, it is possible to single out fat-containing waste produced during fish processing, purification of wastewater in a grease trap and flotation device, cleaning of sewage wells [2-4]. The largest amount of fatty waste is produced during the purification of wastewater, which are diluted emulsions. The content of polluting fatty impurities in wastewater reaches 900 mg/l, while the permissible concentration should not exceed 50 mg/l. To achieve the desired result, the efficiency of wastewater treatment is about 95%. In addition, effluents from fish processing enterprises are characterized by unevenness of flow, changes in the concentration of pollutants during the day, fluctuations in pH values (6.5-8.5) [5-7].

The existing technological schemes of wastewater treatment provide for the periodic (1-2 times a day) removal of the fat sludge that floats to the sludge collector after passing through the grease trap. The volume of the sludge collector is calculated for the accumulation of waste for 3-5 days, then they are buried at the solid waste landfill [8].

The composition of the fatty phase of wastewater at fish processing enterprises can be heterogeneous and very complex [9], which is one of the main problems that arise when using such waste as raw materials.

Currently, a number of technologies are proposed that allow the utilization or processing of fat waste [10-18]. Two main directions of the proposed technologies can be distinguished: physico-chemical and biological.

Analysis of the literature shows that today there is a wide range of technologies based on physical and chemical effects on fatty waste. Some of them manage to obtain a product that can be used in further human economic activity [13].

Despite various researches by scientific groups, both in Ukraine and abroad, there are still no safe technologies for processing low-value fats, and no production has yet been established on an industrial scale. Therefore, low-value fats are destroyed as waste water treatment [15].

One of the modern trends in fat waste processing is the combination of physico-chemical influence and biological oxidation [16; 19]. As part of one of these technologies, it is proposed to use biological oxidation as an intermediate stage by using biological preparations containing a complex of lipolytic enzymes, as well as a live culture of microorganisms. This makes it possible to significantly shorten the terms of wastewater treatment and at the same time reduce economic costs. This technology involves further oxidation of biomass with potassium permanganate and hydrogen peroxide [20].

It should be noted that a number of technological schemes provide for the purification of sewage from fatty impurities with preparations consisting of both monocultures and mixtures of microorganisms of the genus *Mucor, Bacillus, Pseudomonas,* etc. [21-23].

The disadvantage of the proposed technologies is the lack of a product that is of interest for further human activity. Thus, these methods allow only to reduce the toxicity of man-made waste, but not to process it.

Approaches to biosynthetic and enzymatic processing of animal fats into products with increased biological activity have already been developed. For example, there are technologies for the hydrolysis of fats in waste water from food industries using microbial lipases [20; 24; 25], as well as bovine pancreatic lipase. As a result of the enzymatic splitting of fat by animal lipases, the entire spectrum of fatty acids is released from the fat structure [26]. Thus, fat-containing additives with increased biological value for food compositions and microbiological environments can be obtained [27].

It should be noted that technologies are offered that allow for biological destruction both in aerobic conditions and through anaerobic fermentation.

Fermentation with lactic acid bacteria is a fairly widespread method of processing fat-containing waste from food enterprises. This method includes heat treatment of raw materials, enzymatic hydrolysis, and if necessary, it is suggested to additionally carry out filtration [28]. The disadvantage of this method is the need to carry out several stages, as well as the use of an enzyme preparation, which significantly increases the cost of the final product.

Anaerobic fermentation of waste in order to obtain biogas and other gaseous products is also proposed [29]. The residue formed during such waste processing can be used as fertilizer. Its composition depends on the composition of the raw material. Under favorable conditions for anaerobic fermentation, about 70% of organic substances are usually decomposed [30]. The main factor restraining the introduction of this technology at production enterprises, despite all the advantages, is significant capital costs [31].

There are also a number of technological schemes for the aerobic processing of fatty waste using yeast cultures, and a number of researchers recommend the moderately halophilic yeast *Yarrowia lipolytica* [32-36]. An analysis of the literature shows that *Y. lipolytica* yeast is successfully used in the treatment of fat-containing effluents of enterprises engaged in the processing of various types of vegetable raw materials. For example, it has been proven that the strain *Y. lipolytica* 3589 reduces the chemical oxygen consumption (COD) of wastewater from palm oil production enterprises by 95% in two days [34], and the strain *Y. lipolytica* ATCC 20255 reduces the COD of wastewater from olive oil production by 80% in 24 hours. At the same time, the accumulation of yeast biomass was 22.45 g/l [37].

The possibilities of modern biotechnology make it possible to find an alternative way of using fat-containing effluents of fish processing enterprises, which affects not only the ecological aspects of production, but also the problem of feed protein deficiency. Thus, the ability of the thermophilic strain *Candida tropicallis* 928 and the above yeast *Y. lipolytica* to use fat as a carbon substrate has been established [38]. *Y. lipolytica* is recommended for the purification of wastewater from fat-containing pollutants in the case of using the target product as a feed additive.

The above allows us to conclude that fat-containing effluents of food enterprises can be used as a substrate for the cultivation of microorganisms – producers of fodder protein. An analysis of the literature proves that *Y. lipolytica* yeast is one of the cultures, the use of which can be effective in carrying out this process [36].

The purpose of the article is to develop the technological foundations of the aerobic bioconversion of the fat component of the effluents of fish processing enterprises into a protein feed additive. To achieve the goal, the following tasks are set:

1. To determine the chemical and microbiological indicators of the fat phase of the effluents of fish processing enterprises.
2. To isolate and characterize autochthonous microorganisms; choose microorganisms with high lipolytic activity, which are able to assimilate fats as the only source of carbon.
3. To study the processes of cultivation of destructive microorganisms on fatty substrates depending on the preliminary treatment of the substrate.
4. Investigate the influence of different modes of cultivation of microorganisms on the characteristics of the technological process and the quality of microbial biomass; conduct a comparative analysis of methods of concentration of the obtained biomass.
5. To develop a technological scheme for the processing of the fat-containing phase of the effluents of fish processing enterprises.

MATERIALS AND METHODS

The main object of the study was the fatty effluents of the fish processing enterprise "RZK" Pivdenny LLC, whose production facilities are located in the city of Bilhorod-Dnistrovskyi, Odesa region. The chemical parameters of the average waste sample (total fat, free fats, acid value of fat) were determined in accordance with DSTU 660:2019, DSTU ISO 7847:2006, DSTU EN 14105:2009. Microbiological characteristics, as well as isolation and research of autochthonous cultures of microorganisms were carried out using standard methods [39].

Microbial objects were strains of microorganisms with lipolytic activity: bacteria – *B. mesentericus, B. subtilis, Acinetobacter sp.; mushrooms – A. mysae, P. orysae, yeast – C. scottii, Y. lipolytica.* Cultivation was carried out in flasks with a volume of 250 ml (100 ml of medium) with stirring (150 rpm) and in a fermenter with a volume of 5 liters with a nutrient medium filling of 70% with stirring (250 rpm). Lipolytic activity was determined by the hydrolysis reaction of olive oil [40]. The content of crude protein, true protein, total carbohydrates, total fat, and nucleic acids in microbial biomass was determined in accordance with DSTU 8723:2017.

The results of the experiments were processed using the methods of mathematical statistics. The value of the reliability indicator was found by the Student's test with a confidence probability of P=0.95 and the degree of freedom f=n−1. The permissible value of the relative error was considered to be its value, which does not exceed 5%.

RESULTS AND DISCUSSION

Chemical and microbiological indicators of fatty effluents of fish processing enterprises. Since the composition of the fatty phase of the effluents can vary significantly as a result of the vital activity of autochthonous microflora, as well as depending on the quality of the processed raw materials, samples were taken during several cycles of the enterprise's operation from the sludge collector on 1, 5 and 13 days after receipt. The study of the chemical composition of fatty waste effluents of the same storage period (table 1) revealed minor differences in the mass fractions of the analyzed compounds in the composition of fatty raw materials, which indicates the same type of waste generated during the operation of the enterprise. However, clear changes in the composition of the fat mass during its aging in the sludge tank indicate the active development of autochthonous microflora, which consumes fat, reducing its share. At the same time, microbial biomass accumulates, as a result of which the content of crude protein and carbohydrates increases. The parallel decrease in the mass fraction of free fat and the acid number is probably associated with the consumption of the most easily digestible fats by the developing microflora, while the hard-to-digest fats remain unconsumed.

Table 1. *Chemical indicators of the fat-containing phase of fish processing effluents with different periods of storage in the sludge collector*

Waste storage, days	Total fat, %	Free-extracted fat, %	Acid number	Crude protein, %
1	86.9-88.4	82.2-84.3	190.1-219.4	12.5-13.9
5	70.3-76.6	63.3-74.6	131.4-140.3	17.5-21.0
13	58.3-61.4	46.1-48.3	118.8-124.6	19.0-22.1

Notes: **– taking into account the spread of indicators of different samples*

When studying the microbiological parameters of fat waste, high clogging (up to 108 cl/g) of waste was found (Table 2). With the increase.

During the storage period of waste, the number of bacteria decreases and the number of fungi increases.

Table 2. *Microbiological parameters of the fat-containing phase of fish processing effluents with different periods of storage in the sludge collector*

Waste storage, days	CFU, 106 kl/h	
	bacteria	fungi
1	100.2	2.5
5	15.4	86.5
13	8.8	167.9

The study of the fungi isolate revealed a high activity of exolipase (120 units/mg ASB) and endolipase (68 units/mg ASB). Based on the results of determining morphological features and physiological properties, the isolate was classified as a yeast-like fungus *Geotrichum sp*. Since the isolated microorganism was the dominant contaminant of the waste and had a high lipolytic activity, the necessary stage of further research was to find out the perspective of its use for the bioconversion of the fat phase of wastewater.

It was noted that other microorganisms (bacteria, molds), which are present in single quantities, are not capable of assimilating fats and, apparently, are allochthonous for this type of waste. The isolated bacteria, which were Gram-positive rods 1 μm in size, capable of forming endospores without changing the shape of the cell, had relatively high rates of assimilation of the fat substrate. Despite the high exolipolytic activity, as well as the ability to assimilate fats as a carbon source, the growth rate and maximum accumulation of biomass in the isolated bacteria when growing on nutrient media with a fat waste content of 20 g/l did not exceed 0.1 h^{-1} and 2.2 g/l respectively. In addition, the isolated bacteria were highly sensitive to changes in the pH of the environment and contamination by fungi, which does not allow considering them as promising destroyers of fatty waste.

Bioconversion of the fat-containing phase of fish processing effluents using a selected strain of the fungus *Geotrichum sp*. The growth of the fungal isolate was studied in a laboratory fermenter on a medium containing fatty waste (20 g/l) with different periods of storage in a sludge collector (table 3).

The obtained results indicate that the strain *Geotrichum sp*. can be used for bioconversion of fat waste: the resulting biomass contained up to 45% protein. However, the process was long, had an insufficiently high growth rate of the fungus and a low biomass yield. This may be due to the limited ability of the isolated fungus to assimilate higher saturated carboxylic acids.

When studying different modes of mushroom cultivation based on quality indicators of the obtained biomass, a conclusion was made about the advantage of deep heterophase cultivation in a periodic mode. However, this regime is unprofitable in terms of economic indicators. Other modes of cultivation (with substrate feeding, continuous) led to a significant increase in the content of lipids and a decrease in the amount of protein in the final product.

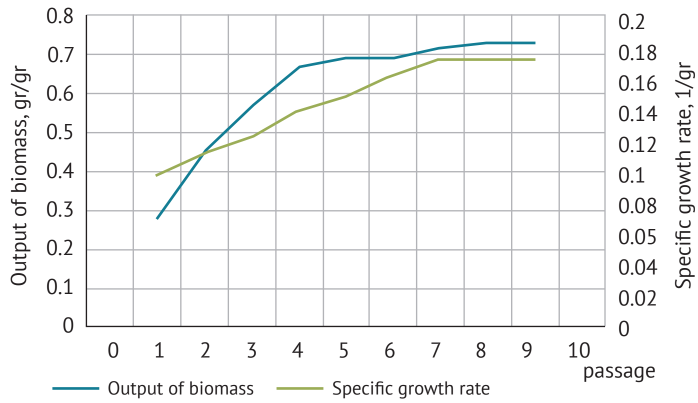

Figure 1. *Change in the growth characteristics of yeast Y. lipolytica during selection with respect to the substrate*

Table 3. *Growth characteristics of Geotrichum sp. during cultivation on fat waste in periodic conditions*

Characteristic	The term of waste storage in the sludge collector, days		
	1	5	13
Cultivation duration, hours	46	72	82
Growth rate, $hour^{-1}$	0.10	0.06	0.04
Maximum accumulation of biomass, g/l	13.5	9.1	6.4
Biomass output, g/g	0.68	0.46	0.37
Biomass composition, % - protein - crude protein - total fat	44-45 53-55 11.0-12.5	28-29 34-35 15.3-19.7	19-20 23-25 25.0-26.5

Since autochthonous cultures are not promising for the bioconversion of the fatty phase of effluents into a protein feed additive, there was a need to find a more effective microbial destructor of fats with a high degree of exolipase production. Exolipase activity and the content of protein substances in the biomass were chosen as the main criteria for the selection of strains. The analysis of the results made it possible to conclude that the yeast *Y. lipolytica*, which has the highest lipolytic activity, provides a high yield of biomass – up to 0.6 g/g when cultivated on fatty waste and crude protein content – 38.3% of ASB (Table 4).

When growing *Y. lipolytica* in a laboratory fermenter in an environment containing fatty waste as a substrate (20 g/l), the duration of the process was 5 days, and the specific growth rate was 0.05 h^{-1}. However, the obtained biomass contained up to 21.5% lipids, which indicates incomplete consumption of the substrate and, therefore, the need to optimize the conditions of the process.

Table 4. *Characteristics of lipase-producing microorganisms*

Culture	Exolipase activity		Raw protein, %
	specific unit/mg ASB	general units/ml	
Bacillus mesentericus	0.53	2.9	25.4
Bacillus subtilis	0.73	6.7	28.3
Acinetobacter sp.	2.6	42.1	40.1
Aspergillus orysae	34.2	4.6	31.5
Penicilliwn orysae	0.7	5.1	29.7
Candida scottii	39.0	42.5	39.2
Yarrowia lipolytica	303.4	919.0	38.3

Therefore, the influence of the mineral composition of the nutrient medium and cultivation conditions (temperature, pH, aeration, "age" and concentration of fatty waste) on the lipolytic activity and biomass accumulation of yeast *Y. lipolytica* was further investigated. The best results were obtained under the following conditions: cultivation temperature 30-32°C; pH 5.0-5.5, fat substrate content 20 g/l. An increase in the concentration of the fat substrate over 20 g/l led to a significant decrease in the growth rate of yeast and the maximum accumulation of biomass, which is explained both by difficulties in aeration, as the content of dissolved oxygen in the nutrient medium decreases, and by the fact that part of it is spent on spontaneous oxidation processes of components fat It was noted that a decrease in the growth characteristics of the yeast culture was observed when using fatty waste that was stored for more than a day. Therefore, only "fresh" waste should be used for an effective process.

In the course of the work, it was established that fat waste contains components that inhibit the growth of *Y. lipolytica* yeast. Since the inhibitory effect was higher in waste with longer storage periods and with high clogging, a conclusion was made about the microbial nature of the inhibitors. This negative effect can be eliminated by the selection of yeast in the direction of their adaptation to the stored fatty substrate. Breeding was carried out by means of multiple successive inoculations of yeast on media containing the waste of fatty effluents from fish processing. As a result, up to the 7th passage, the specific growth rate of microorganisms and the yield of biomass increased significantly to 0.8 h^{-1} and 0.69 g/g, respectively (Fig. 1).

There is also an increase in the content of true protein from 30.6 to 38.9%. It was noted that using an adapted yeast culture as inoculum, the required inoculation volume is reduced to 0.1% v/v. It has been proven that it is most expedient to use the culture in the phase of linear growth. However, when transplanting yeast adapted to fatty wastes to carbon-containing liquid/solid nutrient media, the previously achieved results were lost.

For effective bioconversion of the fat-containing phase of effluents, it is necessary to use the yeast strain *Y. lipolytica*, selected for the substrate, and the yeast should be stored only on fat-containing nutrient media.

Preliminary preparation of fat-containing nutrient medium. Since the process of assimilation of fats by microorganisms can be limited by the surface area of the substrate, the development of ways to increase the efficiency of bioconversion of the substrate by pretreatment of the medium is relevant.

Reducing the size of fat particles can be achieved by chemical or enzymatic hydrolysis, as well as by ultrasonication. In the course of research, alkaline hydrolysis of raw materials was carried out using sodium hydroxide (pH 8-13) followed by autoclaving at 0.5 and 1 atm. Pancreatic lipase (1,500 act units/g) was used for hydrolysis, while the concentration of the enzyme and the duration of treatment were changed. Ultrasonic disintegration was carried out in a laboratory ultrasonic bath with an operating frequency of 22 kHz, changing the temperature and duration of treatment. It was proven that both alkaline and enzymatic hydrolysis, although it allows to reduce the size of fat particles, but does not increase the efficiency of its bioconversion by yeast. In contrast to the described methods, ultrasonic dispersion of fat at the stage of preparation of raw materials had a significant effect on the growth characteristics of yeast, since ultrasonic waves stimulate the processes of oxidation of fats [41; 42] and this contributes to the preliminary partial degradation of the substrate and increasing its bioavailability. The study of the properties (optical density) of the obtained fat dispersion showed that the action of ultrasound at a temperature of 30°C and below allows to achieve the maximum degree of saturation of the system (Fig. 2)

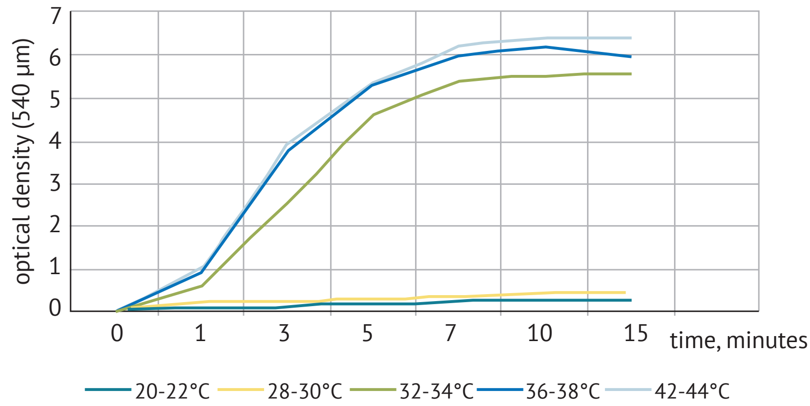

Figure 2. *Change in the optical density of the dispersion of fat waste (1 g/l) in the nutrient medium at different temperatures during ultrasound treatment*

Microscopy of the resulting dispersion revealed a significant reduction in the size of fat particles. Ultrasonic treatment of a nutrient medium containing 20 g/l fatty waste for 7 min resulted in a decrease in the average particle diameter to 1.5 μm. Longer action did not significantly affect the dispersion properties (Fig. 3).

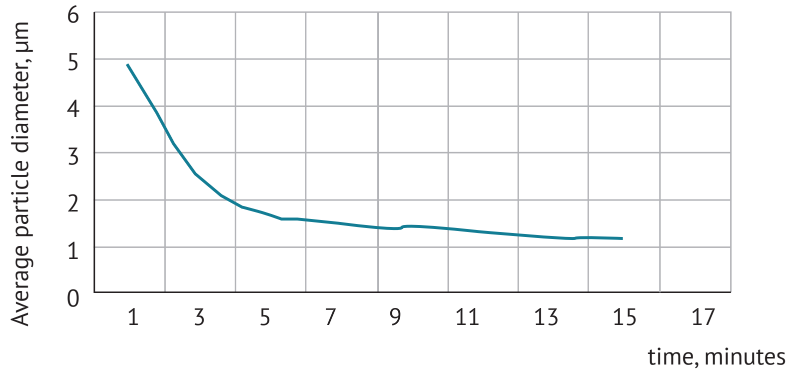

Figure 3. *Influence of the duration of ultrasonic treatment on the diameter of particles*

The properties of the dispersion obtained by ultrasonic treatment in the optimal mode were affected by the concentration of fats: saturation of the dispersion was reached already at 5 g/l of fat, and when the concentration increased above 30 g/l, a decrease in optical density was observed. The latter may be due to the increased intensity of coagulation of microparticles that are formed at high concentrations of the dispersible substance. Optimization of the raw material pretreatment process in terms of all three parameters was carried out based on the results of *Y. lipolytica* yeast growth on it. According to the data in the table. 5, the mode of ultrasonic treatment of the medium containing 20-30 g/l of substrate at an initial temperature of 22-24°C for 7 minutes was optimal, during which the yield of biomass increased by 45%. In addition, an additional positive effect of ultrasonic pretreatment of raw materials was revealed. During the cultivation of yeast on untreated fat-containing nutrient media in a laboratory fermenter, the substrate was unevenly distributed in the volume of the fermenter, stuck to the mixer blade and the lid of the apparatus. After ultrasonic treatment of the nutrient medium, these deficiencies were not found: the fat was in the culture liquid in the form of a dispersion and did not form dense deposits on the surfaces of the fermenter. As a result of preliminary processing of raw materials, the specific growth rate increased (from 0.18 to 0.20 h^{-1}) and biomass accumulation (up to 19.8-28.5 g/l), which is significantly higher than previously achieved results. Therefore, ultrasonic pre-treatment of the fatty nutrient medium is a necessary technological stage of the fat bioconversion process.

Table 5. *Biomass accumulation of Y. lipolytica at different initial concentrations of fat waste and modes of pretreatment of the nutrient medium*

Initial substrate concentration, g/l	Preliminary treatment of the substrate ultrasound		Maximum accumulation of biomass, g/l	Biomass output, g/g
	duration, min	initial temperature, °C		
10	absent		8.14	0.81
10	7	22-24	12.56	1.26
20	absent		13.8	0.69
20	7	22-24	19.8	0.99
30	absent		19.28	0.64
30	7	22-24	28.50	0.95
50	absent		22.71	0.45
50	7	22-24	32.23	0.64
10	6	22-24	9.85	0.99
10	8	22-24	12.57	1.26
10	7	13-15	10.05	1.01
10	7	34-36	12.55	1.26

Study of the influence of cultivation regimes on the efficiency of the process of biodestruction of the fat-containing phase of effluents and the quality of biomass. Cultivation regimes were tested in a laboratory fermenter (volume 5 l, 70% filling).

