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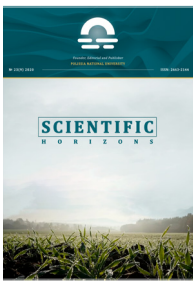

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Morphofunctional Features of Limphoid Tissue of the Stomach in Some Wild Bird Species

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Abstract. The article presents the results of histological studies of topography, microstructure and functional features of the stomach lymphoid tissue in birds. The research was carried out on 12 species of wild birds belonging to 6 orders. Classical methods of histological specimens staining with hematoxylin and eosin, according to Weigert, Van Gieson, and argentum nitrate impregnation according to Kelemen were used when performing the work. It has been confirmed that the birds' stomach has glandular (proventriculus), muscular (ventriculus, gizzard) and pyloric parts, which are not equally expressed in separate species. In all parts of the stomach, lymphoid tissue is represented by local clusters, which in birds of the orders Galliiformes (*P. colchicus, B. bonasia, P. crictatus*); Anseriformes (*B. canadensis*); Passeriformes (*P. pica, C. cornix*); Gruiformes (*G. chloropus, F. atra*); Piconiiformes (*C. piconia*) and Columbiiformes (*C. livia*) are located in the tunica mucosa and submucosa, and in *B. canadensis, F. atra, G. chloropus* also in the tunica muscularis and tunica serosa. In *L. lagopus* and *G. glandarius*, lymphoid tissue has been found only in the proventriculus and its intermediate zone. Structural levels of lymphoid tissue (diffuse form, prenodules, primary and secondary lymphoid nodules) are unequally expressed in the birds' stomach. In *B. bonasia, B. canadensis, P. pica, C. cornix, C. piconia, C. livia*, only a diffuse form appears in all its parts. This form of lymphoid tissue is registered in the ventriculus of other birds species and proventriculus in *L. lagopus* and *G. glandarius*. All levels of the lymphoid tissue structural organization are detected in the proventriculus in *P. crictatus, G. chloropus* and in the proventriculus and pyloric part of the stomach in *P. colchicus* and *F. atra*. The content of lymphoid tissue is different in parts of the birds' stomach. Most of all it is contained in the intermediate zone of the proventriculus and the pyloric part of the stomach. Diffuse form is the most common among the levels of lymphoid tissue structural organization. The research results make it possible to more fully assess the morphofunctional status of wild birds and, accordingly, to find out the state of their immune system

Keywords: digestive system, microstructure, immune formations, lymphoid nodules, lymphoid cells

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INTRODUCTION

It is known that lymphoid tissue forms the functional basis of peripheral organs of hemo- and lymphopoiesis and lymphoid (immune) formations localized in the wall of tubular organs. In them, when exposed to antigens, lymphocytes differentiate into effector cells that determine specific immunity [1].

Despite the significant role of stomach lymphoid tissue in maintaining homeostasis, its structure and, accordingly, functional features in wild birds have been insufficiently studied and require significant clarification. This concerns the topography, features of the location, area and content of separate levels of its structural organization. Information about structure of the birds' stomach and its parts in accordance with the requirements of the modern anatomical nomenclature of these animals demands significant clarifications.

The avian stomach is an enlarged part of the digestive tube and is located between the esophagus and intestines [1]. The general structure of the stomach is typical for all species of birds, but due to the fact that the range of their feed specialization is very wide, it has some specific features. In this regard, it is conventionally divided into three groups. The first group includes the stomach of carnivorous birds, the main function of which is to preserve food. The stomach of granivorous birds belongs to the second group. Its main function is the mechanical processing of the feed. The third group of stomachs is characteristic of herbivorous birds, the main function of which is the storage and mechanical processing of feed [2].

Until recently, it was believed that the avian stomach consists of two parts: proventriculus and ventriculus [3]. According to the modern International anatomical nomenclature of birds [4], three parts are distinguished in it: proventriculus, ventriculus and pyloric, not equally expressed in certain species. The proventriculus is an extension of the esophagus, spindle-shaped and consists of an apex, a body and an intermediate zone (isthmus) [5]. It connects to the esophagus by a narrower apex directed cranially, and with ventriculus by a short intermediate zone located caudally [6]. The ventriculus has a disc-like shape and passes into the pyloric part, from which the duodenum begins. The pyloric part is well developed in wild bird species and poorly expressed in poultry.

The wall of all parts of the stomach is formed by *tunica mucosa, tela submucosa, tunica muscularis and tunica serosa* [7]. Local clusters of lymphoid tissue, which form the functional basis of immune (lymphoid) formations, occur in the mucosa (*tunica mucosa*) and submucosa (*tela submucosa*). They are classified as the part of peripheral immune system. Inside these formations, as well as in other similar formations of digestive organs, the process of T- and B-lymphocytes proliferation takes place under antigenic influence.

According to some authors [8; 9], the development of immune formations in the birds digestive tract depends on their feed specialization. In its development, lymphoid tissue has four levels of structural organization: diffuse form, prednodules, primary and secondary lymphoid nodules, which develop in the given sequence and provide the needs of the animal organism at certain stages of its formation. The presence of all structural organization levels of lymphoid tissue in peripheral organs indicates its complete morphofunctional maturity, that is, the ability to give a full immune response to antigens impact [10].

Lymphoid tissue is unevenly located in parts of the birds' stomach. Its highest content is found in the sphincters area of intermediate zone and pyloric part, which regulate the food flow to ventriculus and the duodenum, respectively [9]. According to separate authors [2; 11], large lymphoid tissue clusters are concentrated in transition zone of the proventriculus to the ventriculus.

The purpose of this study was establish the morphofunctional features of stomach lymphoid tissue in wild birds.

MATERIALS AND METHODS

The studies were carried out during 2015-2020 in the scientific laboratory of immunomorphology, Department of anatomy, histology and pathomorphology of animals named after acad. V.G. Kasyanenko National University of Life and Environmental Sciences of Ukraine, Kyiv. Material for research was selected from 12 species of mature wild birds belonging to 6 orders (Table 1). The material was selected from the funds of the I.I. Shmalhausen Institute of Zoology of the National Academy of Sciences of Ukraine. It was stored in containers with a 10% formalin aqueous solution. The birds were clinically healthy and showed no signs of disease. All interventions and slaughter of the birds were performed in compliance with the requirements of the European Convention for the Protection of Vertebrate Animals Used for Experimental and Scientific Purposes (Strasbourg, 1986) [12] and the Decree of the First National Congress on Bioethics (Kyiv, 2001) [13].