Since the tasks of the research included not only the selection of conditions optimal for the biodegradation of fat-containing effluents, but also the further use of the obtained biomass as a feed additive, it was necessary to conduct a comparative analysis not only of the process characteristics, but also of the quality of the obtained biomass. Several modes of cultivation were tested (Table 6). The obtained results allow us to conclude that for the biodestruction of fatty effluents, it is advisable to use both top-up and continuous methods of cultivation, which do not lead to significant changes in the quality of the obtained biomass.

Table 6. *Characteristics of the process of bioconversion of the fat-containing phase of sewage (20 g/l) by yeast Y. lipolytica under different modes of cultivation*

Characteristic	Modes of cultivation				
	periodic deep	deep with feeding on the substrate	Solid-phase	deep selection and filling	nonstop
Specific growth rate, h^{-1}	0.26	0.14	0.01	0.24*	0.24**
Maximum accumulation of biomass, g/l	24.2	86.9	0.0028	16.5	16.5
Biomass composition, %					
white	43.5	35.7	less 1	42.7	41.4
total fat	6.7	18.3	93.6	7.2	7.9

Notes: ** – rate of sampling of culture fluid every hour; ** – flow rate of culture liquid*

Concentration and drying of biomass

Biomass concentration is one of the most expensive stages of feed protein production technology. We conducted a study of the effectiveness of a number of options for separating biomass from the culture liquid during yeast cultivation *Y. lipolytica* on fatty sewage waste. Such methods of biomass concentration as sedimentation, separation, filtration through fabric filters and flotation have been studied.

The conducted studies showed that a satisfactory degree of concentration is achieved when using sedimentation, which is the cheapest method of biomass separation, as a result of which after three hours the concentration of dry substances in the sediment is 15.8% by mass. At the same time, the decantate contains no more than 2 g/l of ASB, which allows it to be used in the amount of 70-80% in the recycling of culture liquid. It should be noted that the biomass concentrate obtained in this way can be sent for drying without using additional methods of biomass concentration. It is most appropriate to use a belt dryer.

Technological scheme of bioconversion of the fat-containing phase of effluents of fish processing enterprises into yeast biomass for feed purposes. On the basis of the conducted research, we developed a basic technological scheme for the bioconversion of the fat-containing phase of effluents from fish processing enterprises into yeast biomass for feed purposes. The technological scheme provides for:

- use of microorganisms adapted to the substrate;
- preliminary treatment of the nutrient medium with ultrasound to disperse fat;
- fermentation stage in continuous or selective-topping-up mode;
- concentration of biomass by settling and drying.

The developed technology involves the selection of *Y. lipolytica* yeast culture with respect to the substrate (fatty effluents of fish processing) in the laboratory and subsequent cultivation in inoculators of various volumes. With a cell titer of at least 400 million/ml, the finished seed culture is transferred to the main apparatus with sterile air.

The main process is carried out in three parallel devices, the volume of which is determined by the amount of waste. At the same time, the pH is maintained in the range of 5.0-5.5 by adding ammonia water (23-26%) through a meter-doser. The temperature in the fermenter is maintained at the level of 30°C by changing the flow rate of water supplied to the coils and the jacket.

Air for aeration of the seed fermenter is supplied by separate lines from the main blower through air intakes. The air is cleaned of dust on a coarse filter and compressed. Air enters the main sterilizing filter.

To prepare the nutrient medium, all the necessary components of mineral nutrition are supplied from the dispensers. A solution of nutrient salts and fat waste is prepared in temperature-controlled mixers and pumped through a recuperator heat exchanger into the sterilization unit, where it is sterilized. After that, the nutrient medium passes through a heat exchanger-recuperator and a refrigerator, where it is cooled to a temperature of 35°C, passes through an ultrasonic unit and is fed into the fermenter.

The yeast suspension enters the settling tank. The supernatant is fed into a container for clarified culture liquid (OKR), from where it is pumped by a pump into a container for recyclinga.

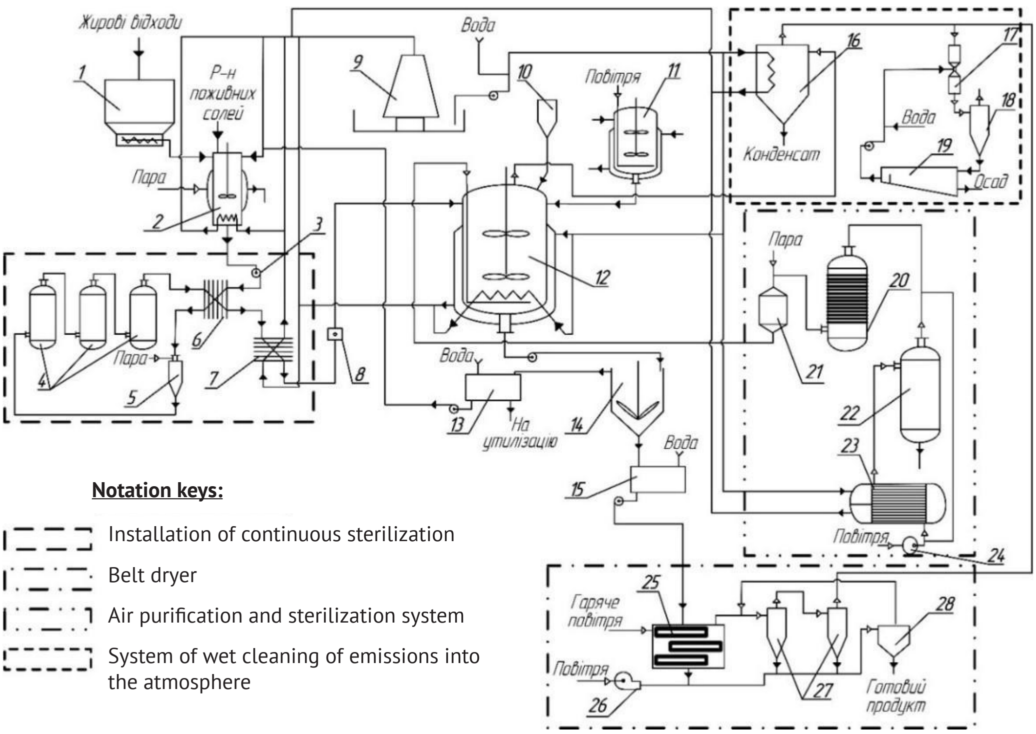

Figure 4. *Basic technological scheme of bioconversion of the fat-containing phase of fish processing effluents into yeast biomass for fodder use: 1 – the container for the fat-containing phase of waste is open; 2 – mixer; 3 – centrifugal pump; 4 – holders; 5 – heater-sterilizer; 6 – heat exchanger-recuperator; 7 – heat exchanger-cooler; 8 – ultrasonic disperser; 9 – cooling tower; 10 – meter-dispenser of ammonia water; 11 – inoculator; 12 – fermenter; 13 – an intermediate container for clarifying the culture liquid; 14 – sedimentation tank of continuous action; 15 – intermediate container for paste; 16 – heat exchanger; 17 – Venturi scrubber; 18 – cyclone; 19 – sump; 20 – coarse cleaning air filter; 21 – fine air filter; 22 – receiver; 23 – heat exchanger; 24 – compressor; 25 – belt dryer; 26 – blower; 27 – dryer cyclone; 28 – storage capacity.*

The paste obtained in the settling process, with a content of 15.8% ASB, is sent to a belt dryer, where it is dried to a moisture content of 9-10%. Part of the yeast from the conical part of the dryer is fed by pneumatic transport through a pipe into the cyclone, where it is separated from the spent coolant, which enters the wet scrubber.

The resulting dried material enters the screw mixer, and from there into the automatic weighing dispenser, where it is packed in kraft bags, which are sent to the warehouse of finished products. A graphic representation of the technological scheme is presented in Figure 4.

CONCLUSIONS

1. The main chemical and microbiological indicators of the fat-containing phase of the effluents of fish processing enterprises were determined.It was established that in the process of holding waste in a sludge collector (1-13 days) as a result of the vital activity of autochthonous microorganisms, the fat content decreases from 87 to 58%.

2. It was established that the dominant organism of the autochthonous microflora of the waste is *Geotrichum sp*. It has been established that *Yarrowia lipolytica* yeast is the most promising fat biodestructor.

3. A method of pretreatment of the fat-containing solid phase - ultrasonic - has been developed dispersion, as a result, the bioavailability of the substrate increases, the specific growth rate and the yield of microbial biomass increase by 11 and 30%, respectively.

4. Methods of seed preparation have been developed, which allow to increase the efficiency of the main process according to indicators: biomass yield by 10.1%); specific growth rate (from 0.20 to 0.26 h^{-1}); protein content (by 16.7%). The methods include the selection (5-7 passages) of high-performance clones, which is carried out in the directions of increasing affinity to the substrate.

5. It was established that for the biodestruction of fatty effluents, it is expedient to use both top-up and continuous methods of cultivation, which do not lead to significant changes in the quality of the obtained biomass.

6. Based on the results of complex step-by-step studies of the bioconversion by *Y. lipolytica* yeast of the fat-containing solid phase of fatty effluents of fish processing enterprises into a protein feed additive, a technological scheme of continuous production was developed.

REFERENCES:

[1] Bal-Prylypko, L.V., Starkova, E.R., Lebskyi, S.O., & Androschuk, O.S. (2018). A*ctual problems of the fish processing industry.* Kyiv: Comprint.

[2] Shahidi F., & Botta J.R. (1994). *Seafood processing by-products. Seafoods chemistry, processing, technology and quality*. Glasgow: Blackie Academic and Professional.

[3] Ioannis, S. (2008). Arvanitoyannis, Aikaterini Kassaveti Fish industry waste: treatments, environmental impacts, current and potential uses. *International Journal of Food Science and Technology*, 43, 726-745.

[4] Dudenko, N.V., Panikarova B.O., & Gorban V.G. (2015). Analysis of nutritional and biological value of fish processing waste. *Technological Audit and Production Reserves*, 6/7(26), 39-41. doi: 10.15587/2312-8372.2015.55765.

[5] Kovalchuk, V.A. (2010). Highly productive biooxidizers in wastewater treatment systems of meat and dairy enterprises. *Scientific Bulletin of Construction,* 60, 247-251.

[6] Kovalchuk, V.A. (2002). *Wastewater treatment*. Rivne: Rivne Printing House.

[7] Yaromsky, V. (2009). *Wastewater treatment of food and processing plants*. Minsk: BSU Publishing Center.

[8] Yulevych, O.I., Kovtun, S.I., Gil, M.I. (2012). *Biotechnology*. Mykolaiv: MSAU.

[9] Paska, M.Z. (2010). *Technology of animal fats*. Lviv: LKT LNUVM and BT named after S.Z. Gzytskoho.

[10] Ruggieri, L., Artola, A., Gea, T., & Sanchez, A. (2008). Biodegradation of animal fats in a co-composting process with wastewater sludge. *International Biodeterioration & Biodegradation,* 62(3), 298-303. doi: 10.1016/j.ibiod.2008.02.004.

[11] Avetisyan, Yu.I., Kopanytsia, Yu.D., & Argatenko, T.V. (2009). Optimal management of the flotation unit of the complex of waste water degreasing of the fat factory. *Problems of Water Supply and Hydraulics*, 12, 78-88.

[12] Sukhatskyi, Yu.V., & Znak, Z.O. (2019). Flotation as a stage of cavitation-flotation technology for the purification of aqueous heterogeneous media from dispersed solid particles and organic compounds. *Chemistry, Technology of Substances and Their Application*, 2(1), 53-58.

[13] Kempers, P. (2009). Lipid biotechnology: Industrially relevant production processes. *European journal of Science and technology*, 111(7), 627-645 doi: 10.1002/ejlt.200900057.

[14] Kolyada, M.K., Plavan, V.P., Safranov, T.A., & Melnyk, K.S. (2016). Development of a method of utilization of collagen-containing waste from the fish processing industry. *Bulletin of KNUTD*, 2(96), 177-182.

[15] Shestopalov, O.V., Getta, O.S., & Rykusova, N.I. (2019). Modern methods of food industry wastewater treatment. *Environmental sciences,* 2(25), 20-27. doi: 10.32846/2306-9716-2019-2-25-4.

[16] Petrova, I.B., & Klymenko, A.I. (2012). Complex processing of waste from fish processing industries: review. *Young Scientist,* 9, 61-63.

[17] Lakhal, D., Bahlaouan, B., Boutaleb, N., Fathi, A., Taiek, T., Abouakil, N., & Lazar, S. (2018). Biotransformation of Ternary Mixture of Organic Industrial Waste into Poultry Feed. *Journal of Agricultural Science and Technology*, 8, 171-181. doi:10.17265/2161-6256/2018.03.005.

[18] Bilal, M., & Iqbal, H. (2019). Sustainable bioconversion of food waste into high-value products by immobilized enzymes to meet bio-economy challenges and opportunities. *Food Research International*, 123, 226-240. doi: 10.1016/j.foodres.2019.04.066.

[19] Rustad, T.O. (2003). Utilisation of marine by-products. *Electronic Journal of Environmental, Agricultural and Food Chemistry*, 2, 458-463.

[20] Kumar, A., Gudiukaite, R., Gricajeva, A., Sadauskas, M., Malunavicius, V., Kamyab, H., Sharma, S., Sharma, T., & Pant, D. (2020). Microbial lipolytic enzymes – promising energy-efficient biocatalysts in bioremediation. *Energy,* 192, 127-142. doi: 10.1016/j.energy.2019.116674.

[21] Meng, F., Wang, H., Zhang, G., Li, X., Zhang, Y., & Zou, Zh. (2018). One-step treatment and resource recovery of high-concentration non-toxic organic wastewater by photosynthetic bacteria. *Bioresource Technology*, 251, 121-127. doi: 10.1016/j.biortech.2017.12.002.

[22] Lu, H., Zhang, G., He, Sh., & Peng, Ch. (2020). Production of photosynthetic bacteria using organic wastewater in photobioreactors in lieu of a culture medium in fermenters: From lab to pilot scale. *Journal of Cleaner Production*, 259, 158-163. doi: 10.1016/j.jclepro.2020.120871.

[23] Cristian A.Sepulveda-Munoz, Daniel Puyol, Raul Munoz. A systematic optimization of piggery wastewater treatment with purple phototrophic bacteria. *Chemosphere*. 2020. Vol. 253. P. 134-145. DOI: https://doi.org/10.1016/j.chemosphere.2020.126621

[24] Zenevicz, M.-C.-P., Debora de Oliveira, A.-J., Agenor Furigo, Jr., Valerio, A., & Oliveira, J.V. (2017). A two- step enzymatic strategy to produce ethyl esters using frying oil as substrate. *Industrial Crops and Products*, 108, 52-55. doi: 10.1016/j.indcrop.2017.06.018.

[25] Vivek, P., & Sanvidhan, G. (2018). Effect of lipase from different source on high fat content wastewater of dairy industry. *Indian Journal of Biotechnology*, 17(2), 44-250.

[26] Chandra, P., Singh, R., & Arora, P.-K. (2020). Microbial lipases and their industrial applications: a comprehensive review. *Microb Cell Fact*, 2-42. doi: doi.org/10.1186/s12934-020-01428-8.

[27] Venugopal, V. (2016). Enzymes from Seafood Processing Waste and Their Applications in Seafood Processing. *Advances in Food and Nutrition Research*, 78, 47-69.

[28] Novik, G., Meerovskaya., & Savich, V. (2017). Waste Degradation and Utilization by Lactic Acid Bacteria: Use of Lactic Acid Bacteria in Production of Food Additives. *Bioenergy and Biogas*, 105-146. doi: 10.5772/intechopen.69284.

[29] Golub N.B., Shinkarchuk M.V., & Kozlovets O.A. (2018). Ways to increase biogas production during fermentation of fat-containing waste from leather production. *Bulletin of the Khmelnytskyi National University*, 2(259), 103-107.

[30] Gatsenko, K.V., & Voloshyn, M.D. (2019). Biogas production technology based on food waste. *Collection of Scientific Works of Dnipropetrovsk Technical University*, 1(34), 131-136. doi: 10.31319/2519-2884.34.2019.26.

[31] Pylypenko, O. (2017). Development of the food industry of Ukraine. *Scientific works of the NUHT*, 23(3), 15-25

[32] Oswal, N., Sarma, P.M., Zinjarde, S.S., & Pant, A. (2002). Palm oil mill effluent treatment by a tropical marine yeast. *Bioresource Technology*, 85, 35-37. doi: 10.1016/s0960-8524(02)00063-9.

[33] Chigusa, K., Hasegawa, T., Yamamota, N., & Watanabe, Y. (1996). Treatment of waste water from oil manufacture plant by yeasts. *Water Science and Technology*, 34, 51-58. doi: 10.1016/S0273-1223(96)00820-7.

[34] Zinjarde, S.S., Pant, A., & Deshpande M.V. (1998). Dimorphic transition in Yarrowia lipolytica isolated from oil-polluted seawater. *Mycological Research*, 10, 553-558. doi: 10.1017/S0953756297005418.

[35] De Felice, B., Pontecorvo, G., & Carfagna, M. (1997). Degradation of waste waters from olive oil mills by *Yarrowia lipolytica* ATCC 20255 and *Pseudomonas putida*. *Acta Biotechnologica*, 17, 231-239. doi: https://doi.org/10.1002/abio.370170306.

[36] Scioli, D., & De Felice, B. (1993). Impiego di ceppi di lievito nella depurazione dei reflu dell’industria olearia. *Ann. Microbiol. Enzimol*, 43, 61-69.

[37] Scioli, C., & Vollaro, L. (1997). The use of Yarrowia lipolytica to reduce pollution in olive mill wastewaters. *Water Resources*, 31(10), 2520-2524. doi: 10.1016/S0043-1354(97)00083-3
[38] Ivankin, A.N., & Ilyukhina, R.V. (2001). On biotechnological processing of low-value animal fats. *Meat Industry,* 5, 46-47.
[39] Gradova, N.B. (2001). *Laboratory workshop on general microbiology*. Moscow: DeLi print.
[40] Polygalina, G.V., Cherednychenko, V.S., & Rymareva, L.V. (2003). *Determining the activity of enzymes: reference book*. Moscow: DeLi print.
[41] Hakopyan, B.V., & Ershov, Yu.A. (2005). *Basics of interaction of ultrasound with biological objects: Ultrasound in medicine, veterinary medicine and experimental biology: textbook. manual*. Moscow: Publishing House of the Moscow State Technical University named after N.E. Bauman.
[42] Valytov, R.B., Kursochkin, A.K., & Badykov, Yu.V. (1985). Rational technology of preparation of working fluids. *Protection of Plants*, 3, 30-31.

Біоконверсія жировмісної фази стоків рибопереробних підприємств у кормову добавку

М. М. Мадані
Кандидат технічних наук, доцент
https://orcid.org/0000-0001-9386-7364

Р. І. Шевченко
Кандидат технічних наук, доцент
https://orcid.org/0000-0002-7924-1987

О. Л. Гаркович
Кандидат технічних наук, доцент
https://orcid.org/0000-0002-7622-521X

Одеська національна академія харчових технологій

Анотація. Запропоновано технологію утилізації жировмісної фази стоків рибопереробки на основі комбінування фізико-хімічного впливу і біологічного окиснення. Установлено, що найбільш перспективним біодеструктором жирів є дріжджі *Yarrowia lipolytica*, селекціоновані щодо субстрату. Розроблено принципову технологічну схему біоконверсії жировмісної фази стоків рибопереробних підприємств в дріжджову біомасу кормового призначення

Ключові слова: технічна екологія, технології захисту, поводження з відходами, нормування навантаження на довкілля, кормова добавка

UDC 595.772; 631.95
DOI: 10.31521/2313-092X/2021-3(111)-8

Ukrainian Black Sea Region Agrarian Science
Vol. 25, No. 3

Processing of plant waste by black lionfly larvae (*Hermetia illucens* L.)

E. Molchanova*
Head of the Research Department of Industrial Entomology
https://orcid.org/0000-0003-1049-7236

T. Markina
Full Doctor in Biological Sciences, Professor, Researcher
https://orcid.org/0000-0002-6313-9814

V. Barkar
Head of the Research Sector of Entomophages of Open Soil
https://orcid.org/0000-0002-0965-9755

E. Tribuntsova
Junior Research Fellow
https://orcid.org/0000-0001-5847-9008

Engineering and Technology Institute "Biotechnics" of the National Academy of Sciences of Ukraine

Abstract. The issue of waste disposal of plant origin is a problem, the solution of which is currently an urgent task. The issue and problematic of excessive accumulation of waste is recognized by the vast majority of highly developed countries of the world. In order to overcome this problem, disposal mechanisms are permanently improved, procedures for their processing and biological cleaning and incineration technologies are introduced. A significant reason for the collection of a large amount of waste as a result of agricultural activity is the organization of their disposal at an insufficient level. As one of the options for solving this ecological situation can be the processing of organic waste with the help of larvae of the Black Lionfly (Hermetia illucens Linnaeus, 1758) (Diptera: Stratiomyidae). Thus, the purpose of this article is to study the processing of various agricultural wastes of plant origin using Black Lionfly larvae and to clarify the structure and sequence of technological processes of a biological-technological enterprise. The breeding process of the Black Lionfly on plant waste was studied, and the biological and technological parameters of the obtained biomaterial were determined. It has been proven that the Black Lion fly is highly effective for processing waste from agricultural production of plant origin. It has been proven that obtaining a highly viable culture of insects is possible under the conditions of feeding the larvae with wheat bran, cake, a mixture of watermelon + cantaloupe, non-standard zucchini, a mixture of potato + carrot + cabbage, non-standard; substandard bread cereals. The structure of a waste processing enterprise is proposed, which includes four stages: obtaining 1st instar larvae for waste processing; preparation of waste for processing by larvae; waste processing; final (receiving humus and larvae)

Keywords: biotechnology, black lioness, processing, plant waste

Article's History:
Received: 8.02.2021
Revised: 1.06.2021
Accepted: 26.08.2021

Suggested Citation:
Molchanova, E., Markina, T., Barkar, V., & Tribuntsova, E. (2021). Processing of plant waste by black lionfly larvae (*Hermetia illucens* L.). *Ukrainian Black Sea Region Agrarian Science*, 25(3), 66-74.