Table 1. *Bird species which histological material was used in the study*

Order	Species	Number
Galliformes	*Phasianus colchicus* Linnaeus, 1758	5
	Bonasa bonasia (Linnaeus, 1758)	3
	Lagopus lagopus (Linnaeus, 1758)	3
	Pavo crictatus Linnaeus, 1758	3

Table 1, Continued

Order	Species	Number
Anseriformes	*Branta canadensis* (Linnaeus, 1758)	3
Passeriformes	*Pica pica* (Linnaeus, 1758)	3
	Garrulus glandarius (Linnaeus, 1758)	3
	Corvus cornix Linnaeus, 1758	3
Gruiformes	*Gallinula chloropus* (Linnaeus, 1758)	3
	Fulica atra Linnaeus, 1758	3
Ciconiiformes	*Ciconia ciconia* (Linnaeus, 1758)	3
Columbiformes	*Columba livia* Gmelin, 1789	3

Birds dissection and stomach preparation were performed according to existing guidelines [14]. Parts of the stomach were cut lengthwise with sharp-pointed scissors and carefully freed from the contents. The cuticle was also removed in the gizzard. From each part of the stomach with a sharp-pointed scalpel, pieces of their wall 1 cm long and 1 cm wide were cut out, which were labeled. The collected material was washed in running water for 24 hours. After that, it was dehydrated in alcohols of increasing concentration (50%; 60%; 70%; 80%; 96%; absolute alcohol). In each alcohol the material was kept for 2-3 hours. Then it was cleared and embedded in paraffin according to the generally accepted technique. The paraffin-embedded material was placed on wooden blocks. From the obtained blocks, with the help of a sled microtome MPS-2, histological sections with a thickness of 5-10 μm were made and placed on slides. Sections were stained with Karatsi hematoxylin and eosin – to establish the general microstructure of the stomach and its lymphoid tissue, according to Weigert – to detect elastic fibers, according to van Giezon – to identify collagen fibers and impregnated with silver nitrate according to Kelemen – for registrationof reticular fibers. Stained and impregnated sections were immersed into Canadian balm and examined with an Olympus light microscope.

Individual histopreparations and their fragments were photographed with a Nicon Coolpix S3100 camera. To compare the area and levels of structural organization of lymphoid tissue in parts of the stomach were used morphometric methods.

RESULTS AND DISCUSSION

General microstructure of the avian stomach

The avian stomach has three parts: glandular proventriculus, muscular ventriculus (gizzard) and pyloric. Each of these parts is formed by the *tunica mucosa, tela submucosa, tunica muscularis and tunica serosa*. Its mural organization have been similarly described in many bird species such as the Japanese quail [1], the Coot bird [15], the pigeon [11], the common moorhen [10].

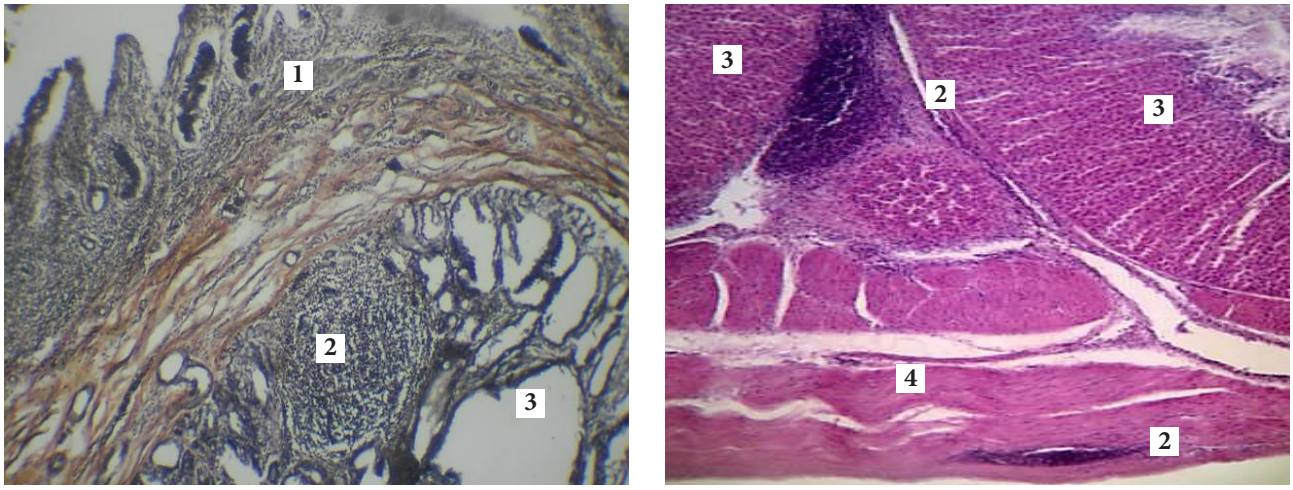
The proventriculus *tunica mucosa* forms low longitudinal folds and is represented by the epithelium, lamina propria and lamina muscularis mucosae. The lamina epithelialis mucosae is a simple columnar and glandular. The lamina propria is formed by loose fibrous connective tissue. It is penetrated by numerous simple, weakly branched glands. The lamina muscularis mucosae is well developed and is represented by bundles of longitudinally oriented smooth muscle cells. The submucosa, like the lamina propria, is formed by loose fibrous connective tissue. It contains lobules of deep glands. Their excretory ducts open on the *tunica mucosa* surface with papillae. The structure of the deep glands lobules of the in birds of the studied species has its own species features. There are no deep glands in the area of the intermediate zone. In birds of certain species, the epithelium of the intermediate zone is covered with a delicate cuticle. The *tunica muscularis* of this zone is formed by three layers of smooth muscle cells: internal oblique, middle circular and external longitudinal (the latter is poorly developed in many bird species). Between the outer and middle layers of the *tunica muscularis,* layers of loose fibrous connective tissue with blood and lymphatic vessels and nerve plexuses are revealed. The *tunica serosa* is formed by loose fibrous connective tissue, which is externally covered with mesothelium.

The gizzard is disc-shaped. On its lateral surfaces, tendon mirrors are visible, and in the cranial and caudal regions – the blind sacs of the same name. The intermediate zone of the proventriculus opens into the cranial blind sac. On the right lateral surface of the gizzard is the pyloric part, from which the duodenum begins. Simple cuboidal epithelium lined the surface of the *tunica mucosa*. The lamina propria contained simple tubular glands. Known, they produce a secret that forms a cuticle on the surface of the stomach mucosa, which performs a protective function. Its density varies in different species of birds. The lamina muscularis mucosae is absent in the *tunica mucosa*. The submucosa is represented by dense fibrous connective tissue. The *tunica muscularis* is best developed. It is formed by massive bundles of smooth muscle cells that form muscles. The pyloric part of the stomach is similar in structure to the gizzard, but its *tunica muscularis* is poorly developed, but lamina muscularis mucosae appears. It is formed by fragmented bundles of smooth muscle cells.

Morphofunctional features of the avian stomach lymphoid tissue

The results of carried studies confirm the data of other authors [15] that in most bird species the stomach lymphoid tissue is associated with its *tunica mucosa* and *tela submucosa*. Thus, this tissue was found in all parts of the birds' stomach of the orders Galliiformes (*P. colchicus, B. bonasia, P. crictatus*) Anseriformes (*B. canadensis*) Passeriformes (*P. pica, C. cornix*) Gruiformes (*G. chloropus, F. atra*) Ciconiiformes (*C. ciconia*) and Columbiiformes (*C. livia*). In *L. lagopus* and *G. glandarius,* lymphoid tissue was recorded only in the proventriculus and its intermediate zone, and it was not detected in other parts of it. In birds of the orders Anseriformes and Gruiformes, single clusters of this tissue are also contained in the *tunica muscularis* and *tunica serosa*. In this regard, it is proposed to distinguish the lymphoid tissue of the mucosa, muscularis and serosa based on the location in the stomach.

Lymphoid tissue in the lamina propria of the *tunica mucosa* of the birds stomach is located under the surface glands and between them, and in the submucosa of proventriculus – in the lobules of deep glands and between them (Fig. 1a, b) (except *B. bonasia, L. lagopus, P. pica, G. glandarius, C. cornix* and *C. ciconia*). Local clusters of lymphoid tissue in the submucosa are detected mainly around the blood vessels in the intermediate zone, the gizzard and pyloric parts of the stomach. In some species of birds, they pass along the blood vessels into the *tunica muscularis* [6].



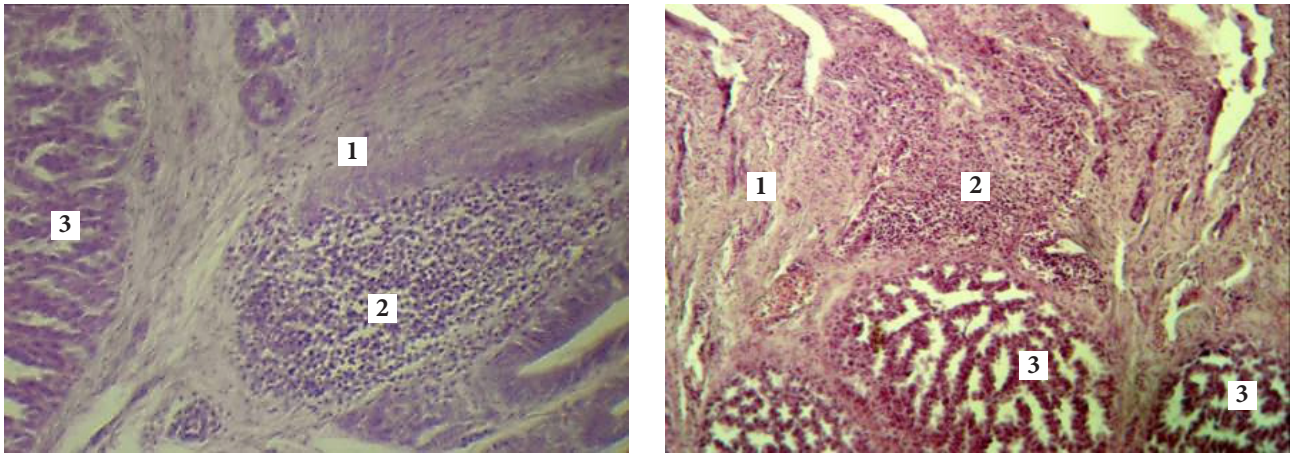
a) b)

Figure 1. *Proventriculus of C. livia (a) and F. atra (b): 1 – lamina propria mucosae; 2 – lymphoid tissue; 3 – lobules of the deep glands; 4 – tunica muscularis. Van–Gieson, ×100; H&E staining, ×90*

Lymphoid cells in the areas of lymphoid tissue localization infiltrate the lamina epithelialis mucosae and the glands epithelium, and are also occasionly detected in the lumens of latter. Similar processes in the stomach of various bird species have been observed by other researchers [16]. In the stomach *tunica muscularis*, lymphoid tissue clusters occur as its continuation from the *tunica mucosa*. In birds of the Anseriformes orders, they are located around the blood vessels in all its parts, in Gruiformes, and in some species of Galliformes (*P. colchicus*) – in the gizzard and pyloric parts of the stomach. In *F. atra*, lymphoid tissue is found in the *tunica muscularis* of the proventriculus and its intermediate zone.