INTRODUCTION

Processing of plant waste is an issue, the solution of which is an urgent task today. The problem of waste accumulation is recognized by most of the developed countries of the world. To overcome it, disposal methods are constantly being improved, procedures for their processing and biological cleaning and incineration technologies are being introduced. The main reason for the accumulation of a large amount of waste as a result of agricultural activity is the unsatisfactory organization of their disposal. The solution to this ecological problem can be the processing of organic waste with the help of larvae of the black lionfly (Hermetia illucens Linnaeus, 1758) (Diptera: Stratiomyidae). The purpose of this work is to study the processing of various agricultural wastes of plant origin with the help of black lionfly larvae and to substantiate the structure and sequence of technological processes of a biotechnological enterprise.

The accumulation of agricultural production waste leads to the deterioration of the ecological conditions of human existence and disrupts the homeostatic properties of ecosystems. It should be noted that due to global warming and the accumulation of greenhouse gases, incineration, as a traditional method of waste disposal, is considered a harmful process and is significantly limited in many countries. This encourages more and more attention to be paid to the possibility of using biological methods of waste processing.

In the post-Soviet space, a large amount of unused waste remains in the agro-industrial complex. A significant amount of waste goes to the landfill due to the lack of a modern technological base for processing secondary raw materials at most enterprises [1]. The problem of waste from the agro-industrial complex, which is not used, is characteristic of many countries [2]. The modern practice of handling plant waste involves either storing it in open areas or burning the harvest residues in the fields. Thus, significant losses of unused nutrients contained in waste occur every year [3].

In economically developed countries, considerable attention is paid to the processing of agro-industrial waste. For example, countries such as Germany, Japan, and Great Britain import secondary agricultural raw materials for further processing. The reason for this is the obsolescence of equipment in other countries and the lack of investment, despite the fact that the products of the processing of these wastes are exported from Germany. The solution to this problem can be the processing of organic waste with the help of larvae of the black lionfly (*H. illucens* L.) with the subsequent use of the larvae as a complete protein feed for animals, and the processed substrate as a fertilizer for crop production [4-10].

These insects belong to the few species of invertebrates capable of developing around the clock in a pure culture in a closed space under artificially created conditions of industrial production. Features of the development of insects allow their use for biotechnological purposes, which is one of the main advantages of this species [11].

H. Illucens thrives in a wide variety of decomposing waste, including rotting fruits and vegetables. The use of larvae of this species for the processing of organic waste is proposed by many authors as a promising and effective technology [12-16]. It is noted that the technology of removing organic residues using *H. illucens* is more effective than traditional composting technologies, and is based on the ability of fly larvae to destroy large masses of various organic wastes in the shortest possible time. Eating waste, *H. illucens* larvae reduce their weight by two or three times in a few days. The ecological benefit from the use of entomological technologies for processing food waste is unquestionable. Their implementation in the processing of food (and not only) waste will make it possible to significantly reduce storage and huge deposits of unprocessed raw materials.

Examples of companies in the world that already use *H. illusens* are Hermetia Baruth GmbH (Germany), Agri Protein Technologies (South Africa) and Corporation Enterra Feed (Canada) [17]. The Environmental Technology and Engineering Corporation (Environmental Technology and Engineering Corporation) has invented a biotransformer of *H. illucens* larvae for home use. In 2007, the Institute of Entomology of Guangdong Province (China) developed a bioconversion system for effective large-scale processing of organic waste. The system has achieved satisfactory reduction, disinfection and recycling of waste [18]. In Southern Italy, there is an experimental facility where processing 10 tons of household waste allows you to get 300 kg of dried larvae and 3346 kg of compost. The productivity of the enterprise can reach 30 tons of waste per day [19]. There are currently no similar productions in Ukraine, which prompts us to conduct research and develop technological schemes for enterprises processing agricultural waste using fly larvae of the above species.

The aim of the work is to establish the possibility of processing plant-derived waste from the food industry and agricultural production by larvae of the *H. illucens* fly. Determine the technological parameters of waste processing, the structure of the enterprise and the sequence of processing processes and operations.

MATERIALS AND METHODS

An artificial population of *H. illucens,* which is maintained at the Center for Insect Maternal Cultures of the ITI "Biotechnique" of the National Academy of Sciences of Ukraine, was used for the research. During the life cycle, the fly goes through four stages: egg, larva, pupa and imago [20]. Fly larvae are pale yellow in color (Fig. 1).

Figure 1. *Larvae of H. illucens of the 3rd instar. Source: Photo by O.D. Molchanova*

Larvae usually grow to 18-20 mm [21]. It is noted that in the last age group they can reach a size of 27 mm [19]. Pre-pupae change their color from whitish-yellow to dark brown [22; 23]. Adult individuals of *H. illucens* reach sizes from 15 to 20 mm. Having a fat body formed at the larval stage, imagos have no need for food, therefore the licking oral apparatus is weakly expressed (Fig. 2) and suitable only for water consumption. There are no digestive organs, which makes it impossible to eat food directly.

Figure 2. *Imago H. illucens*

Source: *Photo by O.D. Molchanova*

Experiments were conducted in an insect box under hygrothermal conditions optimal for the species – air temperature +25-27°C, relative humidity 55-65% according to standard methods of working with insects [24-26]. There are three repetitions in each version.

The experiment was carried out with different variants of the nutrient substrate for growing larvae:

1. Control of the growth of larvae on wheat bran.
2. Growing larvae on potato pulp.
3. Growing larvae on oil production waste (cake).
4. Cultivation of larvae on mushroom production waste.
5. Cultivation of larvae on grape pomace.
6. Growing larvae on sugar beet pulp.
7. Growing larvae on apple pulp.
8. Growing larvae on vegetable residues.
9. Larvae rearing on substandard mulberry fruits.
10. Larvae rearing on substandard plum fruits.
11. Cultivation of larvae on substandard grapes.
12. Rearing of larvae on fallen corn cobs.
13. Growing larvae on dry corn stalks.
14. Rearing larvae on a mixture of watermelon and cantaloupe.
15. Growing larvae on substandard zucchini.
16. Rearing larvae on a mixture of potatoes, carrots, and substandard cabbage.
17. Growing larvae on potato tops.
18. Growing larvae on cucumber tops.
19. Cultivation of larvae on substandard bread cereals.

20. Growing larvae on wheat straw.
21. Growing larvae on barley straw.
22. Larvae rearing on sunflower stems, leaves, baskets.

It is known that the ovipositors of flies are open, the eggs are soft, attached to the substrate and glued together by the secretions of the gonads, it is difficult to extract individual eggs without damage, therefore, the selection of material for experiments was carried out at the larval stage of the first instar.

Larvae usually grow to 18-20 mm [21]. It is noted that in the last age group they can reach a size of 27 mm [19]. Pre-pupae change their color from whitish-yellow to dark brown [22, 23].

Adult individuals of *H. illucens* reach sizes from 15 to 20 mm. Having a fat body formed at the larval stage, imagos have no need for food, therefore the licking oral apparatus is weakly expressed (Fig. 2) and suitable only for water consumption. There are no digestive organs, which makes it impossible to eat food directly.

Different types of plant waste were placed in cages measuring 127×95×100 mm with 200 g of waste in each variant. The food substrate had a soft, moist consistency. For this, a small amount of water was added to the waste as needed and thoroughly mixed. 500 larvae were added to each garden with medium.

When the larvae ate the substrate, new feed was added, which was pre-weighed. The feeding time was determined visually by the appearance of the environment, or by the state of the larvae, which climbed to the surface of the substrate in search of food.

During the experiment, the following indicators were determined: average weight of larvae of one age group (mg); average weight of pupae (mg); viability of larvae (%); duration of development from the egg stage to the prepupa stage (days).

The average weight of larvae in all variants of the experiment was determined as the arithmetic mean of the weight of 30 individuals weighed in triplicate.

To collect prepupae, cages with larvae were placed in trays measuring 150×130×50 mm. 30 prepupae were selected and the average weight was determined. During the research, the period of transformation of larvae into pre-pupae was fixed, and the number of pre-pupae obtained was counted. The viability of larvae was determined as the ratio of the number of prepupae to the number of larvae introduced into the substrate, expressed as a percentage.

RESULTS AND DISCUSSION

The process of growing flies on twenty-two types of vegetable waste was studied, using wheat bran as a control.

It was established that on mushroom waste, sugar beet pulp, corn straw (wheat and barley) fly development practically did not occur, only single specimens of first-instar larvae were recorded (Table 1). Also, rather low indicators of viability were observed when growing larvae on potato and cucumber tops – 21 and 23%, respectively, dry corn stalks – 28% and collapsed corn cobs – 35%. Significantly high ($p<0.001$) viability was observed in the options of feeding with wheat bran 96%, cake 84%, watermelon + melon mixture non-standard 95%, zucchini non-standard 92%, potato + carrot + cabbage mixture non-standard 91%; non-standard bread cereals 84%. In other variants, the viability ranged from 50 to 80%.

Significantly higher ($p<0.01$) in relation to other options was noted the average weight of larvae and pupae when grown on bran media; vegetable trimmings and peelings; mixtures of watermelon + cantaloupe; potatoes + carrots + cabbage substandard; substandard bread cereals; sunflower stems, leaves and baskets (Table 1)

Table 1. *Biological indicators of H. illucens when grown on plant waste*

The composition of the nutrient substrate	Average weight, mg		Larvae viability, %	Duration of development, up to the pre-pupa stage±2
	Older larvae	Larva		
Bran (control)	270±1.5**	160±0.14	96±3.8*	30
Potato mash	170±1.3	110±0.11	71±1.8	51
Makuha	175±1.2	150±0.12	84±3.0*	38
Mushroom waste	-	-	-	-
Grape pulp	90±3.2	65±0.11	78±2.1	37
Sugar beet pulp	-	-	-	-
Apple jam	130±2.1	93±0.12	58±1.1	44
Vegetable trimming and cleaning	230±2.4**	210±0.52	76±2.0	41
Mulberry fruits (non-standard)	100±1.2	60±0.14	49±1.4	54

Table 1, Continued

The composition of the nutrient substrate	Average weight, mg		Larvae viability, %	Duration of development, up to the pre-pupa stage±2
	Older larvae	Larva		
Plum fruits (non-standard)	110±1.5	70±0.12	83±2.7	71
Grapes (unconditioned)	120±2.3	70±0.11	71±1.7	47
Corn cobs (collapsed)	100±1.1	63±0.13	35±1.2	-
Corn stalks (dry)	60±2.1	40±0.11	28±1.0	53
Watermelon + melon (unconditioned)	210±5.2**	180±0.14	95±3.7*	-
Zucchini (unconditioned)	160±1.4	90±0.12	92±3.4*	60
Potatoes + carrots + cabbage (non-standard)	150±2.3**	100±0.12	91±3.0*	55
Potato tops	90±1.7	60±0.11	21±0.6	-
Top of cucumbers	50±1.6	290±0.17	23±0.7	-
Bread cereals (non-standard)	300±1.9**	220±0.15	84±2.8*	35
Wheat straw	50±1.7	30±0.15	-	-
Barley straw	-	-	-	-
Stems, leaves, sunflower heads	120±1.2**	110±0.11	7±0.2	-

Note: **p<0.001 in relation to variants with low viability; **p<0.01 in relation to other options*

Based on the results of research, it was established that the term of development of the black lionfly on agricultural waste of plant origin of different types is different. In control, when cultivated on wheat bran, it lasted 30 days. At the same time, it was more than 5 days on non-standard bread cereals. A relatively short period of development was observed when using grape pulp and cake – 37 and 38 days, respectively. The longest period was observed when grown on substandard fruit (plum) – 71 days. Establishing the causes of this phenomenon requires further research. It can definitely be stated that the different nutritional value of the substrate determines the differences in the biological indicators of the insect culture.

We have established the effectiveness of using the black lionfly for the processing of various types of agricultural waste of plant origin, but it is necessary to take into account the different duration of the processing process for each type of waste. Such technology can be used in the creation of enterprises for the processing of vegetable waste in Ukraine.

The analysis of the situation in the world showed that the commercial products of the waste processing enterprise, depending on the demand, can be: larvae; fly pupae; biohumus The enterprise must be equipped with special equipment for crushing and processing of waste, qualified personnel, have a convenient infrastructure for transporting waste and delivering the products of their processing to consumers. We proposed the structure of such an enterprise (Fig. 3).

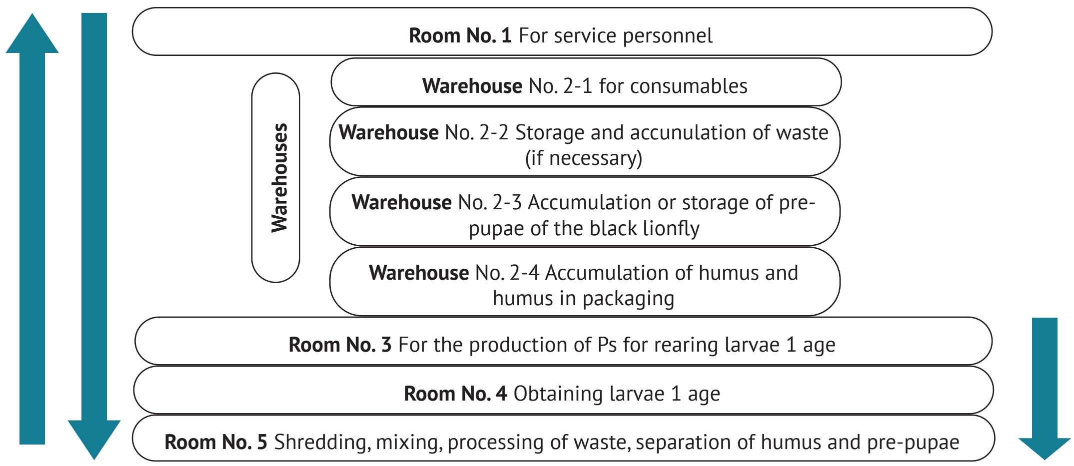

Figure 3. *Structure of a waste processing enterprise*

When organizing waste processing, it is necessary to have five main rooms and storage rooms for consumables, storage and accumulation of waste (if necessary), accumulation or storage of pre-pupae, accumulation and packaging of humus. The main premises are used for service personnel; production of nutrient medium for growing larvae of the first age; obtaining larvae of the first age; grinding, mixing, waste processing, separation of humus and pre-pupae; product formation, marking. In the process of processing waste, it is necessary to create optimal hydro-thermal conditions for keeping larvae, which will contribute to a faster process of their transformation into useful products that can be used later. The technological parameters of the waste processing process using black lionfish larvae are shown in the table (Table 2).

Table 2. *Technological parameters of the waste processing process using H larvae.illucens*

Technological process	Food substrate	Air temperature in the insect holding area, °C	Relative air humidity in the holding area, %	Air aeration in the holding area	Lighting in the holding area
Incubation of eggs, obtaining larvae of the first age	Wheat bran + boiling water Additional hydration	25-26	60	According to the order of the MHU No. 254A dated 20/09/1997, 0.2-0.7 m/s	Not obligatory
Waste processing (larvae rearing)	Waste of vegetable origin or their mixtures Additional hydration	22-24	65	According to the order of the MHU No. 254A dated 20/09/1997, 0.2-0.7 m/s	Not obligatory
Removal of prepupae from the substrate	-	22-24	65	According to the order of the MHU No. 254A dated 20/09/1997, 0.2-0.7 m/s	Not obligatory
Preparation of the substrate for packaging	-	-	45-60	According to the order of the MHU No. 254A dated 20/09/1997, 0.2-0.7 m/s	-

The technological process of waste processing can be divided into four stages: obtaining larvae of the first age for waste processing; preparation of waste for processing by larvae; waste processing; obtaining humus and larvae (Fig. 4).

Obtaining larvae of the first age. At this stage, the following operations are carried out: production of nutrient medium for growing larvae of the first age; placement of eggs in the device for incubation; incubation of eggs; settlement of the nutrient medium by larvae that have just hatched from the eggs.

After two or three days, larvae hatch from the eggs, and they are settled in the PS. After seventy days, the young larvae are ready for settlement in the tank for processing waste.

Preparation of waste for processing. After the waste is delivered to the enterprise, it is sorted. Solid and large fractions of waste are crushed with the help of a feed grinder. The fodder shredder is positioned so that the crushed waste enters the hopper of the screw conveyor. The screw conveyor is designed to move shredded waste into tanks for processing.

Waste processing. The tank for processing waste has dimensions of 2.0×3.0×0.3 m and is placed on a bed, its internal volume is 1.8 m^3, the working volume in which the substrate with larvae is located is 0.9 m^3. In a tank with waste or a mixture of waste, add a food substrate with larvae of the 1st instar black lionfish. The required quantity is determined according to the mass of waste being processed and its composition.

In the process of feeding the larvae, the surface of the tank with the nutrient medium and the growing larvae is covered with shutters of the roller type to create darkness and preserve humidity. The processing plant must be equipped with a sprinkler system and a water tank.

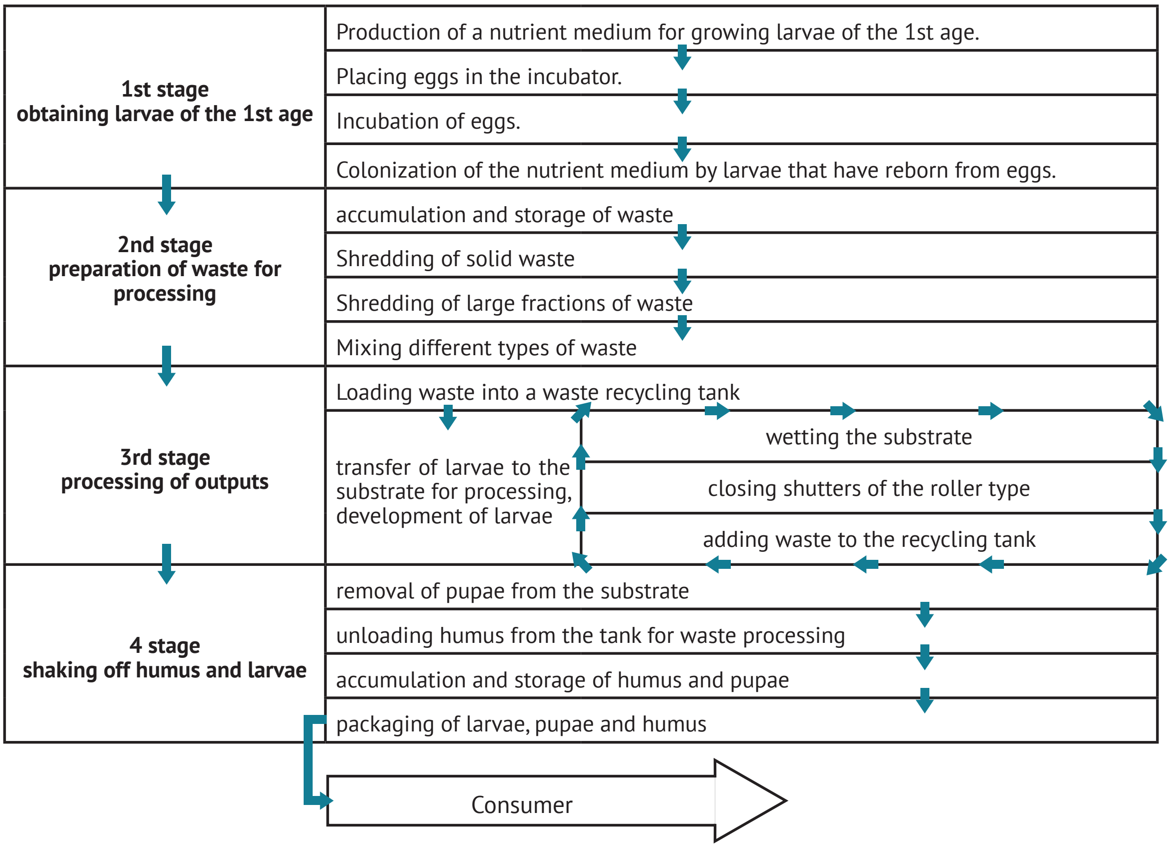

Figure 4. *Scheme of waste processing using H. illucens larvae*

Obtaining humus and pre-pupae

The fourth stage is final. After the end of processing, which lasts 30-55 days depending on the composition of the waste and the conditions of keeping, the pupae are removed from the substrate. The processed substrate is dried and packed. Larvae and pupae, depending on demand, are sold alive or dried and processed into flour.

CONCLUSIONS

1. The effectiveness of the use of the black lionfish fly for the processing of various agricultural wastes of plant origin has been proven.

2. Significantly higher ($p<0.01$) indicators of the average weight of larvae and pupae when grown on bran media were noted compared to other options; vegetable trimmings and peelings; mixtures of watermelon + cantaloupe; mixtures of potatoes + carrots + cabbage are not conditioned; substandard bread cereals; sunflower stems, leaves and baskets.

3. The influence of the nutrient substrate on the duration of larval development was established. Feeding on wheat bran lasted 30 days, on unconditioned bread cereals for 5 days longer. A relatively short period of development was observed when using grape pulp and cake – 37 and 38 days, respectively. The longest development period was recorded when the larvae were grown on substandard fruit (plum) – 71 days. The need to take into account the dependence of larval development rates on the type of nutrient medium is shown.

4. The scheme of the waste processing enterprise was developed, which includes four stages: obtaining larvae of the first age for waste processing; preparation of waste for processing by larvae; waste processing; obtaining humus and larvae.

5. By-products of waste processing are fly larvae and pupae and biohumus.

REFERENCES:

[1] Ovchinnikova, N.V., Aleksandrova, A.V., Shcherbakov, V.G., & Aleshin, V.N. (2011). Analytical, technological and regional aspects of the rational turnover of secondary material resources. *Vector science of TSU*, 4(18), 34-37.

[2] Soroka, A.V., Terletskaya, N.F., Gaponyuk, A.N., & Antonyuk, A.S. (2018). Estimation of waste composition of grain processing enterprises. *Journal of the Belarusian State University. Ecology*, 2, 124-128.

[3] Bynkovskaya, A.V., & Shanina, T.P. (2013). Assessment of crop production waste management in the Odesa region. *International Journal of Experimental Education*, 11, 186-187.

[4] Krutyakova, V.I., Markina T.Yu., Molchanova O.D., & Olshevska L.V. (2020). Cultivation of the black lionfly on plant waste: In the *International Seminar (online) on the occasion of the International Year of Plant Health. "Prospects for the development of regional production and the use of biological means of protecting plants from pests and diseases" (*pp. 111-113). Odesa: Engineering and Technological Institute "Biotechnics" of the National Academy of Agrarian Sciences of Ukraine.

[5] Markina, T.Yu., & Shalamova, I.S. (2018). Ecological features and methods of breeding Hermetia illucens Linnaeus, 1758 (Diptera: Stratiomyidae) in artificial conditions: In *The 9th Congress of the Ukrainian Entomological Society* (pp. 75-76). Kharkiv: Engineering and Technological Institute "Biotechnology" NAAS of Ukraine

[6] Markina, T.Yu., Shalamova, I.S., & Molchanova, O.D. (2018). Prospects for the use of Hermetia illucens Linnaeus, 1758 (Diptera:Stratiomyidae) in the conditions of Ukraine. In *The International scientific and practical conference on the occasion of the 100th anniversary of the National Academy of Agrarian Sciences of Ukraine "Biological method of plant protection: achievements and prospects"* (pp. 224-230). Odesa: ITI "Biotechnics" of the National Academy of Sciences of Ukraine.

[7] Kozhuhar, R.S., & Olshevska, L.V. The black lionfly (Hermettia illicens L.) and its use. In *The International Scientific and Practical Conference "Environmental Safety and Balanced Nature Use in Agricultural Production"* (pp. 128-131). Kyiv: Institute of Agroecology and Nature Use of the National Academy of Agrarian Sciences of Ukraine.

[8] Alvarez, L. (2012*). The Role of Black Soldier Fly*, *Hermetia illucens* (L.) (Diptera: Stratiomyidae) in Sustainable Waste Management in Northern Climates. Electronic Theses and Dissertations.

[9] St-Hilliare, S. (2007). Fish offal recycling by the black soldier fly produces a foodstuff high in omega-3 fatty acids. *J. World Aquac. Soc,* 38(2), 309-313.

[10] Roháček, J., & Hora, M.A. (2013). Northernmost European record of the alien black soldier fly *Hermetia illucens* (Linnaeus, 1758) (Diptera: Stratiomyidae). Čas. *Slez. Muz. Opava* (A), 101-106.

[11] Ushakova, N.A., Nekrasov, R.V. (2015). Prospects for the use of insects and insects in the feeding of agricultural animals. Biotechnology: state and development prospects. In *The VIII Moscow International Congress. CJSC "Expo-biochemical-technologies"* (pp. 147-149). Moscow: RSTU named after D. I. Mendeleev.

[12] Diener, S., Solano, N.M.S., Gutiérrez, F.R., Zurbrügg, C., & Tockner, K. (2011). Biological treatment of municipal organic waste using black soldier fly larvae. *Waste Biomass*, 2, 357-363. doi: 10.1007/s12649-011-9079-1.

[13] Kroeckel, S., Harjes, A.G.E., Roth, I., Katz, H., Wuertz, S., Susenbeth, A., & Schulz, C. (2012). When a turbot catches a fly: Evaluation of a pre- pupae meal of the Black Soldier Fly (*Hermetia illucens*) as fish meal substitute – Growth per-formance and chitin degradation in juvenile turbot (Psetta maxima). *Aquaculture*, 345-352.

[14] Stamer, A., Wesselss, S., Neidigk, R., & Hoerstgen-Schwark, G. (2014). Black Soldier Fly (*Hermetia illucens*) larvae meal as an example for a new feed ingredients' class in aquaculture diets. In *The 4th ISOFAR Scientific Conference. "Building Organic Bridges"* (pp. 1043-1046). Istanbul: Organic World Congress.

[15] Meneguz, M., Schiavone, A., Dama, A., Lussiana, C., Renna, M., & Gasco, L. (2021). Effect of rearing substrate on growth performance, waste reduction efficien-cy and chemical composition of black soldier fly (*Hermetia illucens*) larvae. *Journal of the Science of Food and Agriculture*. 2021. doi: 10.1002/jsfa.9127.

[16] Vogel, H., Müller, A., Heckel, D.G., Gutzeit, H., & Vilcinskas, A. Nutritional immunology: Diversification and diet-dependent expression of antimi-crobial peptides in the black soldier fly *Hermetia illucens*. *Developmental and Comparative Immunology*, 78, 141-148.

[17] Müller, A., Wolf, D., Gutzeit, H.O. (2017). The black soldier fly, *Hermetia illucens* – a promising source for sustainable production of proteins, lipids and bioactive substances. *Zeitschrift für naturforschung*, 72(9-10), 351-363.

[18] Liu, C., Wang, C., & Yao, H. (2019). Comprehensive Resource Utilization of Waste Using the Black Soldier Fly (*Hermetia illucens* (L.) (Diptera: Stratiomyidae*). Animals*, 9(6). doi: 10.3390/ani9060349

[19] Salomone, R., Saija, G., Mondello, G., & Giannetto, A. (2016). Environmental impact of food waste bioconversion by insects: Application of Life Cycle Assessment to process using *Hermetia illucens*. *Journal of Cleaner Production xxx*, 1-16 doi: 10.1016/j.jclepro.2016.06.154.

[20] Paola, G., Anabel, M,S., & Santos, R. (2013). The effects of larval diet on adult life-history traits of the black soldier fly, *Hermetia illucens* (Diptera: Stratiomyidae), *Eur. J. Entomol*, 110(3), 461-468.

[21] Čičková, H., Newton, G.L., Lacy, R.C., Kozánek, M. (2015). The use of fly larvae for organic waste treatment. *Waste Management*, 35, 68-80.

[22] Fernanda, O., Klaus, D., Richard, L., & Joseph, R.O. (2015). Assessment of dip-tera: Stratiomyidae, genus *Hermetia illucens* (L., 1758) using electron microscopy. *Journal of Entomology and Zoology Studies*, 3(5), 147-152.

[23] Diclaro, I.I., Joseph, W, Phillip, E., Kaufman, D. (2010). Black soldier fly *Hermetia illucens* Linnaeus (Insecta: Diptera: Stratiomyidae). *Semantic Scholar*. Retrieved from https://www.semanticscholar.org/paper/Black-soldier-fly-*Hermetia-illucens*-Linnaeus-Diclaro-Kaufman/7a7c9114442e6172835606de4e9a2e2f9c816988.

[24] Markina, T.Yu., & Benkovskaya, G.V. (2015). Mechanisms of maintenance of homeostasis in laboratory populations of insects. *Ecology*, 4, 294-299. doi: 10.1134/S1067413615040128.

[25] Markina, T.Yu. (2016). New approaches to control the quality of crops during breeding. *Bulletin of Dnipropetrovsk University. Biology, Ecology*, 24(1), 164-172. doi: 10.15421/011620

[26] Markina, T.Yu. (2019). *Homeostatic properties of artificial populations of insects and methods of controlling their state: monograph*. Kharkov: Planeta-print.

Переробка відходів рослинного походження личинками мухи чорна львинка (*Hermetia illucens* L.)

О. Д. Молчанова

завідувач науково-дослідним відділом промислової ентомології
https://orcid.org/0000-0003-1049-7236

Т. Ю. Маркіна

Доктор біологічних наук, Професор, науковий співробітник
https://orcid.org/0000-0002-6313-9814

В. П. Баркар

завідувач науково-дослідним сектором ентомофагів відкритого ґрунту
https://orcid.org/0000-0002-0965-9755

О. Б. Трібунцова

молодший науковий співробітник
https://orcid.org/0000-0001-5847-9008

Інженерно-технологічний інститут «Біотехніка» НААН України

Анотація. Досліджено процес розведення мухи чорна львинка на відходах рослинного походження, визначено біологічні та технологічні показники отриманого біоматеріалу. Доведено, що отримання високожиттєздатної культури комах можливе за умов годування личинок пшеничними висівками, макухою, сумішшю кавун + диня некондиційні, кабачками некондиційними, сумішшю картопля + морква + капуста некондиційні; злаками хлібними некондиційними. Запропоновано структуру підприємства з переробки відходів, що включає чотири етапи: отримання личинок 1-го віку для переробки відходів; підготовка відходів для переробки личинками; переробка відходів; завершальний (отримання гумусу та личинок)

Ключові слова: біотехнологія, чорна львинка, переробка, відходи рослинного походження

UDC 636.52/58:636.083:591.044:591.111
DOI: 10.31521/2313-092X/2021-3(111)-9

Ukrainian Black Sea Region Agrarian Science
Vol. 25, No. 3

The influence of the size of the grouping of chickens on the non-specific reactivity of their organism

Yu. Osadcha*

PhD in Agricultural Sciences, Associate Professor
https://orcid.org/0000-0003-4126-2456

National University of Life and Environmental Sciences of Ukraine

Abstract. Over the past decades, egg poultry farming has undergone a certain specificity, concentration and intensification, which contributed to radical changes in the main production processes, as well as to the use of high-tech cage equipment for keeping laying hens, which to one degree or another affects the condition of hens and the quality of edible eggs. Chicken health is an important part of normal functioning and high productivity of chickens. For the health of chickens, the normal and full functioning of the immune system is necessary, which is influenced by various technological factors, one of which is the size of the grouping of chickens in cages. The purpose of the article is to investigate the non-specific reactivity of chickens under the influence of the size of the grouping with the same density of laying hens in cages that are similar in design. Egg-laying hens of the industrial flock "Hy-Line W-36" were used as the object of research. Experiments with experimental animals were conducted in accordance with the rules of the European Convention on the Protection of Vertebrate Animals. Under the conditions of a modern complex for the production of edible eggs, 4 groups of chickens were formed, each of which was kept in a separate analogue poultry house. The non-specific reactivity of the hens' organism under the influence of the size of the grouping with the same density of laying hens in cages analogous to the construction was studied. It was found that with a decrease in the size of the grouping of chickens, there is a shift of the leukocyte formula to the left, a preference for non-specific protective cells, which occurs as a result of a functional increase in the proliferative activity of the bone marrow and is expressed in an increase in the number of heterophils and an increase in their activity in the macrophage-macrophage immune response system

Keywords: chickens, stress, immunohematological indices, nonspecific reactivity, endogenous intoxication

INTRODUCTION

Over the past decades, egg poultry farming has undergone specialization, concentration and intensification, which has led to significant changes in the main production processes, including the use of high-tech cage equipment for keeping laying hens, which in one way or another affects the welfare of chickens and the quality of edible eggs [1]. Health is an integral part of the well-being of chickens and a prerequisite for their high productivity. For good health, the full functioning of the immune system is important, which is affected by various technological stressors, one of which is the size of the grouping of chickens in cages.

The parameters of the size of the grouping of laying hens of an industrial flock in cages are not provided for by the current domestic regulations, and according to the recommendations of the cross developer, they should be at least 7 goals [2], although in practice they reach 100 goals, so they need to be clarified when using 12-tier cage batteries of classic constructions However, the influence of the size of the grouping of chickens on their body, under cage keeping with the same provision of space, was studied mainly on small groups of birds, up to 10 heads in size [3-5], or cages of different designs and manufacturers were

Article's History:
Received: 1.03.2021
Revised: 30.06.2021
Accepted: 26.08.2021

Suggested Citation:
Osadcha, Yu. (2021). The influence of the size of the grouping of chickens on the non-specific reactivity of their organism. *Ukrainian Black Sea Region Agrarian Science*, 25(3), 75-83.

used in the experiments, which makes it impossible to adequately comparison [6]. Thus, there is a need to study the influence of the size of the grouping on the body of chickens, with the same density of laying hens in cages that are similar in design.Non-specific reactions characteristic of all types of stress are mainly the reactivity of the hypothalamic-pituitary-adrenocortical system and autonomic functions, including cardiovascular and hematopoiesis [7; 8]. G. Selye defined stress as a non-specific reaction of the body that develops under the influence of various causal factors. All exogenous and endogenous factors that create increased demands on the body are called stressors [9]. Despite their diversity, the body responds to a stereotyped form of biochemical, functional and structural changes, adaptation to new conditions. G. Selye established that during the action of stressors, the body responds with non-specific defense reactions – the heartbeat accelerates, blood pressure rises, and the concentration of corticosteroids in the blood increases.

Activation of the adrenal cortex, as a center of stress reactions, is accompanied by numerous changes in blood composition. Many researchers [10-12] adopted these changes as criteria for assessing the stress state of birds, which make it possible to detect the stress effect of various factors on their body and to determine the intensity and duration of the stress state. When stress is detected by evaluating these criteria, which are based on the basis of an intense and constant reactive response, the ratio of heterophils and lymphocytes is most often used [13; 14]. Since it has been proven [15] that during the development of a stressful state, this indicator increases due to the increased proliferation of hematopoietic stem cells, increased production of heterophils, and due to the abortive release of immature heterophil cells from the bone marrow into the bloodstream and the migration of lymphocytes from it to the tissues. In addition, changes in the ratio of heterophils and lymphocytes correlate with the concentration of corticosterone in the blood of chickens and are proportional to the degree of exposure to stressors of various nature [16; 17].

The ratio of heterophils and lymphocytes is an integral immunohematological index, which in human medicine is known as the Krebs index [18]. In addition to it, humane medicine uses a whole panel of immunohematological indices that indirectly reflect the state of the immune system and the course of adaptation processes in the body [19; 20].Recently, a marker panel, which includes the index of leukocyte shift (ILS), the index of the ratio of heterophils and lymphocytes (IRHL or the Krebs index), the index of the ratio of leukocytes and IRL, lymphocyte-granulocyte index (LGI), general index (GI), index immunoreactivity (IIR), the index of the ratio of heterophils and monocytes (IRHM), the index of the ratio of lymphocytes and monocytes (IRLM), the leukocyte index (LI) and the index of the ratio of lymphocytes and eosinophils (IRLE) are also used in animal husbandry [21-23].

The size of the bird group puts pressure on the main structures of the brain, which correlates with the increased demands on birds that live in relatively large, complex and dynamic social organizations [24]. These requirements are mostly related to competition for food or access to other valuable resources. Variations in group size in natural populations are self-regulating, but in the conditions of industrial chicken keeping, they are absent. The bird does not have the opportunity to leave the group environment, as a result of which intensified aggressive interactions are formed, which can contribute to despotic behavior [25]. However, recent research shows that the social behavior of birds is not limited to the formation of a hierarchy, and it is much more plastic and dynamic than previously thought.

Thus, earlier it was believed that chickens (Galus galus domesticus) are a social species that, being in a group, creates a stable hierarchy of dominance, which is established due to aggressive interactions [26]. As soon as a stable hierarchy is formed, aggressive interactions are replaced by dominance-subordination interactions. According to this type of hierarchy, chickens recognize group mates individually and remember the results of aggressive encounters. The frequency and intensity of aggressive interactions for the formation of a stable hierarchy is determined by the size of the group, since the establishment of dominance relations in larger groups requires a greater number of interactions between group members. Further studies showed [27] that in large groups it is difficult for chickens to remember the results of all interactions, which leads to a decrease in the stability of the social structure of the group. These results led to the idea that birds in large groups establish a more flexible, tolerant system of behavior. That is, in large groups, where individual recognition is impossible, the bird builds social interactions through a plastic tolerant system of behavior. This behavioral plasticity allows the bird to change strategies and more easily adapt to different technological (social and physical) conditions within a limited grouping [28].

Researchers associate an increase in the size of a group of chickens (more than 10 heads) due to their keeping in cages of multi-tiered batteries with a decrease in the preservation of livestock and a deterioration in productivity, which are manifestations of stressful conditions [28-30]. There are also reports that keeping chickens in medium-sized groups (about 30 heads) can provoke social stress in them, which is also accompanied by a decrease in productivity, since the size of such a group is too large to form a stable hierarchy, but too small for a tolerant social system [31; 32]. *The purpose of the work* is to study the non-specific reactivity of the hens' body under the influence of the size of the grouping with the same density of laying hens in cages that are similar in design.

MATERIALS AND METHODS

Egg-laying hens of the industrial flock "Hy-Line W-36"were used as an object of research. Experiments with experimental animals were performed in accordance with the rules of the European Convention for the Protection of Vertebrate Animals (Official Journal of the European Union L276/33, 2010).

In the conditions of a modern complex for the production of edible eggs, 4 groups of chickens were formed, each of which was kept in a separate aviary-analogue in terms of area (2915 m^2), equipped with 12-tier cage batteries "Big Dutchman" (Germany), the size of which varied. Depending on the size of the cages, with the same stocking density (23.0 heads/m^2), the number of chickens in them was different. The size of the grouping of chickens in each cage of the 1st group (cage 362×112.0 cm) was 93 heads, the 2nd group (cage 360×62.55 cm) – 52 heads, the 3rd (cage 120×62.55 cm) – 17 heads. and 4th (cage 70×56 cm) – 9 goals. (Table 1).

Table 1. *Scheme of the experiment*

Characteristic	Group of hens			
	1	2	3	4
The number of tiers in the poultry house	12Number of cells			
Number of cages	4704	6048	18144	30912
Number of heads in the cage/the size of the grouping	93	52	17	9
Number of heads in the group	437472	314496	308448	278208
Planting density, heads/m^2	23.0			
Provision of area, cm^2/cap	436.0	433.0	441.5	435.6
Cage dimensions, cm: - length - depth	362 112.0	360 62.55	120 62.55	70 56
Cage area, cm^2	40544	22518	7506	3920
The number of nipples in the cage, pcs.	12	17	12	1.5
Feeding front, see	7.8	6.9	7.1	7.8
Area of the poultry house, m^2	2915			

During the experiment, the chickens were provided with drinking water, full-ration compound feed of the same composition and kept according to the requirements (VNTP-APK-04.05.).

The hemogram of laying hens was determined on the hematological analyzer Micros 60 (Horiba Ltd.) in the "Bald" laboratory (certificate No. LB/02/2016). For this, 30 samples of whole blood were taken from laying hens of each group at the age of 52 weeks. 1.0-1.5 ml of blood was collected from the subpterygoid vein in a test tube with EDTA.

To evaluate the non-specific reactivity of the chickens, integral immunohematological indices of intoxication (leukocyte shift index (ILS)), inflammatory activity (heterophil-to-lymphocyte ratio index (IRHL or Krebs index)) or heterophil-lymphocyte coefficient, leukocyte-ESR ratio index (IRHLC) were determined. granulocyte index (ILG), general index (GI)) and non-specific reactivity (immunoreactivity index (IIR), heterophil and monocyte ratio index (ISHM), lymphocyte and monocyte ratio index (ILM), leukocyte index (LI), lymphocyte ratio index and eosinophils (ESLE)) according to the following formulas [18; 20; 33; 34]: The leukocyte shift index (LSI) was calculated according to formula (1):

$$LSI = (E+B+H)/(Mo+L), \quad (1)$$

where E – eosenophils, B – basophils, H – heterophils, Mo – monocytes, L – lymphocytes.

The Krebs index (IK) was calculated according to formula (2):

$$IK = (R+S)/L, \quad (2)$$

where: R – rod-shaped heterophils,S – segmented heterophils, L – lymphocytes.

The lymphocyte-granulocyte index (ILG) was calculated according to the formula (3):

$$ILH = L×10/(M+Y+R+S+E+B), \quad (3)$$

where L are lymphocytes, M are myelocytes, Y are young forms, R are rod-shaped heterophils, S are segmented heterophils, E are eosinophils, and B are basophils.

The ratio index of leukocytes and ESR (IL ESR) was calculated according to the formula (4):

$$IL\ ESR = L×SOE/100, \quad (4)$$

where L – lymphocytes, ESR – erythrocyte sedimentation rate.

The general index (GI) was calculated according to the formula:

$$GI = ILG+IL\ ESR, \quad (5)$$

where ILG is a lymphocyte-granulocyte index, IL ESR is an index of the ratio of leukocytes and ESR.

The immunoreactivity index (IIR) was calculated according to the formula (6):

$$IIR = (L+E)/Mo, \quad (6)$$

where L are lymphocytes, E are eosinophils, Mo are monocytes.

The index of the ratio of heterophils and monocytes (IHM) was calculated according to the formula

$$IHM = (M+Y+R+S)/Mo, \quad (7)$$

where M are myelocytes, Y are young forms, R are rod-shaped heterophils, S are segmented heterophils, Mo are monocytes.

The index of the ratio of lymphocytes and monocytes (ISLM) was calculated according to the formula (8):

$$ISLM = L/Mo, \quad (8)$$

where L are lymphocytes, Mo are monocytes.

The lymphocyte index (LI) was determined from the ratio of lymphocytes and heterophils (9):

$$LI = L/H, \quad (9)$$

where L and H are the percentage of lymphocytes and heterophils in the leukocyte formula, respectively.

The index of the ratio of lymphocytes and eosinophils (ISLE) was calculated according to the formula (10):

$$ISLE = L/E, \quad (10)$$

where E – eosinophils, L – lymphocytes.

To determine the informativeness of changes in indicators of the immune system as possible prognostic factors, the degree of immunological disorders (SIP) was determined. In the presence of immunodeficiency, the indicator was negative "–", the sign "+" indicated hyperfunction of the immune system.

The value of the result in the range of 1-33% was interpreted as the I degree of immunological disorders, 34-66.7% – the II degree, more than 66.7% – the III degree [35].

The obtained digital results were processed by methods of variational statistics. The significance of the differences between the average values was determined by the Student's t-test, the differences were considered significant at $p<0.05$.

Research results and their discussion. To assess the adaptive and general reactive immunological potential of chickens under the influence of the size of the grouping, integral immunohematological indices of intoxication, inflammatory activity and non-specific reactivity were determined (Table 2)

Table 2. *Integral immunohematological indices of chickens*

Index, units	A group of chickens			
	1	2	3	4
Indices of intoxication				
Leukocyte shift index	0.31±0.015	0.39±0.029*	0.55±0.015**°°	0.66±0.023**°°‘‘‘
Indices of inflammatory activity				
Index of the ratio of heterophils and lymphocytes	0.29±0.016	0.35±0.033	0.54±0.021**°°	0.65±0.023**°°‘‘‘
Lymphocyte-granulocyte index	30.51±1.595	30.52±0.323	17.04±0.491**°°	14.68±0.489**°°‘‘‘
Index of ratio of leukocytes and ESR	2.97±0.026	3.02±0.026	3.21±0.016**°°	3.57±0.021**°°‘‘‘
General index	33.48±1.826	33.54±0.223	20.25±0.526**°°	18.26±0.439**°°‘‘
Indices of non-specific reactivity				
Index of immunoreactivity	8.89±0.624	12.85±0.856**	13.98±1.005**	16.58±0.808**°‘
Index of the ratio of heterophils and monocytes	2.30±0.107	4.71±0.553**	7.42±0.703**°	10.18±0.489**°°‘‘
Index of the ratio of lymphocytes and monocytes	8.52±0.582	12.18±0.837**	13.49±1.001**	16.16±0.820**°°‘‘
Lymphocyte index	3.84±0.217	3.06±0.263*	1.96±0.087**°°	1.61±0.053**°°‘‘‘
Index of the ratio of lymphocytes and eosinophils	24.64±0.796	27.37±0.899*	37.23±0.538**°°	38.94±0.607**°°‘

Notes: **p<0.05, **p<0.001 – compared to the first group; °p<0.01, °°p<0.001 – compared to the second group; ‘p<0.05, ‘‘p<0.01, ‘‘‘p<0.001 – compared to the third group*

It was found that the lymphocyte index (LI), lymphocyte-granulocyte index (ILG) and total index (GI) decreased with decreasing group size, while the leukocyte shift index (LESI), heterophil-to-lymphocyte ratio index (HLRI), leukocyte ratio index and ESR (ILSHOE), immunoreactivity index (IIR), lymphocyte-monocyte ratio index (ILM), heterophil-monocyte ratio index (ISGM) and lymphocyte-eosinophil ratio index (ILLE) – on the contrary, increased.