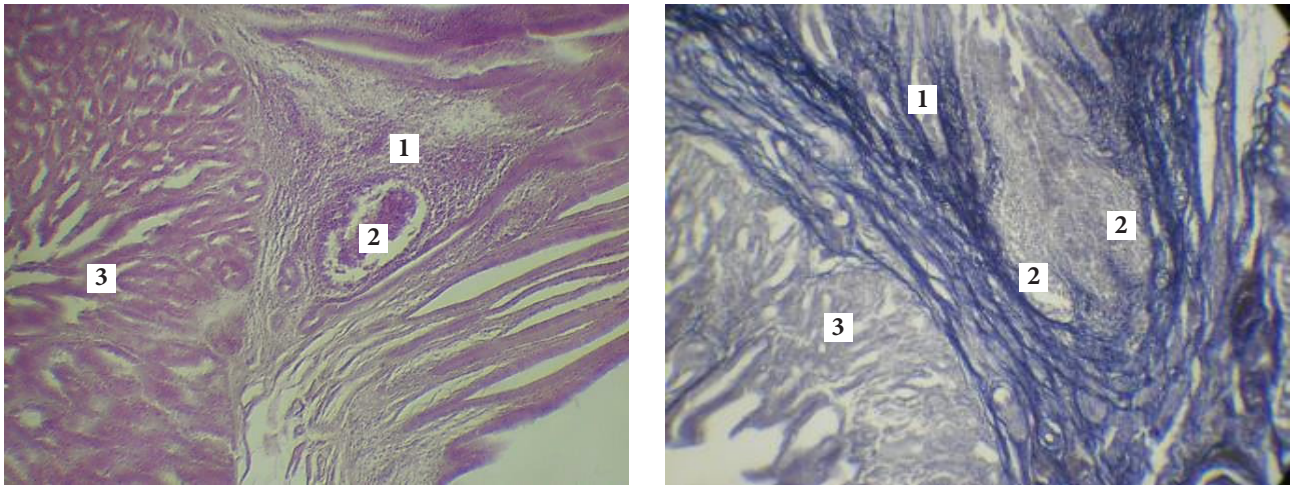
In the subserosa of the stomach *tunica serosa*, lymphoid tissue is detected mainly in birds of the Anseriformes and Gruiformes orders. Thus, in the subserosa of the proventriculus and the intermediate zone of *G. chloropus* and *F. atra*, clusters of diffuse lymphoid tissue and primary and secondary lymphoid nodules are revealed. The presence of lymphoid tissue in the *tunica muscularis* and *tunica serosa* of the stomach of certain bird species is confirmed by the data of other authors [16] and indicates that their digestive system experience a greater antigenic effect, which is associated with their feed specialization.

In all parts of the birds' stomach, lymphoid tissue is represented by unequal levels of structural organization. Thus, in the proventriculus, gizzard and pyloric part of the stomach of *B. bonasia* (Fig. 2a), *B. canadensis, P. pica, C. cornix* (Fig. 2b), *C. ciconia* and *C. livia,* only its diffuse form is revealed. In *L. lagopus* and *G. glandarius,* the lymphoid tissue of the proventriculus and its intermediate zone is also represented by a diffuse form, while in other parts of the stomach it is not observed. *P. colchicus* (Fig. 3a) and *F. atra* lymphoid tissue of the proventriculus, its intermediate zone and the pyloric part of the stomach is represented by both diffuse lymphoid tissue and lymphoid nodules. In *G. chloropus,* lymphoid nodules are found only in the proventriculus and its intermediate zone. In *P. crictatus* (Fig. 3b), lymphoid nodules are found only in the proventriculus.



a) b)

Figure 2. *The proventriculus of B. bonasia (a) and C. cornix (b): 1 – lamina propria mucosae; 2 – diffuse lymphoid tissue; 3 – lobules of the deep glands. H&E staining, ×100; ×90*



a) b)

Figure 3. *The proventriculus of P. colchicus (a) and P. crictatus (b): 1 – lamina propria mucosae; 2 – lymphoid nodules; 3 – lobules of a deep glands. H&E staining, ×90; Weigert staining, ×100*

To establish the development of lymphoid tissue in the *tunica mucosa* and *submucosa* of various parts of the birds' stomach, we determined the area that it occupies in them (Table 2). Most of all it is contained in the intermediate zone and the pyloric part of the stomach in most birds. In the intermediate zone, the largest area of this tissue is observed in *B. canadensis*, somewhat smaller in *P. colchicus*, and the smallest in *L. lagopus, P. pica, C. ciconia* and *C. livia*. In the pyloric part of the stomach, the largest area of lymphoid tissue is recorded in *P. colchicus* and the smallest in *P. pica* and *C. livia,* while it is absent in *L. lagopus* and *G. glandarius*. In the proventriculus and gizzard (ventriculus), lymphoid tissue occupies a much smaller area. In the proventriculus, it is the largest in *F. atra*, slightly smaller in *P. colchicus* and *G. chloropus,* and the smallest – in *L. lagopus, G. glandarius, C. ciconia* and *C. livia*. In the gizzard, the largest area of lymphoid tissue is recorded in *P. colchicus,* somewhat smaller in *P. crictatus* and *G. chloropus*, the smallest in *C. ciconia* and *C. livia*, and in *L. lagopus* and *G. glandarius* it is not observed. According to the obtained results, this is due to the morphological and functional characteristics of separate parts of the stomach, and in fact, with the time the contents remain in them and, accordingly, the duration of the effect of its antigens on the *tunica mucosa*. So, it is known [3] that food in the proventriculus does not linger for a long time. It is impregnated with the secretion of the glands, which contains bactericidal substances, and enters its intermediate zone. In the intermediate zone, the contents are retained for a longer time, which is due to the presence between it and the gizzard of the annular sphincter, which regulates the flow of contents into the gizzard [8].

***Table 2**. The area of lymphoid tissue in the stomach mucosa of birds (M±m, %)*

Species of birds	Glandular part	Intermediate zone	Muscular part	Pyloric part
P. colchicus	6.14±0.06	17.66±0.12	7.75±0.30	31.22±0.25
B. bonasia	3.29±0.33	5.65±0.16	2.10±0.06	6.57±0.25
L. lagopus	1.25±0.05	0.89±0.05	–	–
P. cristatus	2,15±0,04	10.10±0.16	5.78±0.09	25.60±0.17
B. canadensis	3.62±0.04	28.76±0.16	3.98±1.24	13.60±0.15
P. pica	3.12±0.14	1.87±0.06	1.13±0.06	1.05±0.05
G. glandarius	1.36±0.05	8.17±0.48	–	–
C. cornix	3.98±0.30	7.46±0.51	1.62±0.20	3.10±0.41
G. chloropus	5.01±0.07	3.01±0.1	4.92±0.16	7.92±0.24
F. atra	7.23±0.21	7.44±0.19	1.65±0.13	6.32±0.19
C. ciconia	1.05±0.04	1.75±0.03	0.88±0.02	3.54±0.06
C. livia	1.10±0.07	1.50±0.22	0.58±0.12	1.14±0.14

In the gizzard, as noted above, the area of the lymphoid tissue is insignificant, which is primarily due to its morphological features. It is known that the secretion of the glands of this part of the stomach contains keratin-like substances. It thickens on the surface of the *tunica mucosa*, forming the cuticle. The latter prevents the impact of antigens on it, which has also been reported by other researchers [17-19]. In the pyloric part of the stomach, due to the presence of a sphincter between it and the duodenum, its contents are retained for a longer time. Accordingly, the period of exposure to its antigens on the *tunica mucosa* is much longer.