The index of leukocyte shift (ILK), which characterizes the ratio of granulocytes and agranulocytes and does not depend on the number of leukocytes in the blood [36], increased with a decrease in the size of the grouping of chickens. Chickens of the 4th group had the highest EILK – by 0.35 units. or 112.9% ($p<0.001$) compared to the 1st group and by 0.27 units. or 69.2% ($p<0.001$) and 0.11 units. or 20.0% ($p<0.001$) compared to the 2nd and 3rd groups, respectively. At the same time, in the chickens of the 2nd group, the ICP was higher by 0.08 units. or 25.8% ($p<0.05$) compared to the 1st group, and in chickens of the 3rd group – by 0.24 units. or 77.4% ($p<0.001$) and 0.16 units. or 41.0% compared to groups 1 and 2, respectively. An increase in ILC with a decrease in the size of a group of chickens indicates a shift in the leukocyte formula of their blood to the left, which indicates a violation of immunological reactivity [37] and the entry into the peripheral blood of a large number of "young" forms of leukocytes [36].The index of the ratio of heterophils to lymphocytes (ICHL or Krebs index), which is classically a marker of stress and reflects the ratio of cells of specific and non-specific immunity [14; 22], increased with an increase in the size of the grouping of chickens. The highest ICHL was found in chickens of the 4th group – by 0.36 units. or 121.4% ($p<0.001$) compared to the 1st group, and by 0.3 units. or 85.7% ($p<0.001$) and 0.11 units. or 20.4% ($p<0.001$) compared to the 2nd and 3rd groups, respectively. In the chickens of the 3rd group, ICG was higher by 0.25 units. or 86.2% ($p<0.001$) and 0.19 units. or 54.3% ($p<0.05$) compared to the 1st and 2nd groups, respectively. The difference between the 1st and 2nd groups was only 0.06 points. or 20.7% and was not statistically confirmed. ICHL characterizes the activity of phagocytic reactions and factors of specific immunity, as well as their participation in maintaining the general reactivity of the body [36], therefore, its increase with a decrease in the size of the group of chickens indicates the superiority of non-specific protective cells, which occurs as a result of a functional increase in the proliferative activity of the bone marrow and is expressed in increasing the number of heterophiles [38].

The lymphocyte-granulocyte index (ILH), which allows to differentiate auto-intoxication caused by a malfunction of the immune or enzymatic system, and infectious intoxication, and also expresses in numbers the degree of shift in the leukocyte formula of the blood [33; 39], decreased with a decrease in the size of the grouping of chickens. The lowest ILH was found in chickens of the 4th group – by 15.8 units. or 107.4% ($p<0.001$), 15.8 units. or 107.9% ($p<0.001$) and 2.36 units. or 16.1% ($p<0.001$) compared to the 1st, 2nd and 3rd groups, respectively. In chickens of the 1st and 2nd groups, ILH was at the same level – 30.51-30.52 units, and in the 3rd group it was lower by 13.5 units. or 79.0% ($p<0.001$) compared to the 1st group. A decrease in ILH indicates a shift of the leukocyte formula to the left and confirms the presence of autoimmune intoxication [19; 34; 39]. A decrease in ILH can also be considered as a violation of the factors and mechanisms of immunological reactivity [40].

A simultaneous increase in ILP and a decrease in ILH indicates the development of endogenous intoxication and a violation of immunological reactivity due to auto-intoxication of the body during the destruction of its own cells [34].

The index of the ratio of leukocytes to ESR (ILSHOE), changes in which indicate the presence of intoxication associated with an infectious (decrease in ILSHOE) or autoimmune (increase in ILSHOE) process [41], increased with a decrease in the size of the grouping of chickens. The highest ILSHOE was observed in chickens of the 4th group - by 0.6 units. or 20.2% ($p<0.001$) compared to the 1st group and by 0.55 units. or 18.2% ($p<0.001$) and 0.36 units. or 11.2% ($p<0.001$) compared to the 2nd and 3rd groups, respectively. At the same time, ILSHOE in chickens of the 1st and 2nd groups differed by only 0.05 units.or 1.7% without statistical confirmation, while in chickens of the 3rd group it was higher by 0.24 units. or 8.1% ($p<0.001$) and 0.19 units. or 6.3% ($p<0.001$) compared to the 1st and 2nd groups, respectively. A decrease in ILSHOE with a decrease in the size of a group of chickens indicates the presence of a pronounced systemic inflammatory response in their body with a high level of endogenous intoxication and a violation of immunological reactivity [19], and also confirms the autoimmune nature of the pathological process [18; 42].

The general index (GI), which is the sum of lymphocyte-granulocyte (ILG) and the ratio of leukocytes and ESR (ILSHOE) indices and allows to distinguish the nature of intoxication in the early stages of the development of the pathological process [34], decreased with a decrease in the size of the grouping of chickens. The lowest CI was found in chickens of the 4th group – by 15.22 units. or 45.5% ($p<0.001$) than in chickens of the 1st group and by 15.28 units. or 45.6% ($p<0.001$) and by 1.99 units. or 9.8% ($p<0.01$) than in chickens of the 2nd and 3rd groups, respectively. It should be noted that the difference in CI between the 1st and 2nd groups was only 0.06 units. or 0.2% and was not statistically confirmed, and in chickens of the 3rd group, the CI was lower by 13.23 units. or 39.5% ($p<0.001$) and 13.29 units. or 39.6% ($p<0.001$) than in chickens of the 1st and 2nd groups, respectively. A decrease in CI indicates the presence of an intoxication process in the body of chickens [43].

The index of immunoreactivity (IIR), which reflects the state of the main cytokine-producing cells and the imbalance in the cytokine profile [44], increased with a decrease in the size of the grouping of chickens. The highest IIR was observed in chickens of the 4th group – by 7.69 units. or 86.5% ($p<0.001$) than in chickens of the 1st group and by 3.73 units.or 29.0% ($p<0.01$) and by 2.60 units. or 18.6% ($p<0.05$) than in chickens of the 2nd and 3rd groups, respectively. At the same time, in chickens of the 2nd group, the IIR was higher by 3.96 units. or 44.5% (p<0.001), and in chickens of the 3rd group – by 5.09 units. or 57.3% (p<0.001) compared to the 1st group. The differences between the 2nd and 3rd groups were only 1.13 units. or 8.8% and were not statistically confirmed. An increase in IIR with a decrease in the size of the group (up to 25 units) indicates the compensation of endogenous intoxication [45].

The index of the ratio of heterophils and monocytes (ISGM), which indicates the ratio of the components of the microphage-macrophage system [19], increased with a decrease in the size of the grouping of chickens. The highest ISGM was observed in chickens of the 4th group – by 7.88 units. or 342.6% (p<0.001) compared to the 1st group, and by 5.47 units. or 116.1% (p<0.001) and 2.76 units. or 37.2% (p<0.01) compared to the 2nd and 3rd groups, respectively. At the same time, hens of the 2nd group were characterized by a higher ISGM by 2.41 units. or 104.8% (p<0.001) compared to the 1st group, and chickens of the 3rd group – by 5.12 units. or 222.6% (p<0.001) and 2.71 units. or 57.5% (p<0.01) compared to the 1st and 2nd groups, respectively. An increase in ISGM with a decrease in the size of the chicken group indicates an increase in the activity of heterophils in the microphage-macrophage system of the immune response [46].

The index of the ratio of lymphocytes and monocytes (ILM) reflects the relationship between affective and effector links of the immunological process [4], increased with a decrease in the size of the grouping of chickens. The highest ISLM was observed in chickens of the 4th group – by 7.64 units. or 89.7% (p<0.001) compared to the 1st group, and by 3.98 units. or 32.7% (p<0.001) and 2.67 units. or 19.8% (p<0.01) compared to the 2nd and 3rd groups, respectively. At the same time, in chickens of the 2nd group, ISLM was higher by 3.66 units. or 43.0% (p<0.001), and in chickens of the 3rd group – by 4.97 units. or 58.3% (p<0.001) compared to the 1st group. The differences between the 2nd and 3rd groups were 1.31 units. or 10.8% and were not statistically confirmed. An increase in ISLM indicates the predominance of the effector link of a non-specific immunological process over the affective one [43].The lymphocyte index (LI), which reflects the relationship between the humoral and cellular links of the immune system [34], decreased with a decrease in the size of the grouping of chickens. Thus, LI in chickens of the 2nd was lower by 0.78 units. or 25.5% (p<0.05) compared to the 1st group, and in chickens of the 3rd group – by 1.88 units. or 95.9% (p<0.001) and 1.1 units. or 56.1% (p<0.001) compared to the 1st and 2nd groups, respectively. In chickens of the 4th group, LI was lower by 2.23 units. or 138.5% (p<0.001) compared to the 1st group and by 1.45 units. or 90.1% (p<0.001) and 0.35 units. or 21.7% (p<0.001) compared to the 2nd and 3rd groups, respectively. A decrease in LI with a decrease in the size of a group of chickens indicates the dominance of the activation of the cellular link of the immune system, and also indicates an active adaptive response of white blood and a decrease in non-specific anti-infective protection due to intoxication [43].

The index of the ratio of lymphocytes and eosinophils (ISLE), which reflects the ratio of the processes of hypersensitivity of the immediate and delayed type [34], increased with a decrease in the size of the grouping of chickens. The highest ISLE was found in chickens of the 4th group, namely by 14.3 units. or 58.0% (p<0.001) compared to the 1st group and by 11.57 units. or 42.3% (p<0.001) and 1.71 units. or 4.6% (p<0.05) compared to the 2nd and 3rd groups, respectively. ISLE in chickens of the 2nd group was higher by 2.73 units. or 11.1% (p<0.05), and in chickens of the 3rd group – by 12.59 units. or 51.1% (p<0.001) and 9.86 units. or 36.0% compared to groups 1 and 2, respectively. An increase in ISLE reflects the predominance of immediate-type hypersensitivity reactions over delayed-type reactions [47], which indicates an increase in autointoxication and a violation of immunological reactivity [48] in chickens with a decrease in the size of the grouping.

Determining the informativeness of changes in integral immunohematological indices as indicators of the immune system showed that all of them to one degree or another reflected the reaction of the chickens' body to the influence of changes in group size (Table 3).

Thus, the informative immunohematogolic indices that responded to the decrease in the size of the group of chickens, that is, to the degree of intensity of the stress factor, turned out to be ISK, ISGL (IC), ZI, IIR, ISLM, LI and ISLE. Whereas ILH did not respond to the reduction of the group from 93 to 52 goals, and ISGM and ILSHOE showed the same degree of immunological disturbances for the reduction of the group from 93 to 9 goals.

Table 3. *The degree of immunological disorders according to blood indices of chickens*

Index, units	A group of chickens		
	2 (52 pcs.)	3 (17 pcs)	4 (9 pcs.)
Indices of intoxication			
Leukocyte shift index	+I	+III	+III
Indices of inflammatory activity			
Index of the ratio of heterophils and lymphocytes (Krebs index)	+I	+III	+III
Lymphocyte-granulocyte index	–	-II	-II

Table 3, Continued

Index, units	A group of chickens		
	2 (52 pcs.)	3 (17 pcs)	4 (9 pcs.)
The index of the ratio of leukocytes and ESR	+I	+I	+I
General index	+I	-II	-II
Indices of non-specific reactivity			
Index of immunoreactivity	+II	+II	+III
Index of the ratio of heterophils and monocytes	+III	+III	+III
Index of the ratio of lymphocytes and monocytes	+II	+II	+III
Lymphocyte index	-I	-II	-II
Index of the ratio of lymphocytes and eosinophils	+I	+II	+II

CONCLUSIONS

The optimal group size of laying hens of modern white-egg crosses during their keeping in cages of 12-tier cage batteries is 52-93 head. For reducing the size of the grouping of chickens to 17 and 9 heads. there is an increase in the leukocyte shift index, the index of the ratio of heterophils and lymphocytes (Krebs index), the index of immunoreactivity, the index of the ratio of heterophils and monocytes, the index of the ratio of lymphocytes and monocytes, the index of the ratio of leukocytes and ESR, and the index of the ratio of lymphocytes and eosinophils. This indicates a shift of the leukocyte formula to the left, the predominance of nonspecific protective cells, which occurs as a result of a functional increase in the proliferative activity of the bone marrow and is expressed in an increased number of heterophils, an increase in their activity in the microphage-macrophage system of the immune response, and indicates the presence of a high level of endogenous intoxication in the body of chickens and violation of immunological reactivity, and can also inform about the autoimmune nature of the pathological process. At the same time, there is a decrease in the lymphocyte-granulocyte index, the total index, and the lymphocyte index, which confirms the shift of the leukocyte formula to the left and indicates the dominance of activation of the cellular link of the immune system, indicating an active adaptive reaction of white blood. A simultaneous increase in the leukocyte shift index and a decrease in the lymphocyte-granulocyte index indicates the development of endogenous intoxication in chickens and a violation of their immunological reactivity due to autointoxication of the body during the destruction of its own cells.

REFERENCES:

[1] Hemsworth, P.H. (2021). Cage production and laying hen welfare. *Animal Production Science*,. 61, 821-836. doi:10.1071/AN19609.

[2] Guide to the content of the final hybrid Hy-Line W-36, 2019. 32 p. Retrieved from https://www.hyline.com/userdocs/pages/36_COM_RUS.pdf.

[3] Abrahamsson, P., & Tauson, R. (1997). Effects of group size on performance,health and birds' use of facilities in furnished cages for laying hens. *Acta Agriculturae Scandinavica – Section A: Animal Science*, 47, 254-260. doi: 10.1080/09064709709362394.

[4] Appleby, M.C. (1998). The Edinburgh modified cage: effects of group size andspace allowance on brown laying hens. *Journal of Applied Poultry Research*,7, 152-161. doi: 10.1093/japr/7.2.152

[5] Sierzega, M., Lenart, M., Rutkowska, M., Surman, M., Mytar, B., Matyja, A., Siedlar, M., & Kulig, J. (2017). Preoperative Neutrophil-Lymphocyte and Lymphocyte-Monocyte Ratios Reflect Immune Cell Population Rearrangement in Resectable Pancreatic Cancer. *Annals of Surgical Oncology*, 24(3), 808-815. doi:10.1245/s10434-016-5634-0.

[6] Shimmura, T., Azuma, T., Eguchi, Y., Uetake, K., & Tanaka, T. (2009). Effects ofseparation of resources on behaviour, physical condition and production oflaying hens in furnished cages. *British Poultry Science*, 50, 39-46. doi: 10.1080/00071660802613260.

[7] Kryzhanovsky, G.N., Magaeva S.V., & Makarov S.V. (1997). *Neuroimmunopathology*. Moscow: Medicine.

[8] Fedorov, B.M. (1990). *Stress and circulatory system*. Moscow: Medicine.

[9] Sellier, G.(1969). *Essays on the Adaptation Syndrome.* Moscow: Medgiz.

[10] Miftahutdinov, A.V. (2014). Experimental approaches to the diagnosis of stress in poultry (review). *Agricultural Biology*,. 2, 20-30. doi: 10.15389/agrobiology.2014.2.20eng.

[11] Gupta, S.K., Behera, K., Pradhan, C.R., Acharya, A.P., Sethy, K., Behera, D., Lonel, S.A., & Shinde, K.P. (2017). Influence of stocking density on the performance, carcass characteristics, hemato-biochemical indices of Vanaraja chickens. *Indian Journal of Animal Research*, 51(5), 939-943. doi: 10.18805/ijar.10989.

[12] Hetland, H., Moe, R.O., Tauson, R., Lervik, S., & Svihus, B. (2004). Effect of includingwhole oats into pellets on performance and plumage condition in laying henshoused in conventional and furnished cages. *Acta Agriculturae Scandinavica – Section A: Animal Science*, 54, 206-212. doi: 10.1080/09064700410010026.

[13] Kholodkovskaya,V.D., & Barabanov A.L.(2015). Using integral hematological indices to assess severity of endogenous toxicosis in chronic dermatoses. *International Scientific and Practical Conference "World Science",* 3(2), 69-72.

[14] Maxwell, M.H., Hocking, P.M., & Robertson, G.W. (1992). Differential leucocyte responses to various degrees of food restriction in broilers, turkeys and ducks. *British Poultry Science*, 33(1), 177-187. doi: 10.1080/00071669208417455.

[15] Heidt, T., Sager, H.B., Courties, G., Dutta, P., Iwamoto, Y., Zaltsman, A., von Zur Muhlen, C., Bode, C., Fricchione, G.L., Denninger, J., Lin, C. P., Vinegoni, C., Libby, P., Swirski, F.K., Weissleder, R., & Nahrendorf, M. (2014). Chronic variable stress activates hematopoietic stem cells. *Nature Medicine*, 20(7), 754-758. doi: 10.1038/nm.3589.

[16] Nwaigwe, C.U., Ihedioha, J.I., Shoyinka, S.V., & Nwaigwe, C.O. (2020). Evaluation of the hematological and clinical biochemical markers of stress in broiler chickens. *Veterinary World,* 13(10), 2294-2300. doi: 10.14202/vetworld.2020.2294-2300.

[17] Vits, A., Weitzenburger, D., Hamann, H., & Distl, O. (2005). Production, egg quality,bone strength, claw length, and keel bone deformities of laying hens housed infurnished cages with different group sizes. *Poultry Science*, 84, 1511-1519. doi:10.1093/ps/84.10.1511.

[18] Raznatovskaya, E.N. (2012). Integral indicators of endogenous intoxication in patients with chemoresistant pulmonary tuberculosis. *Actual Problems of Pharmaceutical and Medical Science and Practice*, 2(9), 119-120.

[19] Rekalova, O.M., Panasyukova, O.R., & Koval, N.G. (2017). Application of leukocyte indices in immunological assessment of inflammatory process activity in patients with chronic obstructive pulmonary disease. *Asthma and Allergy,* 1, 27-33.

[20] Siplyvyi, V.A., Kon, E.V, & Yevtushenko, D.V. (2009). The use of leukocyte indices to predict the outcome of peritonitis. *Clinical Surgery*, 9, 21-26.

[21] Belyaeva, E.Yu., & Buslovskaya, L.K. (2012). Adaptive reactions and biochemical indicators of chicken blood in different conditions of illumination. *Scientific Journal. Series of Natural Sciences*, 21(140), 143-148.

[22] Letkin, A.I. (2020). Leukocytic blood parameters of laying hens with nonspecific stress syndrome. *Bulletin of the Altai State Agrarian University*, 2(184), 102-108.

[23] Derho, M.A., & Samoilova, E.S. (2011). Integral indices of intoxication as a criterion for evaluating the level of endogenous intoxication in babesiosis. *Scientific Notes of KGAVM Named After N.E. Bauman*, 207, 170-177.

[24] Croney, C.C., & Newberry, R.C. (2007). Group size and cognitive processes. *Applied Animal Behaviour Science*, 103(3-4), 215-228. doi:10.1016/j.applanim.2006.05.023.

[25] Bas Rodenburg, T., & Koene ,P. (2007). The impact of group size on damaging behaviours, aggression, fear and stress in farm animals. *Applied Animal Behaviour* Science, 103(3-4), 205-214. doi:10.1016/j.applanim.2006.05.024.

[26] Wood-Gush, D.G.M. (1971). *The Behaviour of the Domestic Fowl*. London: Heinemann Educational Books Ltd.

[27] Estevez, I., Andersen, I.-L., & Nævdal ,E. (2007). Group size, density and social dynamics in farm animals. *Applied Animal Behaviour Science,* 103(3-4), 185-204. doi:10.1016/j.applanim.2006.05.025.

[28] Appleby, M.C. (1998). Modification of laying hen cages to improve behavior. *Poultry Science*, 77, 1828-1832. doi: 10.1093/ps/77.12.1828.

[29] Appleby, M.C., Walker, A.W., Nicol, C.J., Lindberg, A.C., Freire, R., Hughes B.O., & Elson, H.A. (2002). Development of furnished cages for laying hens. *British Poultry Science*, 43, 489-500. doi: 10.1080/0007166022000004390.

[30] Hemsworth, P.H. (2021). Cage production and laying hen welfare. *Animal Production Science,*. 61, 821-836. doi:10.1071/AN19609.

[31] Guo, Y.Y., Song, Z.G., Jiao, H.C., Song, Q.Q., & Lin, H. (2012). The effect of group size and stocking density on the welfare and performance of hens housed in furnished cages during summer. *Animal Welfare*, 21, 41-49. doi: 10.7120/096272812799129501.

[32] Kang, H.K., Park, S.B., Kim, H.S., & Kim, C.H. (2016). Effects of stock density on the laying performance, blood parameter, corticosterone, litter quality, gas emission and bone mineral density of laying hens in floor pens. *Poultry Science*, 95, 2764-2770. doi: 10.3382/ps/pew264.

[33] Levandovsky, R.A. (2014). Cellular and immunological reactivity of the body in patients after resection of the upper and lower jaws to remove malignant tumors. *Clinical and Experimental Pathology*, 2(48), 83-87.

[34] Ostrovska, L.Y., Moshel, T.M., & Ivanitsky, I.O. (2016). Analysis of hemogram parameters in patients with inflammatory and inflammatory-dystrophic changes of periodontal tissues. *Bulletin of Problems of Biology and Medicine*, 1(126), 360-363.

[35] Bondarchuk, R.V., Sydorchuk, L.P., & Sydorchuk, I.Y. (2016). The level of adaptive stress and cellular reactivity of the body in patients with arterial hypertension in combination with coronary heart disease. *Bukovyna Medical Herald*, 20(2), 16-19.

[36] Tkachenko, E.A., & Derho, M.A. (2014). Leukocytic parameters in experimental cadmium intoxication in mice. *Proceedings of the Orenburg State Agrarian University*, 3, 81-83.

[37] Yabluchansky, N.I. (1983). Leukocyte shift index as a marker of reactivity of the organism in acute inflammation. *Laboratory Business*, 1, 60-61.

[38] Gao, S.Q., Huang, L.D., Dai, R.J., Chen, D.D., Hu, W.J., & Shan, Y.F. (2015). Neutrophil-lymphocyte ratio: a controversial marker in predicting Crohn's disease severity. *Journal of Clinical and Experimental Pathology*, 8(11), 14779-14785.

[39] Keeling, L.J., Estevez, I., Newberry, R.C., Correia, M.G. (2003). Production-relatedtraits of layers reared in different sized flocks: The concept of problematicintermediate group sizes. *Poultry Science*, 82, 1393-1396. doi: 10.1093/ps/82.9.1393.

[40] Matolych, U.D (2016). Diagnostic value of hematological indices in phlegmon of the maxillofacial area and neck. *Scientific Bulletin of Uzhhorod University, Series "Medicine"*,1(53), 108-110.

[41] Mustafina, J.G.G., Kramarenko, Y.S., & Kobtseva, V. (1999). Integral hematological parameters in the evaluation of the immunological reactivity of the organism in patients with ophthalmopathology. *Clinical Laboratory Diagnostics*, 5, 47-48.

[42] Zubchenko, S.O., Akimova, V.M., & Lapovets, L.E. (2014). Identification of pre-hospital disorders based on changes in integral hematological indices in patients with the latent stage of chronic Epstein-Barr virus infection. *Herald of Problems of Biology and Medicine*, 4, 1(113), 125-128.

[43] Radzykhovsky, M.L., Goralsky, L.P., Borisevich, B.V., & Dyshkant, O.V. (2018). Integral indices of intoxication of dogs with coronavirus enteritis. *Scientific Bulletin of Veterinary Medicine*, 2, 13-19. doi: 10.33245/2310-4902-2018-144-2- 13-19.

[44] Shabalov, N.P., Ivanov, D.O., & Shabalova, N.N. (2001). Heterogeneity of the systemic inflammatory response in neonatal sepsis. *Medical Academic Journal*, 1(3), 81- 90.

[45] Khabirov, T.Sh. (2002). The level of reactive response of neutrophils as an indicator of the severity of endogenous intoxication in abdominal sepsis. Lugansk: WFUMS.

[46] Rushen, J.(1991). Problems associated with the interpretation of physiological data in the assessment of animal welfare. *Applied Animal Behaviour Science*, 28, 381-386. doi: 10.1016/0168-1591(91)90170-3.

[47] Brodyak, I., & Sibirna, N. (2006). Morphofunctional studies of peripheral blood leukocytes under conditions of experimental diabetes mellitus in rats. *Bulletin of Lviv University. Biological Series*, 42, 117-127.

[48] Mazur, O.A, Olenovych, O.A., Plaksivyi, A.G., Kalutskyi, I.V., Yakovets, K.I., & Bogach, V.A (2017). Indicators of endogenous intoxication in patients with chronic purulent maxillary sinusitis with type 1 diabetes mellitus. *Bukovinian Medical Bulletin*, 1(81), 76-80.

Вплив величини угрупування курей на неспецифічну реактивність їх організму

Ю. В. Осадча

Кандидат сільськогосподарських наук, доцент
https://orcid.org/0000-0003-4126-2456

Національний університет біоресурсів і природокористування України

Анотація. Досліджено неспецифічну реактивність організму курей за впливу величини угрупування з однаковою щільністю посадки несучок в клітках-аналогах за конструкцією. Виявлено, що за зменшення величини угрупування курей спостерігається зсув лейкоцитарної формули вліво, перевага неспецифічних захисних клітин, що відбувається внаслідок функціонального підвищення проліферативної активності кісткового мозку і виражається у збільшенні кількості гетерофілів та підвищенні їх активності у мікрофагальномакрофагальній системі імунної відповіді

Ключові слова: кури, стрес, імуногематологічні індекси, неспецифічна реактивність, ендогенна інтоксикація

UDC 631.31
DOI: 10.31521/2313-092X/2021-3(111)-10

Ukrainian Black Sea Region Agrarian Science
Vol. 25, No. 3

Field tests of the experimental installation for soil processing

D. Babenko*
PhD in Technical Sciences, Professor
https://orcid.org/0000-0003-2239-4832
Mykolayiv National Agrarian University

M. Khramov
https://orcid.org/0000-0002-2537-7344
Mykolayiv National Agrarian University

Yu. Syromyatnikov
PhD in Technical Sciences
https://orcid.org/0000-0001-9502-626X
State Biotechnological University

I. Sukovitsyna
https://orcid.org/0000-0001-5201-7830
Mykolayiv National Agrarian University

Abstract. It is experimentally established that the quality of soil grinding by the experimental ripper-separator is especially affected by the humidity and density of the composition, so at a soil density of 1.3-1.4 g/cm^3 and a minimum soil moisture of 11.4-14.4% rotor speed must be increased up to 127 rpm

Keywords: tillage, cultivation, soil layer, rotor, differentiation

INTRODUCTION

Differentiation of the cultivated soil layer according to the structural composition in which agronomic valuable lumps ranging in size from 5 to 20 mm – 20-25%, from 0.25 to 5.0 mm – 60-65% and not more than 15% of lumps less than 0.25 mm, provides plants with nutrients and moisture.

It is carried out by deep surface processing in the fall and mulched processing to the depth of sowing in the spring. In this case, lumps from 5 to 20 mm in size prevail in the surface soil layer, and from 0.25 to 10 mm in the seed embedding zone (Fig. 1) [1].

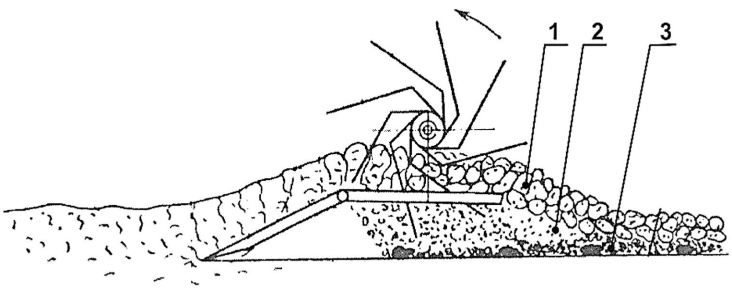

Figure 1. *The structure of the processed layer: 1 – above the seed layer (lumps size from 5 mm to 20 mm); 2 – seed layer (lumps size from 5 mm to 20 mm); 3 – seed embedding zone (lumps size from 0.25 mm to 10 mm)*

Article's History:
Received: 17.02.2021
Revised: 4.07.2021
Accepted: 26.08.2021

Suggested Citation:
Babenko, D., Khramov, M., Syromyatnikov, Yu., & Sukovitsyna, I. (2021). Field tests of the experimental installation for soil processing. *Ukrainian Black Sea Region Agrarian Science*, 25(3), 84-91.

There is a machine for optimizing the agro physical properties of the arable soil layer [2-4].The use of an active working body (rotor) [5] allows for a single pass of the unit to ensure high quality tillage. However, the action of the rotor knives on the soil layer fed to the separating grid has a ambiguous effect on the getting of agronomic valuable aggregates depending on the rotational speeds of rotor, moisture and soil density. To a certain extent, even the minimum rotor speed is sufficient to optimize soil crumbling. Determination of indicators of crumbling of the seed soil layer depending on the rotor speed at various initial parameters of moisture and soil density will improve the quality of grinding the soil layer. Analysis of research and publications. In precision farming systems, modern soil cultivation methods are based on layer processing both in width and depth [6; 7]. Differentiation of the cultivated soil layer according to the structural composition using the technological operations of its processing, increases the stability of the system in unstable climatic conditions. An example is various technologies based on strip tillage [8-10]. For these purposes, complex aggregate are used that perform a number of technological operations. Existing technologies are based on the fact that seeds should be in contact with soil with high capillary conductivity [11-13]. During this period, looser soil composition is desirable, which provides better absorption of moisture of precipitation, especially at their high intensity. The task of preparing the soil for sowing is to create optimal conditions for seedling, which is provided by cultivating the soil to a depth of seed placement. Direct sowing is not excluded in the presence of appropriate machines [14].

The effectiveness of soil cultivation using cultivating-separating active working bodies was studied in one stationary field experiment, 6 field experiments and 8 vegetation-field (model micro field) experiments. The effective fertility of individual soil layers was studied in four model micro field experiments. The feedback of crops on the cultivation of soil layers was studied on models where superposition of various combinations of layers of 0-10, 10-20 cm was used. The study of changes in the effective fertility of the soil from mixing or moving of its parts (loosening, turnover) artificially imitate methods of soil cultivation against the background various fertilizers, which were studied in two micro field experiments. It was found that the differentiation of the arable layer by fertility occurs both on good and on medium cultivated soil. The difference with respect to the effective fertility of the soil layers is 10-20 cm less than that of the 0-10 cm layer. With depth in the soil, the content of humus, basic nutrients, the total duty cycle, and the duty cycle of aeration decrease, but the agronomic content of valuable aggregates and their resistance to moisture absorption, equilibrium density of stow and soil hardness [15-17].

It was established that careful loosening of the top ten centimeter layer of soil in the spring provided an increase in crop yields compared with mixing or turnover. At a processing depth of 0-10 cm, loosening compared to turnover increased yield by 16%. Mixing the soil with a depth of 30 cm reduced the productivity of plants compared with the option of loosening and increased compared with the option where a full revolution was carried out.

Research V.V. Medvedev established the basic agro physical properties and regimes that determine the fertility of chernozem soils, revealed the relationships between them, fertility models developed for some cultures and ways to optimize them [18-21].

However, the technical capabilities of means of mechanization, taking into account the heterogeneity of the fields and the characteristics of plants in precision farming systems, are still insufficient. They are limited only by the introduction of fertilizers and plant protection products [22; 23; 24; 25]. A significant reserve for realizing the advantages of precision farming is mechanical tillage, which, provided there are appropriate tools, makes it possible, on the one hand, to process it taking into account its physical properties, and, on the other hand, to create the necessary parameters of these properties in accordance with agricultural requirements [26-28]. The key to managing these properties of the arable (sowing) layer is to regulate the structural composition and density of the soil structure. Moreover, it is important to at least reduce the difference between the real and optimal parameters of these properties before sowing. The differentiation of the cultivated soil layer according to the structural composition is the reason for a very high (up to 2-3 times) variation in yield. Moreover, it is believed that the structure of the soil cover is a difficult to regulate factor and affects the efficiency of fertility management [29, 30].

The statement of objectives of the article. Determine the indicators of crumbling of the sowing layer of the soil depending on the rotational speed of the rotor of the tillage installation at various initial parameters of moisture and density of the soil structure.

MATERIAL AND METHODS

The small-lumpy structure of the soil in the seed embedding zone is ensured by the redistribution of particles along the depth of the seed layer, which eliminates the need to crumbling the soil intensively. For carrying out experiments in the field, the installation was made that stratifies the soil by separating lumps according to the depth of processing [31-33]. The unit was aggregated with a general-purpose agricultural tractor T-150K-08 [34]. It is a rigid frame with a hitch.

On both sides of the frame are metal support wheels with mechanisms for adjusting the depth of tillage. At the rear of the frame is a four-part rotor. The rotor is driven from the tractor power take-off shaft, which is tuned to a rotation speed of 540 rpm. In this case, the rotor speed is changed using a twostage gearbox and by adjusting the engine speed in the range from 1000 to 2100 rpm.

The rotor is a pipe onto which separator knives are welded in increments of 50 mm (Fig. 2).

Figure 2. *The rotor of an experimental tillage installation*

The location of the knives on the rotor shaft affects the change in drive torque and speed. In this case, the knives are placed on the shaft along a helix with the number of connection equal to the number of knives on the shaft, and the beginning of the first helix should coincide in the opposite part of the shaft with the end of the second helix, etc. In addition, the knives must be placed evenly around the entire circumference of the shaft with an angular distance between adjacent knives.

$$a_2 = \frac{360°}{2n} \quad (1)$$

where n – is the number of knives.

An example of the arrangement of 18 rigidly fixed in pairs knives symmetrically to the longitudinal axis is shown in Fig. 3.

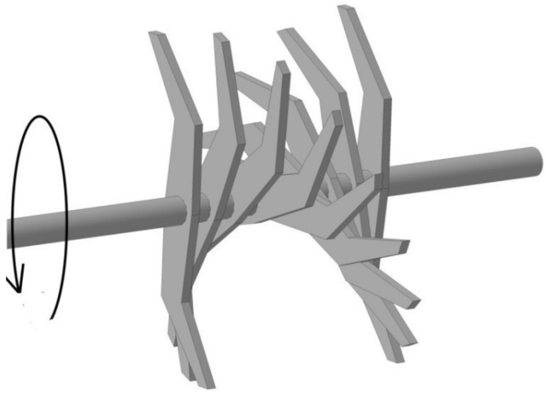

Figure 3. *The rotor of the tillage cultivating-separating machine with 18 knives fixed in pairs symmetrically to the longitudinal axis*

In the table 1 shows the angle of shear between knivesinstalled on the shaft and their sequence of adjacent knives αz depending on the number of entry into operation.

***Table 1**. The sequence of entry into operation of the knives and the angle of shift between them*

The number of rotor knives 2n	The angle of shift between adjacent knives αz	The sequence of entry into operation of the knives
5	35° 0′	1 – 4 – 2 – 5 – 3
7	25° 42′	1 – 5 – 2 – 6 – 3 – 7 – 4
8	33° 45′	1 – 4 – 7 – 2 – 5 – 8 – 3 – 6
9	20° 0′	1 – 6 – 2 – 7 – 3 – 8 – 4 – 9 – 5

The above shows that a certain number of knives corresponds to a well-defined angle of shear and the sequence of entry into operation.

Obviously, reducing or adding knives without changing the arrangement can lead to poor stability of the machine and an increase in the unevenness of torque.

In the front of the frame are cutting-lifting working bodies [32, 35]. They are a flat cutter paw with a crumbling angle of 15° with curved ends of the wings. The wings are welded towards a chisel. To the wing with a flat cutter paw, bars of the separating lattice are welded in such a way that the rotor separator knives enter between the bars of the separating lattice.

The working length of the separating grate is selected from the conditions for obtaining the guaranteed thickness of the finely lumpy soil layer covering the seeds. The thickness of the soil layer sifted through the gaps of the separating lattice is determined by the specific throughput of the latter, and the translational speed of the tillage installation. Specific throughput is the ability of a separating lattice to pass a certain soil weight in one second through a unit of gap area.

The weight of the soil that passes through the gaps of the separation lattice in one second can be determined by the expression:

$$Q' = \frac{1}{2t} l \cos\psi_p \, h' b\gamma \, , \quad (2)$$

where t – is the travel time, $l\cos\psi_p$, s; h' – thickness of the soil layer sifted through the separating lattice, m; b – the width of the finely cloddy soil layer covering the seeds, m; γ – is the volumetric weight of the soil, kg/m^3.

The travel time lcos ψ_p is determined by the expression:

$$t = \frac{l \cos \psi_p}{V_M}, \tag{3}$$

where V_M – is the translational speed of the machine, m/s.

Throughput of the separating lattice in one second is found using its specific throughput according to the formula:

$$Q' = Ql \cos \psi_p b'(z + 1), \tag{4}$$

where Q – is the specific throughput of the separating grate, kg/m^{3}s; b' – the distance between the rods of the separating lattice, m; z – is the number of rods in the separating lattice, pcs.

From the equation:

$$V_\Pi = \frac{V_M}{\cos \psi_p}, \tag{5}$$

where V_Π – is the speed of the soil along the separating grid, V_M – is the translational speed of the tillage machine m/s; ψ_p – is the angle of inclination of the separating lattice.

From the equation:

$$V' = V \cos(\alpha_{вх} + \psi), \tag{6}$$

where V_0' – is the projection of the peripheral speed of the rotor knife on the surface of the movable separating lattice, m/s; V_0 – is the peripheral speed of the rotor knife, m/s; $\alpha_{вх}$ – the angle of entry of the rotor knife into the soil. It is seen that: $\psi_p = 0$, the peripheral speed of the rotor knife, necessary to move the soil along the separating lattice, can be reduced to a minimum.

So, to reduce the rotor speed, the separating lattice must be placed horizontally.

The distance between the rods of the separating lattice is determined by the agro-technical requirements for the soil structure in the seed embedding zone. To exclude particles larger than 10 mm from this zone, the distance between the rods of the separating lattice should be equal to or less than the specified size.

The experimental field installation works as follows. The working bodies cut the soil at a given depth of cultivation and raise it. This ensures preliminary grinding of the soil, which is then fed to the separating lattice by a rotary working body. Knives of a rotating rotor with a relatively low speed pick up a layer of soil and move it further along the lattice. This ensures the active grinding and separation of the cut soil layer. Lumps of soil of a small fraction wake up behind a wing of a flat-cutter paw through a lattice and find themselves at the depth of the trimmed layer. Large lumps crumble with rotor knives and wake up through the grate, occupying a position above the fine fraction. Lumps, the linear dimensions of which are larger than the step of the separating lattice, leave it and occupy a position on the surface of the cultivated soil. Here are the crop residues and rhizomes of plants that cover the surface of the soil, forming plant mulch.

Since the rotor knives pass between the rods of the separating lattice, their mutual cleaning of weeds and soil is ensured. At the same time, the rotor knives do not reach the bottom of the furrow, leaving its bottom tight.

RESULTS

This experiment was carried out jointly with the laboratory of soil physics of the National Science Center "Institute of Soil Science and Agrochemistry named after A.N. Sokolovsky". The results of field tests (only for fractions with a size of 10-1 mm) are given in Table 2.

Table 2 *The crumbling of the seed layer, depending on the rotational speed of the rotor of the tillage installation with different initial parameters of moisture and soil density*

Output parameters of the soil		The output of aggregates (%) with a size of 10-1 mm at a rotor speed, rpm		
humidity, %	Mass density of the structure, g/cm^3	99	127	180
11.4	1.14	36.4	50.2	33.2
	1.19	43.7	55.7	47.8
	1.32	24.2	26.2	33.9
14.4	1.21	50.6	48.1	50.5
	1.38	51.9	30.0	47.1
	1.45	53.4	35.8	30.6
23.6	1.06	69.6	68.7	74.4
	1.26	60.5	73.4	58.0
	1.36	45.2	55.6	49.5

Table 3. *The reliability of the data, determined by the Fisher criterion*

One-factor dispersion analysis organized repetitions			
number	average	standard deviation	relative deviation (%)
1	39.933	9.034	22.623
2	49.067	6.099	12.431
3	28.100	5.122	18.226
4	49.733	1.415	2.846
5	43.000	11.511	26.770
6	39.933	11.949	29.922
7	70.900	3.065	4.322
8	63.967	8.265	12.920
9	50.100	5.226	10.431

Influence of the factor share	
source of influence	determination index
V-option	79.20
iteration	0.38
random	20.42

Analysis of the variation table				
a source	quadrotic mean	degree of freedom	F-Fisher experimental	F-Fisher tabular
V-option	501.83	8	7.76	2.59
Z-residual	64.70	16		
P-factor	9.76	2	0.15	3.63

Statistical characteristics	
matrix average	48.304
standard deviation	8.043
error of experience (average)	4.644
accuracy indicator, %	9.614
mean difference error	6.567
smallest existing difference	13.923

The reliability of the data, determined by the Processing data by the method of factor analysis Fisher criterion, is 95%. The influence of the factor is allowed us to come to more specific conclusions. 79.2%. The smallest significant difference is 13.923%. To do this, we determined the effect of each of the investigated factors on grinding by approximately the same other two factors. The result is shown in Table 4.

Table 4. *The influence of the studied factors on the crumbling of the soil*

Factor	Level of factor	Crumbling soil, %
rotation frequency rotor, about rpm	99	48.4
	127	49.3
	180	47.2
soil density	small	53.5
	moderate	52.0
	increased	39.4
Soil moisture	small	39.0
	moderate	44.2
	optimal	61.7

After processing the experimental data, a mathematical model of soil crumbling was obtained

$$Z = 95.5 - 0.4W^3p^3 - 25.2p^2 + 2.82\upsilon^{2/3} + 0.82W^{1,5}p^{2,5} + 0.3W^{1,5}p^{1,5}\upsilon^{1/3} - 22.2p\upsilon^{1/3}, \quad (7)$$

where: W – soil moisture, %; p – soil structure density, g/cm^3; υ – rotor speed, vol./min.

DISCUSSION

Based on this model, a graph of surfaces was constructed $Z(W, p)$; $Z(W, \upsilon)$; $Z(p, \upsilon)$; $Z(W)$; $Z(g)$ subject to fixation, υ, pand W, p, respectively, at the levels of their average values in the experiments. For practical purposes, approximations to the quadratic model are carried out. The results of regression multivariate analysis are shown in Fig. 4.

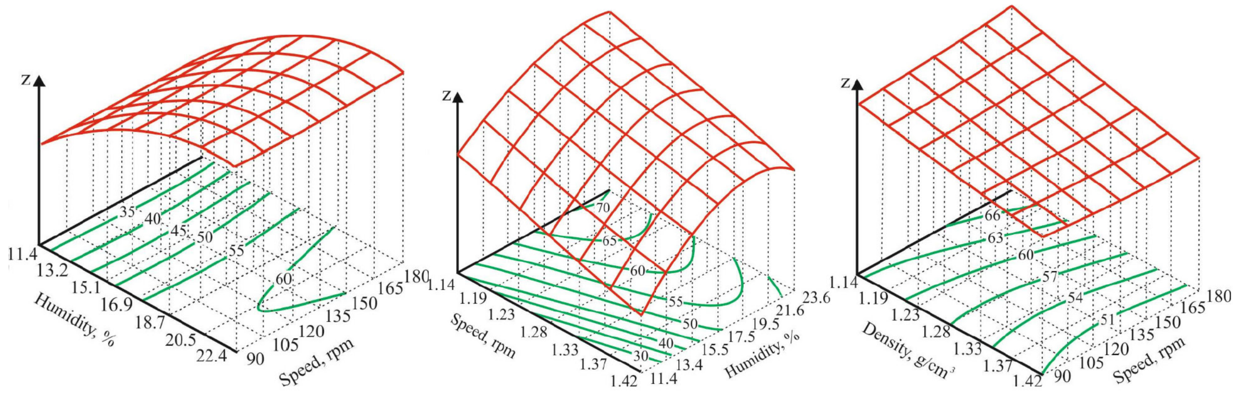

Figure 4. *Crumbling of the seed layer (Z) depending on the rotational speed of the rotor of the tillage plant with various initial parameters of moisture and density of the soil structure*

Active soil grinding by a tillage installation has proven effective with a wide range of output parameters of the structure density and humidity of the surface soil layer. With an increase in the rotor speed, a tendency towards a decrease in the number of lumps (>10 mm) was manifested. The efficiency of increasing the speed increased with unfavorable parameters of soil density and moisture. Even in variants with increased parameters of the structure density (1.3-1.4 g/cm^3) after the passage of the installation, it was possible to obtain a seed layer with a satisfactory content of agronomic useful lumps.