As noted above, all levels of the structural organization of the lymphoid tissue are not detected in all parts of the birds' stomach. In some species, only diffuse lymphoid tissue is recorded in the stomach, and in some parts of it there is no lymphoid tissue at all. That is, the morphofunctional ma-turity of the birds' stomach lymphoid tissue and its separate parts is not the same. It is possible that such a presence of lymphoid tissue forms in the birds' stomach, or its absence in some its parts, is their specific feature. For a more exact answer to this question, it is necessary to conduct research on the development of the birds' stomach lymphoid tissue in their ontogenesis.

In most bird species, in all parts of the stomach, only the first level of the structural organization of lymphoid tissue is recorded – its diffuse form (Table 3, 4). In birds, in which all levels of the structural organization of this tissue are found, diffuse lymphoid tissue occupies the largest area, primary and secondary lymphoid nodules occupy a smaller area, and perinodules – the smallest one. The latter were not observed in some parts of the stomach. Secondary lymphoid nodules in the lymphoid tissue of the proventriculus are most detected in *F. atra,* somewhat less in *G. chloropus*, and the least in *P. crictatus* and *P. colchicus*. In the intermediate zone, there are more of them in *F. atra*, somewhat less in *G. chloropus*, and least of all in *P. colchicus*. Their highest content in the pyloric part is recorded in *F. atra,* and the lowest – in *P. colchicus*. In the gizzard, the structural level of lymphoid tissue is represented only in a diffuse form, other levels of the structural organization of the lymphoid tissue are not found.

***Table 3**. The content of lymphoid tissue components in the proventriculus and in the intermediate zone (M±m, %)*

Species of birds	Glandular part				Intermediate zone			
	Diffuse lymphoid tissue	Pre-nodules	Primary nodules	Secondary nodules	Diffuse lymphoid tissue	Pre-nodules	Primary nodules	Secondary nodules
P. colchicus	79.03±0.26	1.67±0.15	4.71±0.25	14.59±0.19	88.83±0.20	–	0.94±0.16	10.23±0.30
B. bonasia	100	–	–	–	100	–	–	–
L. lagopus	100	–	–	–	100	–	–	–
P. cristatus	87.52±0.76	1.56±0.26	5.56±0.70	5.36±0.63	100	–	–	–
B. canadensis	100	–	–	–	100	–	–	–
P. pica	100	–	–	–	100	–	–	–

Table 3, Continued

Species of birds	Glandular part				Intermediate zone			
	Diffuse lymphoid tissue	Pre-nodules	Primary nodules	Secondary nodules	Diffuse lymphoid tissue	Pre-nodules	Primary nodules	Secondary nodules
G. glandarius	100	–	–	–	100	–	–	–
C. cornix	100	–	–	–	100	–	–	–
G. chloropus	57.05±1.29	6.70±0.48	11.9±0.66	24.28±0.82	44.44±1.0	11.6±1.30	14.44±1.83	29.44±1.63
F. atra	47.31±0.21	2.23±0.38	6.57±0.55	43.9±0.7	38.85±0.87	1.79±13.22	17.97±0.98	44.39±1.40
C. ciconia	100	–	–	–	100	–	–	–
C. livia	100	–	–	–	100	–	–	–

***Table 4**. The content of lymphoid tissue components in the gizzard and the pyloric part of the birds' stomach (M±m, %)*

Species of birds	Pyloric part				Muscular part			
	Diffuse lymphoid tissue	Pre-nodules	Primary nodules	Secondary nodules	Diffuse lymphoid tissue	Pre-nodules	Primary nodules	Secondary nodules
P. colchicus	96.85±0.14	–	0.84±0.10	2.32±0.12	100	–	–	–
B. bonasia	100	–	–	–	100	–	–	–
P. cristatus	100	–	–	–	100	–	–	–
B.canadensis	100	–	–	–	100	–	–	–
P. pica	100	–	–	–	100	–	–	–
C. cornix	100	–	–	–	100	–	–	–
G. chloropus	100	–	–	–	100	–	–	–
F. atra	75.0±5.22	–	–	25.0±5.22	100	–	–	–
C. ciconia	100	–	–	–	100	–	–	–
C. livia	100	–	–	–	100	–	–	–

CONCLUSIONS

The lymphoid tissue in the stomach wall of the studied species birds is unevenly located. In terrestrial species, it is contained mainly in the *tunica mucosa* and *tela submucosa,* and in waterfowl – also in the *tunica muscularis* and *tunica serosa*. The lymphoid tissue is unevenly located in certain parts of the stomach. It occupies the largest area in the wall of the intermediate zone of the proventriculus and in pyloric part, and in the gizzard – the smallest. The lymphoid tissue of the stomach not in all species of the studied birds has all levels of structural organization, which is an indicator of its morphological and functional maturity. To clarify this issue, it is necessary to conduct research on the development of lymphoid tissue in the ontogenesis of certain bird species.

The obtained data on the morphofunctional features of the lymphoid tissue of the birds stomach are recommended to be used in the work of scientists studying the organs of the immune system, and in educational work.