It should be borne in mind that when analyzing the data obtained, some of their inconsistency is explained by the fact that we were not able to create equal conditions for the initial density of the structure before processing (crumbling) due to the different humidity of the seed layer of the soil. For example, at the slightest moisture in the soil, the range of the created structure density was 1.14-1.32 g/cm^3, average humidity 1.211.45 g/cm^3, and increased 1.06-1.36 g/cm^3. That is, during the experiment we were not able to create comparable conditions of crumbling soil. But certain patterns were discovered.

1. As expected, the largest (almost optimal) quantity of agronomic valuable lumps was obtained with physical ripeness of the soil and with its loose and moderately compacted structure. It is important that under these conditions, the rotor speed does not matter much. The soil disintegrates almost equally well into agronomic valuable lumps at both minimum and maximum speed. But when the initial soil structure density of 1.36 g/cm^3 is achieved, grinding is significantly degraded, and with an increase in the rotor speed, there is an obvious tendency to improved crumbling.

2. With a decrease in the output level of soil moisture to the lower limit of plasticity and, especially, to 0.5 physical ripeness of soil, it deteriorates significantly. The lowest crumbling rates (24-34%) are observed at the highest initial soil structure density 1.32 g/cm^3 and higher. But even in this case, increasing the rotor speed raises the quantity of valuable structural lumps.

CONCLUSIONS

It was determined that the output parameters of the soil moisture and structure density significantly affect its grinding by the working bodies of the experimental tillage installation. This process acquires a particularly unfavorable character at the maximum density and minimum soil moisture in the seed layer. The influence of the rotor significantly affects the output of agronomic valuable aggregates (compared with the worst indicators of crumbling). To a certain extent, even the minimum rotor speed is sufficient to optimize crumbling. With increasing rotor speed, there is a clear tendency to improve crumbling, especially with unfavorable parameters of structure density and soil moisture.

REFERENCES:

[1] Syromjatnikov, Ju. N. (2021). Obosnovanie parametrov ryhlitelja pochvoobrabatyvajushhej mashiny stratifikatora. Inzhenernye tehnologii i sistemy. 31, (2), 257-273. [in Russian].

[2] Syromyatnikov, Y. N., Khramov, N. S. (2021). The process of lifting the soil by the working bodies of the tillage looseningseparating unit. Podilian Bulletin: Agriculture, Engineering, Economics. 33, 86-96. [in Ukrainian].

[3] Syromyatnikov, Y. et al. (2021). Productivity of tillage loosening and separating machines in an aggregate with tractors of various capacities. Journal of Terramechanics. 98, 1-6. [In English].

[4] Syromjatnikov, Ju. N., Khramov, N. S. (2020). Opredelenie tjagovogo soprotivlenija ustrojstva dlja podema pochvy v zavisimosti ot ugla postanovki napravljajushhih diskov. Agrarnaja nauka-sel'skomu hozjajstvu, 78–80. [in Russian].

[5] Syromjatnikov, Ju. N. (2018). Rabochie organy dlja podrezanija i podjoma pochvy pochvoobrabatyvajushhej ryhlitel'noseparirujushhej mashiny. Vestnik agrarnoj nauki Dona. 3, 49-56. [in Russian].

[6] Olesen, J.E., Munkholm, L.J. (2007). Subsoil loosening in a crop rotation for organic farming eliminated plough pan with mixed effects on crop yield. Soil and Tillage Research. 94 (2), 376-385. [In English].

[7] Starovojtov, S. I., Ahalaja, B. H., Mironova, A. V. (2019). Konstruktivnye osobennosti rabochih organov dlja uplotnenija i vyravnivanija poverhnosti pochvy. Jelektrotehnologii i jelektrooborudovanie v APK. 4, 51-56. [in Russian].

[8] Chaudhary, V.P., Singh, B. (2002). Effect of zero, strip and conventional till system on performance of wheat. Journal of Agricultural Engineering. 39 (2), 27–31. [In English].

[9] Celik, A., Altikat, S. & Way, T.R. (2013). Strip tillage width effects on sunflower seed emergence and yield. Soil and Tillage Research. 131, 20–27. [In English].

[10] Hossain, M.I. et al. (2014). Strip tillage seeding technique: a better option for utilizing residual soil moisture in rainfed moisture stress environments of north-west Bangladesh. Int J Recent Dev Eng Technol. 2, 132-136. [In English].

[11] Wuest, S. (2007). Vapour is the principal source of water imbibed by seeds in unsaturated soils. Seed Science Research. (1), 3-9. [In English].

[12] Wuest, S.B. (2002). Water transfer from soil to seed. Soil Science Society of America Journal. 66 (6), 1760–1763. [In English].

[13] Arnold, S. *et al*. (2014). Effects of soil water potential on germination of co-dominant Brigalow species: implications for rehabilitation of water-limited ecosystems in the Brigalow Belt bioregion. Ecological Engineering. 70, 35-42. [In English].

[14] Parhomenko, G.G. *et al*. (2021). Agrotehnicheskie i jenergeticheskie pokazateli pochvoobrabatyvajushhih rabochih organov. Inzhenernye tehnologii i sistemy. 30, 1. 109-126. [in Russian].

[15] Hou, X. *et al*. (2012). Effects of rotational tillage practices on soil properties, winter wheat yields and water-use efficiency in semi-arid areas of north-west China. Field crops research. 129, 7-13. [In English].

[16] Koller, K., El Titi, A. (2003). Techniques of soil tillage. Soil tillage in agroecosystems. 1-25. [In English].

[17] Hamza, M.A., Anderson, W.K. (2005). Soil compaction in cropping systems: A review of the nature, causes and possible solutions. Soil and tillage research. 82, (2), 121–145. [In English].

[18] Medvedev, V.V. (2013a). Physical degradation of chernozems. Diagnostics. Causes. The consequences. Warning. Kharkov: City Printing House. 324. [in Russian].

[19] Medvedev, V.V. (2013b). Physical properties and soil treatment in Ukraine. Kharkov: City Printing House. 224. [in Russian].

[20] Medvedev, V.V., Laktionova, T.N. (2011). Granulometric composition of Ukrainian soils (genetic, environmental and agronomic aspects). Kharkov: Apostrophe. 292. [in Russian].

[21] Medvedev, V.V. (2010). Standards are a key element of a high crop culture. Agriculture. 8, 6-7. [in Russian].

[22] Melnik, V.I., Kalyuzhny, O.D., Ridny, R.V. (2017). Liquid chemicals unit dosing and delivery module. Environmental Engineering. 1 (7), 76-79. [in Ukrainian].

[23] Melnik, V.I. et al. (2018). Improvement of the rotary spreader of organic fertilizers. Environmental Engineering. 2 (10), 59-62. [In English].

[24] Aniskevich, L.V. (2005). Control systems for the norms of making materials in precision farming technologies: abstract of the dissertation of the doctor of technical sciences. 36. [in Ukrainian].

[25] Medvedev, V.V. (2007). Soil heterogeneity and precision farming. Kharkov: "13th printing house". 296. [in Russian].

[26] Kunz, C., Weber, J., Gerhards, R. (2015). Benefits of precision farming technologies for mechanical weed control in soybean and sugar beet – comparison of precision hoeing with conventional mechanical weed control. Agronomy. 5 (2), 130-142. [In English].

[27] Cooper, J. et al. (2016). Shallow non-inversion tillage in organic farming maintains crop yields and increases soil C stocks: a meta-analysis. Agronomy for sustainable development. (1). 22. [In English].
[28] Barwicki, J., Gach, S., Ivanovs, S. (2012). Proper Utilization of the Soil Structure for the Crops Today and Conservation for Future Generations. Proceedings of 11-th International Scientific Conference «Engineering for Rural Development». 11, 10-15. [In English].
[29] Bottinelli, N. et al. (2015). Why is the influence of soil macrofauna on soil structure only considered by soil ecologists? Soil and Tillage Research. 146, 118–124. [In English].
[30] Guimarães R.M.L. *et al*. (2013). Relating visual evaluation of soil structure to other physical properties in soils of contrasting texture and management. Soil and Tillage Research. 127, 92–99. [In English].
[31] Nanka, O.V., Syromjatnykov, Ju.M. (2019). Rezul'taty pol'ovyh vyprobuvan' eksperymental'noi' g'runtoobrobnoi' ustanovky. Visnyk Harkivs'kogo nacional'nogo tehnichnogo universytetu sil's'kogo gospodarstva. 201, 191-202. [in Ukrainian].
[32] Nanka, O.V., Siromjatnikov, Ju.M. (2019). Vpliv chastoti obertannja rotora g'runtoobrobnoï eksperimental'noï ustanovki na pokazniki jakosti. Tehnichnij servis agropromislovogo, lisovogo ta transportnogo kompleksiv. 15, 96–110. [in Ukrainian].
[33] Pashchenko V.F., Syromyatnikov Y.N. & Khramov N.S. (2018). G'runtoobrobna ustanovka z vykorystannjam gnuchkogo robochogo organu dlja kontrolju rostu bur'janiv. Vegetable and Melon Growing. 64, 33-43. [in Ukrainian].
[34] Pashhenko, V.F. *et al*. (2016). Obg'runtuvannja docil'nosti derzhavnoi' pidtrymky vitchyznjanogo sil'gospmashynobuduvannja. Visnyk Harkivs'kogo nacional'nogo tehnichnogo universytetu sil's'kogo gospodarstva imeni Petra Vasylenka. 173, 53-68. [in Ukrainian].
[35] Syromjatnykov, Ju.M. (2017). Vdoskonalennja robochyh organiv dlja pidrizannja ta pidjomu g'runtu rozryhljuval'no-separujuchoju mashynoju. Inzhenerija pryrodokorystuvannja. 2, 74-77. [in Ukrainian].

Польові випробування експериментальної ґрунтообробної установки

Д. В. Бабенко

Кандидат технічних наук, Професор
https://orcid.org/0000-0003-2239-4832
Миколаївський національний аграрний університет

М. С. Храмов

https://orcid.org/0000-0002-2537-7344
Миколаївський національний аграрний університет

Ю. М. Сиромятников

Кандидат технічних наук
https://orcid.org/0000-0001-9502-626X
Державний біотехнологічний університет

І. М. Суковіцина

https://orcid.org/0000-0001-5201-7830
Миколаївський національний аграрний університет

Анотація. Розглянуто результати дослідження технологічного процесу обробітку ґрунту, конструктивно технологічні схеми органів ґрунтообробної установки. Експериментально встановлено, що на якість кришіння ґрунту експериментальною розрихлювально-сепаруючою установкою особливий вплив робить вологість та щільність складання, тому при щільності ґрунту 1,3-1,4 г/см^3 та мінімальній вологості ґрунту 11,4-14,4 % частоту обертання ротора необхідно збільшити до 127 об/хв

Ключові слова: обробіток, культивація, шар ґрунту, ротор, диференціація

UDC 595.772; 631.951
DOI: 10.31521/2313-092X/2021-3(111)-11

Ukrainian Black Sea Region Agrarian Science
Vol. 25, No. 3

Analysis of occupational diseases at work in Ukraine

A. Berezovskyi*
PhD in Agricultural Sciences, Associate Professor
https://orcid.org/0000-0002-9526-3721

O. Trus
PhD in Agricultural Sciences, Associate Professor
https://orcid.org/0000-0002-9493-5469

E. Prokopenko
PhD in Agricultural Sciences, Associate Professor
https://orcid.org/0000-0003-4642-7635

Uman National University of Horticulture

Abstract. The study of occupational and industrial diseases is one of the important tools for developing mechanisms for their prevention and injury avoidance. Occupational diseases are a significant part of the general morbidity rates of the population, the cause of large-scale social and economic losses. It includes categories of diseases that occurred on the basis of an individual's professional activity and are mostly caused by the negative flow of production factors and specific types of work. Occupational diseases include diseases caused by the direct effect on people of harmful production factors and certain types of work. In addition, occupational diseases pose a great threat to workers in various fields, both in Ukraine and throughout the world. Thus, the purpose of the article is to study the level of occupational morbidity at work in various regions and branches of the economy of Ukrainian enterprises, to establish the reasons for the occurrence of acute occupational diseases (poisoning), as well as to recommend preventive measures for their prevention. The level of occupational disease at work by region and by economic sector of Ukrainian enterprises was analyzed. It was established that the number of victims of cases of chronic occupational disease (poisoning) at work during the last five years remains high. Most occupational diseases occurred in the extractive industry and quarrying. In 2020, the number of victims of acute occupational disease COVID-19 increased significantly, especially in the health care sector. The practical value of the work consists in establishing the causes of the appearance of occupational diseases, and, as a result, in helping to solve them, as well as providing recommendations on preventive measures that will help prevent the appearance of occupational diseases

Keywords: industrial activity, chronic occupational disease, acute occupational disease, the field of enterprise economy, occupational safety

INTRODUCTION

The analysis of occupational diseases (poisoning) at the factories of Ukraine is one of the main and necessary ways of developing mechanisms for the prophylaxy and prevention of injuries.

Occupational morbidity is an integral part of the general morbidity of the population, the cause of the largest socio-economic costs. It unites the categories of diseases that arose as a result of human professional activity and are caused exclusively or mainly by the influence of harmful production factors and certain types of work. Occupational diseases include, first of all, diseases that arise as a result of the direct effect on

Article's History:
Received: 14.01.2021
Revised: 23.05.2021
Accepted: 26.08.2021

Suggested Citation:
Berezovskyi, A., Trus, O., & Prokopenko, E. (2021). Analysis of occupational diseases at work in Ukraine. *Ukrainian Black Sea Region Agrarian Science*, 25(3), 92-100.

people of industrial harmful factors, as well as those that, under certain industrial conditions, develop much more often than usual. Also, it is impossible not to pay attention to the fact that occupational diseases pose a threat to workers in a wide variety of fields, not only in Ukraine, but all over the world.

An occupational disease is a chronic or acute disease caused by prolonged exposure to harmful industrial factors.

Chronic occupational disease (poisoning) – a disease that arose as a result of the employee's professional activity exclusively or mainly due to the influence of harmful factors of the industrial environment and work process related to work.

An acute occupational disease (poisoning) is an illness (or death) that occurred after a single (during no more than one work shift) exposure of an employee to harmful factors of a physical, biological, and chemical nature (including infectious, parasitic, allergic diseases).

Despite the improvement of the level of occupational safety through the implementation of preventive measures, the development and implementation of modern and safer innovative technologies, new types of individual and collective protection, etc., the issue of occupational morbidity does not lose its relevance today.

The European Agency for Safety and Health at Work notes that although the number of accidents at work has decreased by 25% over the past 10 years, work-related diseases still account for 2.4 million deaths worldwide [1].

The increase in the number of occupational diseases, as well as the increase in public awareness of their consequences, draw the attention of researchers to various aspects of diseases and the importance of improving the state of occupational health and safety. Therefore, there is a need for appropriate information management tools to recognize disease patterns and then make decisions about prevention, early detection, and treatment [2].

According to O.A. Tryukhan [3], occupational diseases cannot be considered as arising as a result of a random coincidence of circumstances, because occupational diseases are always covered by a violation of safety requirements. In order to prevent occupational diseases, it is necessary, first of all, to know and eliminate the causes that cause them, because under this condition, preventive measures can have the desired effect.

The results of the analysis of the labor market at the end of 2020, according to Grafton Recruitment in Slovakia, show that more than half of the employed consider their workload excessive. About 60% of Slovaks feel stressed at work. According to statistics from Everest College in the USA, up to 83% of employees feel stressed at the workplace. In the UK, 79% of workers experience work-related stress [4; 5].

The study of the patterns of the formation of the risk of occupational disease of the working population in the coal, metallurgical and mechanical engineering industries of Ukraine showed that the most dangerous regions for the formation of occupational pathology remain where large enterprises of the leading branches of the national economy (coal, metallurgical, mechanical engineering) are located and where a significant number of workers are concentrated in harmful conditions (Donetsk, Luhansk, Dnipropetrovsk and other regions). The greatest risk of developing occupational pathology was observed in the mining industry (coal, metallurgical, including iron ore), which is associated with a complex of unfavorable production factors (dust, noise, vibration, etc.) during underground mining of minerals [6].

Recently, there has been ongoing controversy over whether or not COVID-19 is an occupational disease. The virus spreads through community spread as well as workplaces and certain work environments. This issue is especially important in those places where there are large cases of infection of workers with the virus, especially in health care facilities [7; 8].

The development of occupational diseases in the world was monitored and evaluated by a large number of authors [9-12]. In their works, they presented retrospective studies that analyzed the structure, causes, occurrence and development trends of occupational diseases during a certain period of time in a certain country.

In Ukraine, among the authors who addressed the study of certain legal aspects of the issue of creating safe and harmless working conditions and made a significant contribution to their development, it is necessary to note such scientists as N.B. Bolotin, P.I. Zhigalkina, A.R. Matsyuk, K.Yu Melnyka, Yu.P. Orlovsky, S.M. Prylypko, V.I. Prokopenko, O.M. Yaroshenko and others. [13-16]. The method of calculating the forecasting of accidents and occupational diseases, their prevention is presented in the works of M.P. Handziuk, E.P. Zhelyby, V.Ts. Zhydetskyi, O.I. Zaporizhia, O.O. Oleinyk [17-20].

The purpose of the article is to investigate the level of occupational morbidity at work by region and by economic sector of Ukrainian enterprises, to establish the circumstances that caused chronic/acute occupational diseases (poisoning) and to propose preventive measures for their prevention.

RESULTS AND DISCUSSION

Characteristics of the phenomenon of occupational diseases at factories. An occupational disease, like any disease, is associated with a certain profession or industry. Such diseases arise as a result of a variety of biological, chemical, physical and psychological factors that are present in the work environment or are encountered in other ways during work activities. Scientific and technical progress, fundamentally changing the nature of work, creates new factors of the production environment that adversely affect workers. In this regard, occupational morbidity is one of the problem areas at Ukrainian enterprises [21].

In any enterprise, organization or institution where a person works, there will always be a threat of illness caused by working conditions. The degree of this threat depends on the specifics of work, the profile of the enterprise, the level of job security and other reasons. Therefore, the detection of occupational diseases contributes to the improvement of occupational safety and hygiene and increases awareness of the harmful effects of work.

The study of chronic/acute occupational diseases (poisoning) at the enterprises of Ukraine was carried out using the statistical method based on official data of the working bodies of the executive directorate of the Social Insurance Fund of Ukraine [22]. For the distribution of chronic/acute occupational diseases (poisoning), indicators of the number of victims at work were used according to these acts in form P-4 and form H-1/P in the cross-section of regions and branches of the economy of enterprises of Ukraine.

During the study, occupational diseases (poisoning) that occurred at enterprises located in populated areas, on the territory of which state authorities temporarily do not or do not fully exercise their powers in accordance with the Decree of the Cabinet of Ministers of Ukraine dated November 7, 2014, were not taken into account. No. 1085.

Studies of the dynamics of the level of occupational morbidity in Ukraine during 2016-2020 indicate that the number of cases of chronic occupational diseases (poisoning) at work, according to acts P-4 [22], remains at a high level (Fig. 1).

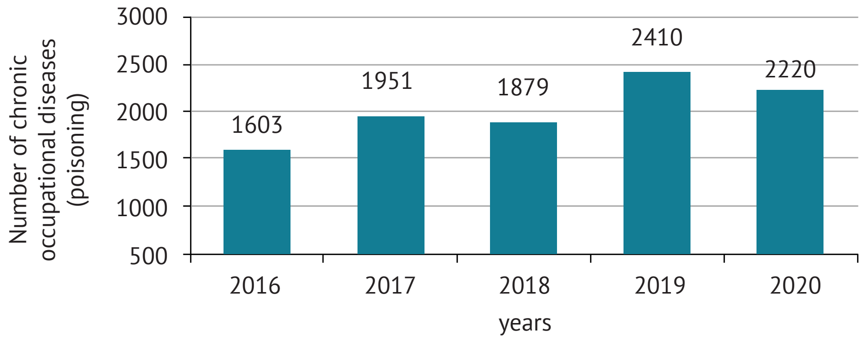

Figure 1. *Dynamics of the number of cases of chronic occupational diseases (poisoning) at work in Ukraine according to the data of Acts P-4 for 2016-2020*

Source: *[22]*

Figure 1 shows that the number of victims of chronic occupational diseases (poisoning) at work in 2017 compared to 2016 increased by 348 people, or by 21.7%. In 2018, compared to 2019, the number of chronic occupational diseases (poisoning) decreased by 72 cases, or 3.7%. In 2020, the number of chronic occupational diseases (poisoning) compared to 2016 increased by 617 cases, or by 38.5%. The highest level of occupational disease at work in Ukraine was observed in 2019 – 2,410 cases, which is 1.5 times more than the number in 2016.

In 2020, the working bodies of the executive directorate of the Social Insurance Fund of Ukraine received and registered 2,242 reports of chronic occupational diseases (poisoning), which is 6.8% less than in 2019. A significant increase in the number of reports of chronic occupational diseases (poisoning) occurred in: Zaporizhzhia region – by 1.6 times and Donetsk region – by 21.2%. A decrease in the number of reports of chronic occupational diseases (poisoning) was observed in Lviv Region, Dnipropetrovsk Region, Sumy Region, Kirovohrad Region, and Volyn Region.

For clarity, we will display the distribution of the number of cases of chronic occupational diseases (poisoning) at work by regions of Ukraine in Table 1. It has been investigated that a significant increase in the number of victims of chronic occupational diseases (poisoning) at work in 2020 compared to 2016 occurred in: Donetsk Region – by 307 cases, or 2.9 times, Dnipropetrovsk Region – by 206 cases, or 28.6%, Kirovohrad Region – by 77 cases, or 2.2 times, Zaporizhia Region – by 69 cases, or 2.6 times, Luhansk region – in 36 cases, or 1.7 times. In 2019, the largest number of chronic occupational diseases (poisoning) was registered in the Dnipropetrovsk region – 1,015 cases.

A decrease in the number of victims of chronic occupational diseases (poisoning) at work is noted in: Volyn region – by 25 cases, or 28.1%, Sumy region – by 21 cases, or 2.6 times, Kharkiv region – by 12 cases, or 29.3%, Cherkasy Region – six times, or 6 times, Vinnytsia Region – in four cases, or 3 times, in Zhytomyr region – in four cases, or 25%, and in the city of Kyiv – in two cases, or 33.3%. The number of victims who received chronic occupational diseases (poisoning) in these regions is, on average, 78.7% of the total number of victims in Ukraine who have occupational diseases during the relevant research period.

Table 1. *Distribution of chronic occupational diseases (poisoning) by regions of Ukraine according to the data of acts P-4 for 2016-2020*

Regions	Years				
	2016	2017	2018	2019	2020
city of Kyiv	6	9	11	2	4
Vinnytsia Region	6	5	4	3	2
Volyn Region	89	50	69	86	64
Dnipropetrovsk region	720	674	811	1015	926
Donetsk Region	156	319	316	382	463
Zhytomyr region	16	13	18	15	12
Zaporizhia Region	43	47	44	76	112
Kirovohrad Region	64	74	77	187	141
Luhansk region	48	31	68	91	84
Lviv Region	358	595	347	436	359
Sumy region	34	47	45	66	13
Kharkiv region	41	51	46	26	29
Cherkasy Region	7	9	4	8	1
Others Regions	15	27	19	17	10

Source: *[22]*

It was established that the most injury-prone regions of Ukraine in terms of the number of victims of chronic occupational diseases (poisoning) at work, on average for 2016-2020, are Dnipropetrovsk Region (43.1%), Lviv Region (21.1%), Donetsk Region (15.9%), Kirovohrad Region (5.2%), Volyn Region (3.6%), Luhansk Region (3.2%), Zaporizhzhia Region – (3.1%), Sumy Region (2%) and Kharkiv Region (2%) of the region. The number of victims of occupational diseases in these regions is 97.5% of the total number in Ukraine (Fig. 2).

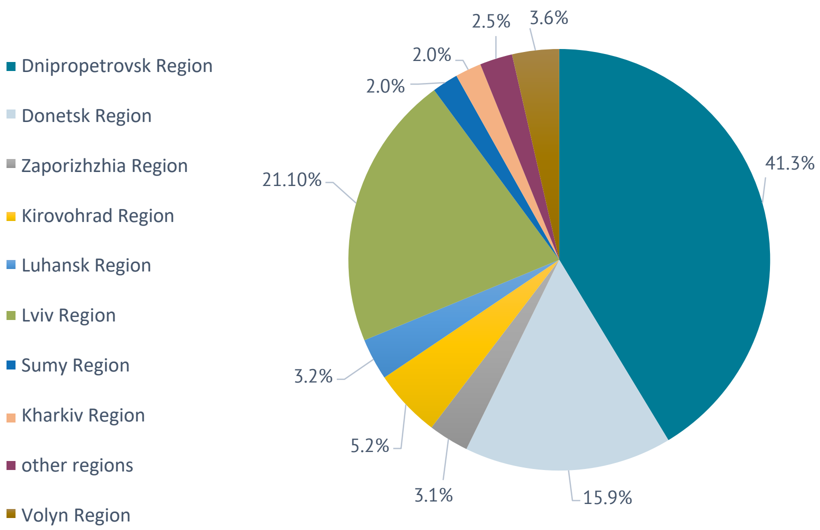

Figure 2. *Distribution of the most injury-prone regions of Ukraine by the number of chronic occupational diseases (poisoning) in 2016-2020, % of the total number in Ukraine*

Occupational diseases threaten workers in a wide variety of industries not only in Ukraine, but all over the world. Any favorite and desired work is not immune to certain risks and troubles. Any profession can be associated with danger and harm to health. Economic losses caused by work-related diseases and accidents amount to 4.0-6.0% of the gross domestic product of the respective countries and regions in the world. The problem of occupational health and safety is present all over the world, but in China a much larger number of workers are at risk due to the relatively larger number of the working population in the country [23].

Analysis of indicators of morbidity due to professional activity. The study of occupational diseases at work is one of the main and necessary ways of developing prevention mechanisms and their prevention at this or that production facility or at production as a whole. Considering the socio-economic situation in Ukraine, the distribution of the number of occupational diseases (poisoning) is closely related to the state of individual sectors of the economy of enterprises (Table 2).

Table 2. *Distribution of chronic occupational diseases (poisoning) by economic sector of Ukrainian enterprises according to the data of acts P-4 for 2016-2020*

Branches of the economy	Years				
	2016	2017	2018	2019	2020
Mining and quarrying	1311	1612	1580	2038	1913
Production of machines and equipment	67	97	98	98	50
Metallurgical production, production of finished metal products, except for machines and equipment	68	65	57	79	105
Other types of processing industry, repair and installation of machines and equipment	33	38	33	43	48
Health care	29	29	–	–	–
Production of coking coal and oil refining products	31	25	23	55	32
Construction	–	–	22	31	27
Other industries	64	85	66	66	45

Source: *[22]*

From the data of Table 2, it can be seen that an increase in the number of cases of chronic occupational diseases (poisoning) at work in 2020, compared to 2016, was observed at enterprises of such branches of the economy as: extractive industry and quarry development – by 602 cases, or 45.9%; metallurgical production, production of finished metal products, except for machines and equipment – in 37 cases, or 54.4%; construction – in 27 cases; other types of processing industry, repair and installation of machines and equipment – in 15 cases, or 45.5%; production of coke and oil refining products – for one case, or 3.2%.

A decrease in the number of victims of chronic occupational diseases (poisoning) at work is noted in such sectors of the economy as: health care – by 29 cases, other industries – by 19 cases, or 29.7%, and the production of machinery and equipment – by 17 cases, or 25.4%.

The distribution of the most trauma-hazardous sectors of the economy of Ukrainian enterprises by the number of victims of chronic occupational diseases (poisoning) is shown in fig. 3. It was established that among the most trauma-hazardous sectors of the economy of Ukrainian enterprises in terms of the number of chronic occupational diseases (poisoning), on average for 2016-2020., include: mining and quarrying (83.8%), production of machinery and equipment (4.1%), metallurgical production, production of finished metal products, except for machinery and equipment (3.7%), other types of processing industry, repair and installation of machines and equipment (1.9%), production of coke and oil refining products (1.6%), health care and construction (0.7%, respectively). The number of victims of occupational diseases in these sectors of the economy is 96.7% of the total number in Ukraine.

The main circumstances that caused chronic occupational diseases (poisoning) at work were: imperfection of the technological process – 24.5%, imperfection of mechanisms and work tools – 18.7%, and failure to use personal protective equipment – 11.6% of their total number. In the structure of occupational diseases (poisoning), the first place belongs to respiratory diseases – 40.2% of the total number of diagnoses in Ukraine. In second place are diseases of the musculoskeletal system (radiculopathy, osteochondrosis, arthritis, arthrosis) – 27.7%. The third place for hearing diseases – 17.4%, the fourth in terms of vibration disease – 6.6%.

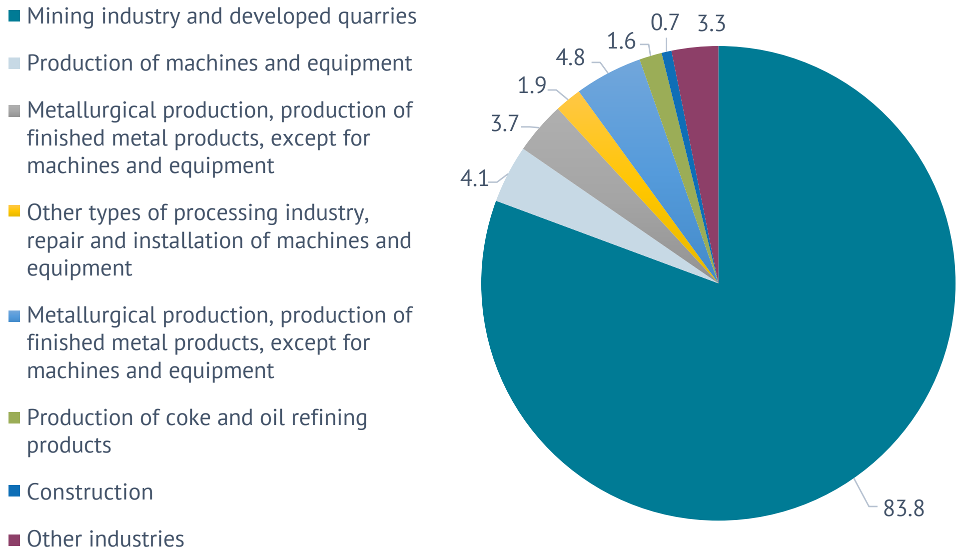

Figure 3. *Distribution of the most injury-prone sectors of the economy of Ukrainian enterprises by the number of chronic occupational diseases (poisoning) in 2016-2020,% of the total amount in Ukraine.*

Based on the results of research, it was established that due to the coronavirus pandemic in Ukraine, the number of victims of acute occupational disease (poisoning) at work has increased significantly. Thus, in 2020, 3,054 victims of cases of acute occupational disease with a diagnosis of COVID-19 were registered in Ukraine, for which an act in the form of H-1/П, related to production [22] was drawn up, which is 46% of the total number victims during this period. A significant part of the victims are health care workers, which is caused by cases of infection of medical and other workers with COVID-19, whose work is related to the performance of professional duties in conditions of increased risk of infection. From fig. 4 shows that the largest number of cases of acute occupational disease diagnosed with COVID-19 were registered in: Kyiv region – 401 cases, or 13.1%, Kyiv city – 288 cases, or 9.4%, Kharkiv region – 262 cases, or 8.6%, Lviv region – 221 cases, or 7.2%, Khmelnytskyi region – 219 cases, or 7.2% and Ivano-Frankivsk region – 210 cases, or 6.9%. The number of cases of acute occupational disease with a diagnosis of COVID-19 in these regions is 52.4% of the total number of injured people in Ukraine.

It was established that in 2020, 66 fatalities from cases of acute occupational disease (poisoning) with a diagnosis of COVID-19 were registered in the regions of Ukraine (Fig. 5), for which an act in the form of H-1/P related to production was drawn up , which is 16.8% of the total number of victims during this period. From the data of fig.5 shows that the largest number of fatal cases of acute occupational disease (poisoning) diagnosed with COVID-19 were registered in: Lviv region – 10 cases, or 15.1%, Kyiv region – eight cases, or 12.1%, Vinnytsia region – six cases, or 9.1%, Zakarpattia, Odesa, and Chernivtsi regions – five cases, or 7.6%, respectively. The number of fatal cases of acute occupational disease with a diagnosis of COVID-19 in these regions is 59.1% of the total number of injured people in Ukraine.

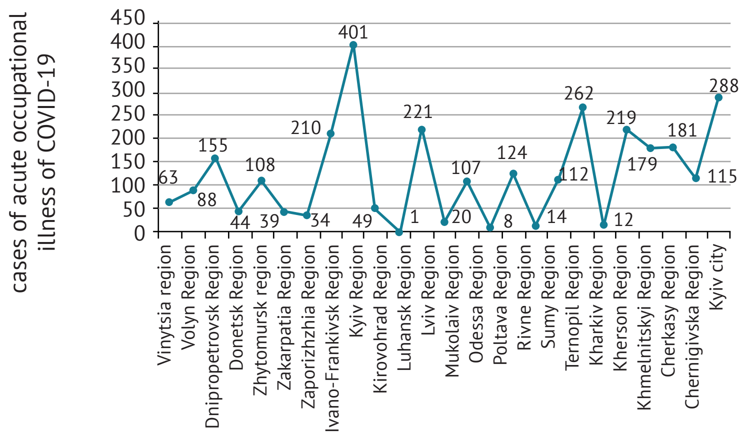

Figure 4. *Number of victims of cases of acute occupational illness of COVID-19 by regions of Ukraine in 2020, persons*

Source: [22]

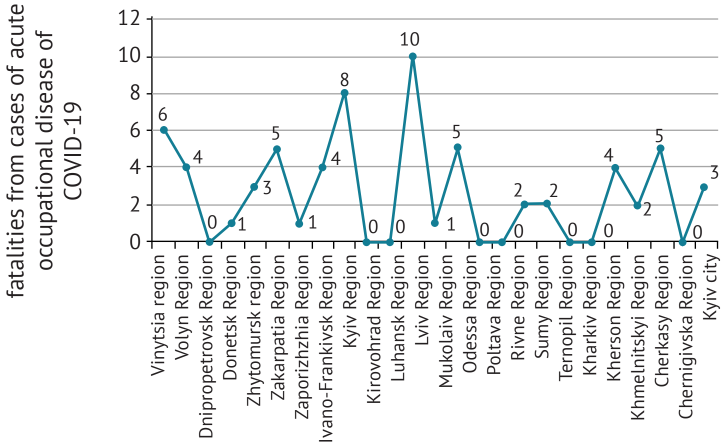

Figure 5. *Number of fatalities from cases of acute occupational disease of COVID-19 by regions of Ukraine in 2020, persons*

Source: *[22]*

The largest number of victims of cases of acute occupational disease of COVID-19 was observed among workers of the following professions: medical nurse (medical brother), junior medical nurse (junior medical brother) for patient care, junior medical nurse (sanitary cleaner, sanitary barista, etc.), a general practitioner – a family doctor and a medical nurse (medical brother) of a hospital.

CONCLUSIONS

The study of occupational morbidity by region and economic sector of Ukrainian enterprises indicates that over the past five years, the number of victims of chronic occupational disease (poisoning) at work has increased by 38.5%. The main reasons for the occurrence of chronic occupational diseases (poisoning) are the imperfection of the technological process, the imperfection of mechanisms and working tools, as well as the failure to use personal protective equipment. In the structure of occupational diseases, a significant share belongs to diseases of the respiratory organs, diseases of the musculoskeletal system, hearing diseases, and vibration diseases.

It has been established that the most traumatic regions of Ukraine in terms of the number of cases of chronic occupational disease (poisoning) are Dnipropetrovsk Region, Lviv Region, Donetsk Region, Kirovohrad Region, Volyn Region, Luhansk Region, Zaporizhia Region, Sumy Region, and Kharkiv Region, which accounts for 97.5% of the total number of victims. The mining industry and quarry development remains the most dangerous branch of the economy of Ukrainian enterprises in terms of the number of chronic occupational diseases (poisoning) at work – 83.8%.As a result of the spread of the coronavirus disease, there was a sharp increase in the number of victims of cases of acute occupational disease COVID-19 at work, which is 46% of their total number. A significant part of the victims are medical and other workers whose work is related to the performance of professional duties in conditions of increased risk of infection with COVID-19.

Therefore, in order to reduce the level of occupational disease and preserve the health of workers, employers must ensure the implementation and compliance by all employees of the following preventive measures: conducting training on occupational safety and industrial sanitation, reducing the working time of workers in harmful working conditions, implementing automatic and remote control of production equipment, providing employees with means of individual and collective protection, carrying out medical and preventive measures, strengthening the responsibility of employers and key specialists for the state of working conditions and its safety.

Prospects for further research. One of the priority tasks of the state is the creation of safe and healthy working conditions aimed at reducing the risks of occupational diseases at work, and therefore it remains one of the promising areas of research.

REFERENCES:

[1] Skrzypczak, A. (n.d.) *Work-related diseases*. Retrieved from https://osha.europa.eu/en/themes/work-related-diseases.

[2] Somayeh, D., Khosro, S.H., Sharareh, R.N.K., Narges, Sh.H., Zeinab, M., & Reza, S. (2017). Occupational disease registries – characteristics and experiences. *Acta Informatica Medica*, 25(2), 136-140.

[3] Tryukhan, O.A. (2018). Prevention of occupational diseases: Theoretical aspect. *Legal Scientific Electronic Journal*, 4, 66-69.

[4] Pracovný stres ovplyvňuje výkon dvoch tretín zamestnancov na Slovensku. Retrieved from https://www.webnoviny.sk/pracovny-stres-ovplyvnuje-vykon-dvoch-tretin-zamestnancov-na-slovensku.

[5] Piňosova, M., Andrejiova, M., Badida M., & Moravec M. (2021). Occupational disease as the bane of workers' lives: a chronological review of the literature and study of Its development in Slovakia. Part 1. *International Journal of Environmental Research and Public Health,* 18, 1-29. doi: 10.3390/ijerph18115910.

[6] Nagorna, A.M., Witte, P.M., Sokolova, M.P., Kononova, I.G., Orekhova, O.Z., & Mazur V.V. (2012). Assessment of the risk of developing occupational diseases among workers in the metallurgical, coal industry, and mechanical engineering of Ukraine. *Ukrainian Journal on Problems of Occupational Medicine*, 3(31), 3-13.

[7] Androschuk, H. (n.d.). *COVID-19 is an occupational disease: the demand of doctors*. Retrieved from https://yur-gazeta.com/publications/practice/medichne-pravo-farmacevtika/covid19--profesiyne-zahvoryuvannya-vimoga-likariv.html.

[8] Kowalska, K. (2020). *Koronawirus: lekarze apelują o uznanie COViD–19 za chorobę zawodową*. Retrieved from https://www.rp.pl/sluzba-zdrowia/art796851-koronawirus-lekarze-apeluja-o-uznanie-covid-19-za-chorobe-zawodowa.

[9] Kudász, F., Nagy, K., & Nagy, I. (2017). Occupational diseases in Belgium, the Czech Republic and Hungary – a comparison. Central European journal of occupational and environmental medicine, 23(1-2), 32-49.

[10] Gómez, M.G., López, R.C., Ortiz, Z.H., & Soria F.S. (2017). Differences in the recognition of occupational diseases by sex, occupation and business activity in Spain (1990–2009). *Revista Española de Salud Pública*, 91, 1-12.

[11] Oksa, P., Sauni, R., Talola, N., Virtanen, S., Nevalainen, J., Saalo, A., & Uitti, J. (2019). Trends in occupational diseases in Finland, 1975-2013: a register study. *BMJ Open*, 9, 1-8.

[12] Rushton, L., Hutchings, S.J., Fortunato, L., Young, C., Evans, G.S., Brown, T., Bevan, R., Slack, R., Holmes, Ph., Bagga, S., Cherrie, J.W., & Tongeren, M.V. (2012). Occupational cancer burden in Great Britain. *British Journal of Cancer*, 107, 53-57.

[13] Bolotina, N.B. (2000). The human right to social security in Ukraine: problems of terms and concepts. *Law of Ukraine*, 4, 35-39.

[14] Zhigalkin, P.I., Prilypko, S.M., Yaroshenko, O.M. (2008). *Court practice and its significance for regulating relations in the labor sphere: a monograph*. Kharkiv: FINN.

[15] Melnyk, K.Yu. Science of labor law and codification of labor legislation: In *the VI All-Ukrainian scientific and practical conference "Directions of development of the science of labor law and social security law"* (pp.29-31). Kharkiv: Kharkiv National University of Internal Affairs.

[16] Prokopenko V. I. (1998). *Labor law: a textbook*. Kharkiv: Konsum.

[17] Handziuk, M.P., Zhelibo, E.P., & Khalimovskyi, M.O. (2011). *Fundamentals of labor protection (5th edition)*. Kharkiv: Karavela, 2011. 384 p.

[18] Zhydetsky, V.Ts., Dzhigirei, V.S., & Melnikov, O.V. (2000). *Fundamentals of labor protection: a textbook* (5th ed). Lviv: Afisha.

[19] Zaporozhets, O.I., Khalmuradov, B.D., Prymenko, V.I., Zaplatinskyi, V.M., Mykhailiuk, V.O., & Konitsula, T.Ya. (2013). *Life safety: a textbook*. Kyiv: Center of Educational Literature.

[20] Oliinyk, O.O. (2020). Social responsibility assessment in the field of employment (case study of manufacturing). *Scientific Bulletin of National Mining University*, 3, 131-136.

[21] Gordiychuk, L.M. (2017). Aspects of industrial injuries and occupational morbidity. *Scientific Bulletin of S. Z. Gzhitskyi LNUVMBT*, 76(19), 136-138.

[22] Social Insurance Fund of Ukraine. Retrieved from http://www.fssu.gov.ua/fse/control/main/uk/publish/category/919872.

[23] Yaoqin, L, Huan, Ya., Lijiang, Z., & Jiwen, L. (2019). A comparative study on the prediction of occupational diseases in China with hybrid algorithm combing models. *Computational and Mathematical Methods in Medicine*. doi: 10.1155/2019/8159506.

Аналіз професійних захворювань на виробництві в Україні

А. П. Березовський
Кандидат сільськогосподарських наук, доцент
https://orcid.org/0000-0002-9526-3721

О. М. Трус
Кандидат сільськогосподарських наук, доцент
https://orcid.org/0000-0002-9493-5469

Е. В. Прокопенко
Кандидат сільськогосподарських наук, доцент
https://orcid.org/0000-0003-4642-7635

Уманський національний університет садівництва

Анотація. Проаналізовано рівень професійної захворюваності на виробництві по регіонах і за галузями економіки підприємств України. Встановлено, що кількість потерпілих від випадків хронічного професійного захворювання (отруєння) на виробництві протягом останніх п'яти років залишається високою. Найбільше професійних захворювань сталося в галузі добувної промисловості і розробленні кар'єрів. У 2020 році значно збільшилася кількість потерпілих від випадків гострого професійного захворювання COVID-19, особливо в галузі охорони здоров'я

Ключові слова: виробнича діяльність, хронічне профзахворювання, гостре профзахворювання, галузь економіки підприємств, безпека праці

Editorial Board

UKRAINIAN BLACK SEA REGION AGRARIAN SCIENCE

Scientific Journal

Volume 25, No. 3. 2021

Year of establishment: 1997
Publication frequency: Four times a year

The original layout of the publication was made in the Publishing Department
of Mykolaiv National Agrarian University

Editing English-language texts:
S. Vorovsky, K. Kasianov

Desktop publishing:
M. Kryshtal

Signed for print of August 26, 2021
Format 60*84/8
Conventional printed pages 11.4
Circulation 300 copies

Publishing Address:
Mykolaiv National Agrarian University
54008, 9 Georgiy Gongadze Str., Mykolaiv, Ukraine
tel.: +38(0512) 70-93-54
E-mail: info@bsagriculture.com.ua
www: https://bsagriculture.com.ua/en