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Морфофункціональні особливості лімфоїдної тканини шлунка у окремих видів диких птахів

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Анотація. У статті наведені результати гістологічних досліджень топографії, мікроструктури та функціональних особливостей лімфоїдної тканини шлунка птахів. Дослідження проведені на 12 видах диких птахів, які належать до 6 рядів. При виконанні роботи використовували класичні методи пофарбування гістопрепаратів гематоксиліном та еозином, за Вейгертом, Ван Гізон та імпрегнації арґентуму нітратом за Келеменом. Підтверджено, що шлунок птахів має залозисту, м'язову і пілоричну частини, які не однаково виражені в окремих видів. В усіх частинах шлунка лімфоїдна тканина представлена локальними скупченнями, які у птахів ряду Galliiformes (*P. colchicus, B. bonasia, P. crictatus*); Anseriformes (*B. canadensis*); Passeriformes (*P. pica, C. cornix*); Gruiformes (*G. chloropus, F. atra*); Ciconiiformes (*C. ciconia*) і Columbiiformes (*C. livia*) розташовані у слизовій оболонці та підслизовій основі, а у *B. canadensis, F. atra, G. chloropus* ще й у м'язовій та серозній оболонках. У *L. lagopus* і *G. glandarius* лімфоїдна тканина була виявлена тільки у залозистій частині шлунка та її проміжній зоні. Структурні рівні лімфоїдної тканини (дифузна форма, передвузлики, первинні та вторинні лімфоїдні вузлики) неоднаково виражені у шлунку птахів. У *B. bonasia, B. canadensis, P. pica, C. cornix, C. ciconia, C. livia* в усіх його частинах виявляється тільки дифузна форма. Ця форма лімфоїдної тканини реєструється у м'язовій частині шлунка інших видів птахів і залозистій його частині у *L. lagopus* і *G. glandarius*. Усі рівні структурної організації лімфоїдної тканини виявляються в залозистій частині шлунка *P. crictatus, G. chloropus* і в залозистій та пілоричній частинах шлунка *P. colchicus* і *F. atra*. Вміст лімфоїдної тканини неоднаковий у частинах шлунка птахів. Найбільше її міститься у проміжній зоні залозистої частини та пілоричній частині шлунка. Серед рівнів структурної організації лімфоїдної тканини найбільш поширена дифузна форма. Результати досліджень дають змогу більш повно оцінити морфофункціональний статус диких птахів і відповідно з'ясувати стан їх імунної системи

Ключові слова: апарат травлення, мікроструктура, імунні утворення, лімфоїдні вузлики, лімфоїдні клітини

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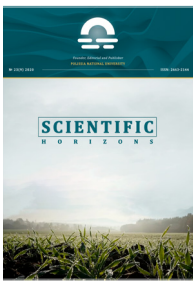

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Technological Aspects of Energy-Efficient High-Quality Cleaning of Indoor Air from Harmful Impurities

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Abstract. Bringing to safe health standards and maintaining the basic parameters of the air (microclimate) in the premises for various purposes within the established limits with a high level of efficiency, pro-vides an opportunity to solve the problem of national importance – public health and the necessary environmental characteristics. The purpose of the study is to develop technology and foundations for the construction of universal systems of automated high-quality air purification in rooms for various purposes. Methods of analysis, synthesis, mathematical modelling, and engineering calculations were used in the research process. The technology, composition, and structure of universal systems for au-tomated cleaning and maintenance of the required indoor air quality, which provides automatic control of air parameters, have been developed. The composition and features of software and hardware are substantiated, the method of engineering calculation, structure of air purification system is developed and its technical parameters are defined. The synergetic effects in the implementation of air purification, which are achieved through a comprehensive, consistent with the procedures and pro-cesses of sequential parallel processing of injected and filtered air, have been investigated and proved. Developed technology and systems provide the ability to purify large volumes of air at high speed and quality in rooms with different levels of mechanical contamination, microflora, other harmful impurities, including microorganisms, allergens, dangerous viruses that cause infections with pathogens diseases characterised by mass and high rate of spread, such as COVID-19. For the first time, the problem of creation of energy-efficient high power systems of complex air purification for industrial premises of large sizes, which are 2.5-4 times more effective on all basic indicators in com-parison with the best analogues has been solved

Keywords: air purification system, ultraviolet, ozone, disinfection, microclimate

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INTRODUCTION

The recommended parameters of the microclimate of livestock premises are regulated by departmental norms of technological design for each type of premises and animal species [1-4]. The main parameters of the air environment of livestock premises are: temperature, relative humidity, speed and pollution of air by harmful impurities. Components of biological or chemical pollution of the air environment of animal housing, such as: ammonia, carbon dioxide, hydrogen sulphide, methane, biological impurities (viruses, bacteria, fungi, mould, etc.), dust and other mechanical impurities [1-4], in case of exceeding the maximum permissible concentration (MPC) lead to a decrease in productivity, increased animal morbidity or death of livestock.

To ensure the recommended parameters of the air environment of agricultural buildings and structures, active ventilation is used, air exchange is recommended to be installed depending on the live weight of the animals in the room [1-4]. In particular, the minimum permissible air exchange for pigs in the warm period of the year is 60 m^3/h per 1 quintal of live weight, in the heating period – 30 m^3/h, respectively, the minimum air exchange of a pig farm per 1 thousand animal units is 30-60 thousand m^3/year. A significant amount of electricity is used to drive the fans, at the same time, together with the air, a significant amount of harmful substances enters the environment, energy costs increase to maintain the temperature in the room [4; 5]. The development and application of energy-efficient technology for cleaning and disinfecting the air of livestock premises from harmful impurities of chemical and biological origin would ensure the specified parameters of the microclimate, save a significant amount of thermal energy for heating in the cold season, and reduce the anthropogenic load on the environment [5].

An effective technical solution for cleaning and disinfecting the air of livestock premises from harmful chemical and biological impurities is the use of open [6-13] and closed [9; 14; 15] bactericidal installations based on low-pressure ultraviolet lamps [5; 16-22]. Such installations are widely used in medical and preventive treatment facilities (hospitals, clinics, sanatoriums, etc.), civilian premises with large crowds (children's educational institutions, commercial and office premises, offices, etc.), for disinfection of food, water, etc. The disinfecting effect of ultraviolet bactericidal lamps is photochemical damage to the DNA of the microorganism when using irradiation of the ultraviolet range with a peak wavelength of 265 nm, which leads to cell death, and in the bactericidal and disinfecting action of the disinfectant [20; 22; 23]. The dependence of bactericidal efficiency of ultraviolet radiation on the wavelength is called the spectrum of action [20]. Bacteria and viruses (rods, cocci) are more sensitive to the disinfecting effect of ultraviolet radiation, protozoa and fungi are less sensitive, and spore forms of bacteria are the most resistant. The use of irradiators of the ultraviolet range in closed recirculators provides air disinfection from pathogenic microflora up to 99.9% [6; 7; 20; 22].

The use of bactericidal devices for purification and disinfection of air is possible in the form of irradiators (open bactericidal units), recirculators (closed bactericidal units) or purification modules in supply and exhaust units of general exchange ventilation [17]. The main difference between recirculators and irradiators is that irradiators neutralise pathogenic microflora both in the air of the working area and on surfaces, but cannot be used in the presence of humans and animals due to the risk of skin and mucous membrane burns. Ultraviolet bactericidal recirculators decontaminate the air flow in an isolated channel or chamber; can be used in constant operation in the presence of humans and animals, because the flow of UV-c radiation does not enter the working area of the room.

If ultraviolet radiation of the bactericidal spectrum neutralises pathogenic microflora and chemical compounds only in the irradiation zone, then ozone is able to oxidise harmful impurities both in the recirculator channel and in the working area of the room. At the same time, ozone is a chemical of the highest class of danger, because its maximum concentration limit for humans is 0.1-0.2 mg/m^3, and therefore there is a need to develop and apply ACS parameters of the air purification system and air parameters in the working area.

The purpose of the study is to establish the technical and technological parameters of the auto-matic energy-efficient system for purifying the air of livestock premises from harmful impurities to achieve maximum energy efficiency of their use.

MATERIALS AND METHODS

To determine the initial technical, technological, and design parameters of the recirculator for cleaning the air of livestock premises from harmful impurities, the study considers modern effective bactericidal technical means of irradiation of air and surfaces, industrial ozone generators and technological requirements for their use in agricultural premises. Substantiation of technical parameters of air purifiers is carried out taking into account the requirements for microclimate parameters and modern research and trends in this field. Using the conducted analytical and laboratory investigations, the technological schemes of the automated bactericidal system of a recirculator for creation of an energy-efficient microclimate of livestock premises are developed. The method of engineering calculation is based on the establishment of the power of bactericidal radiation to achieve a given value of bactericidal efficiency. The dynamics of the concentration of harmful substances in the working area of the livestock premises during irradiation with ultraviolet waves was studied in laboratory and industrial conditions, and a decrease in the concentration of harmful

impurities from the intensity and time of air treatment was found. The concentration of harmful impurities in the laboratory chamber and the working area of the livestock premises was recorded by Dozor-SP and Dozor-SM gas analysers, ozone concentration – 01-02.P-P cheluminescent ozone analyser, tempera-ture and relative humidity – Testo 608H1 thermohygrometer.

To develop an algorithm for controlling the modes of operation of energy efficient equipment to create a microclimate of livestock facilities, analytical studies of modern technical means for control and management of microclimate parameters of livestock facilities were carried out taking into ac-count the recommended air parameters and devices for monitoring temperature, humidity, physical and chemical composition of air. When substantiating the system of energy-efficient equipment for creating a microclimate of livestock premises, a set of technical means for creating a microclimate is taken as a basis: supply and exhaust unit with heat recovery and closed and open bactericidal units for air purification from harmful impurities. The algorithm takes into account the permissible limits of the parameters of the air environment of the working area and the mechanisms of their control: ozone (up to 1 mg/m^3), ammonia (up to 20 mg/m^3), hydrogen sulphide (up to 10 mg/m^3), carbon dioxide (up to 0.3%), and temperature and relative humidity in accordance with departmental standards of technological design. The basic electrical scheme was developed and an experimental sample of the control system of energy-efficient equipment for creating the microclimate of livestock premises was manufactured using the developed algorithm. The scheme provides control of the recommended parameters of the air environment, control of the summer ventilation system, supply and exhaust units with heat recovery of exhaust air, devices for air purification from harmful impurities, and the indication signalling the operation of the microclimate system. CZMCU-131 MQ131 sensors with sensitivity from 0 to 0.5 ppm were used for ozone monitoring in the working area of the room.

RESULTS AND DISCUSSION

To clean and disinfect the air of livestock premises from harmful impurities of chemical and biological origin, it is proposed to use an air purification system consisting of an air treatment duct, an ozoniser, low-pressure ultraviolet bactericidal lamps, which are installed in the air flow blown by a fan (recirculator), automatic control system (ACS) parameters of the cleaning system and equipment to create a microclimate of the room (Fig. 1).

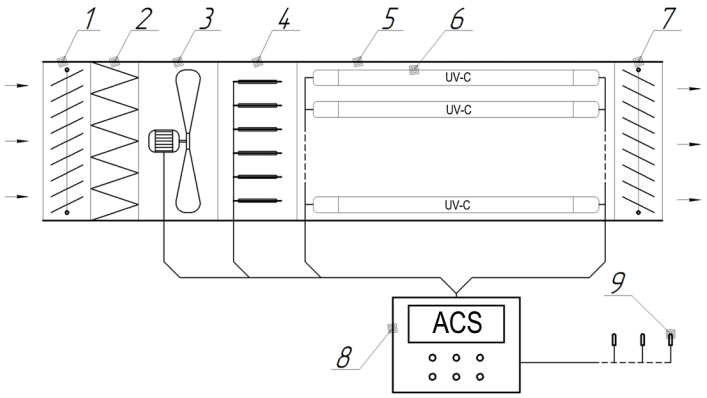

Figure 1. *Energy efficient system for cleaning the air environment of livestock premises from harmful impurities*
Notes*: 1 – intake protective grid (blinds); 2 – filter; 3 – fan; 4 – ozoniser; 5 – irradiation chamber; 6 – UVB lamps; 7 –exhaust protective grid (blinds))*

Fans inject the flow of air entering the recirculator through the ventilation grilles, ozone is generated from the oxygen contained in the air, then the air flow is treated simultaneously with ozone and irradiated with bactericidal lamps, disinfected and released. The recirculator housing forms an efficient irradiation chamber, as the inner surface of the recirculator is made of reflective material (polished metal, stainless steel, aluminium, etc.).

If the recirculation air flow in the irradiation chamber is significantly exceeded or if the irradiator power is reduced, the volumetric bactericidal dose will decrease, and the bactericidal efficiency of the recirculator as a whole will decrease accordingly. Therefore, to achieve the specified value of bactericidal efficiency of bactericidal air recirculators, it is first necessary to agree on the power of bactericidal radiation and air productivity of fans. Bactericidal radiation power Φ_{bc}, W to achieve a given level of bactericidal efficiency J_{bc}, % can be determined by the equation [17; 20; 24; 25]:

$$\Phi_{bc} = \frac{-V_{air} \cdot \ln(1 - J_{bc} \cdot 10^{-2})}{3600 \cdot k_f \cdot k_r \cdot k_d \cdot \sigma_v} \quad (1)$$

where Φ_{bc} – bactericidal power of UVB lamps, W; V_{air} – volume of air treated in the recirculator chamber, m^3; k_f – UFB flow utilisation factor. In the case of the location of lamps in the air flow – k_f=0.4-0.5, if not in the flow – k_f=0.7-0.8; k_r – coefficient of multiple reflections of UVB flow from the inner walls of the recirculator chamber, k_r=1.2-1.5; k_d – decay coefficient of bactericidal flux by the end of lamp life, k_d=0.7-0.8; σ_v – microorganism

photosensitivity constant. Rational values of bactericidal efficiency of UV-c radiation Jbc for industrial premises are in the range of 80-95% [26]. With a further increase in the set value of bactericidal efficiency Jbc, it is necessary to significantly increase the installed power of the emitters. Therefore, the rational values of the specific power of bactericidal radiation is in the range Φ_{bc}=65-121 W/thsd. m^3 of air.

If pathogenic microflora or chemical impurities are present in the air of the work area, which are ineffectively neutralised by UV-c radiation, they can be destroyed or inactivated by ozone during ultraviolet irradiation (photooxidation). Ozone is generated from oxygen contained in atmospheric air under the action of ultraviolet radiation with a wavelength of 185 nm (during the operation of ultraviolet lamps). This method of ozone generation depends on the power of ultraviolet lamps, control of its concentration in the chamber and the working area of the room can be done only by exposure to radiation, as a result of which the lamps fail prematurely. In addition, given the instability of ozone, the concentration of which depends on the oxygen concentration at the recirculator intake, temperature and humidity, the presence and concentration of oxidising substances, it is more appropriate to use ozone-free UV-c lamps and ozonisers with control of ozone concentration in the working area of the room.

The productivity of the ozone generator QOZ, mg/h can be determined by the equation:

$$Q_{OZ} = k_{air} \cdot k_d \cdot V_{ro} \cdot C_{oz} \quad (2)$$

where k_{air} – multiplicity of air exchange of the room, h^{-1}; k_d – ozone decomposition factor; V_{ro} – volume of the room, m^3; C_{OZ} – set concentration of ozone in the room, mg/m^3.

The maximum concentration limit of ozone in the working area of the room during the presence of people is 0.1 mg/m^3. Therefore, the minimum specific productivity of the ozoniser in this case (excluding the coefficient of ozone decomposition) in the presence of people in the room is Q_{OZspec}=0.1 mg/hour·m^3.

When cleaning the air from harmful impurities and pathogenic microflora using a cleaning system based on a type RPB 1.0-6/30 recirculator (Fig. 2), the air exchange of the room can be reduced without violating the specific parameters of the air. The most significant energy savings to maintain the specific air temperature will be when maintaining the concentrations of harmful impurities at the level of their MPC.

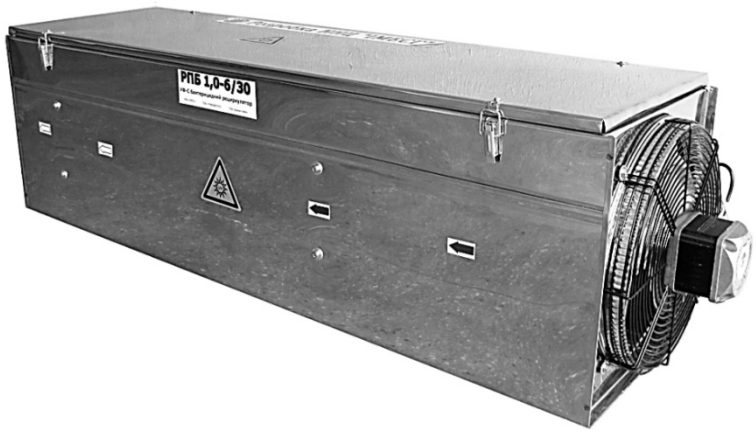

Figure 2. *Experimental-industrial sample of RPB 1.0 UFB air recirculator (NSC "IMESG" – LLC Turboventus)*

Possible modes of bactericidal recirculator operation: manual (switched on by service personnel for preventive purposes), cyclic (with setting of operating time and downtime) and automatic (automatic air quality control is carried out). For effective cleaning of the air of the working area of the room, it is advisable to use recirculators in a cyclic or fully automatic mode with the use of air quality sensors. The advantage of the cyclic mode of operation of recirculators is a simple control scheme and long operation of UVB low pressure lamps, which has a positive effect on their service life, the disadvantage is the lack of control over air pollution, ozone concentration in the working area, and cyclic cleaning.

In automatic mode, it is advisable to control the air parameters in the working area of the room, turn off the recirculator when the ozone level reaches the MPC value for humans or animals, and when the MPC of harmful substances after air treatment to turn on general ventilation. Thus, it is possible to ensure maximum efficiency of air purification and disinfection and minimum loss of thermal energy with ventilation air during the heating period. In summer, the ventilation of the room can work normally without considering the recirculator operation.

According to the defined modes of operation of the energy-efficient system of microclimate of livestock premises to create an automatic control system, the algorithm should consist of blocks of initial parameters: temperature and humidity in the room, maximum concentration of ozone and harmful substances in the working area, and units comparing these parameters with values and decision blocks (Fig. 3).

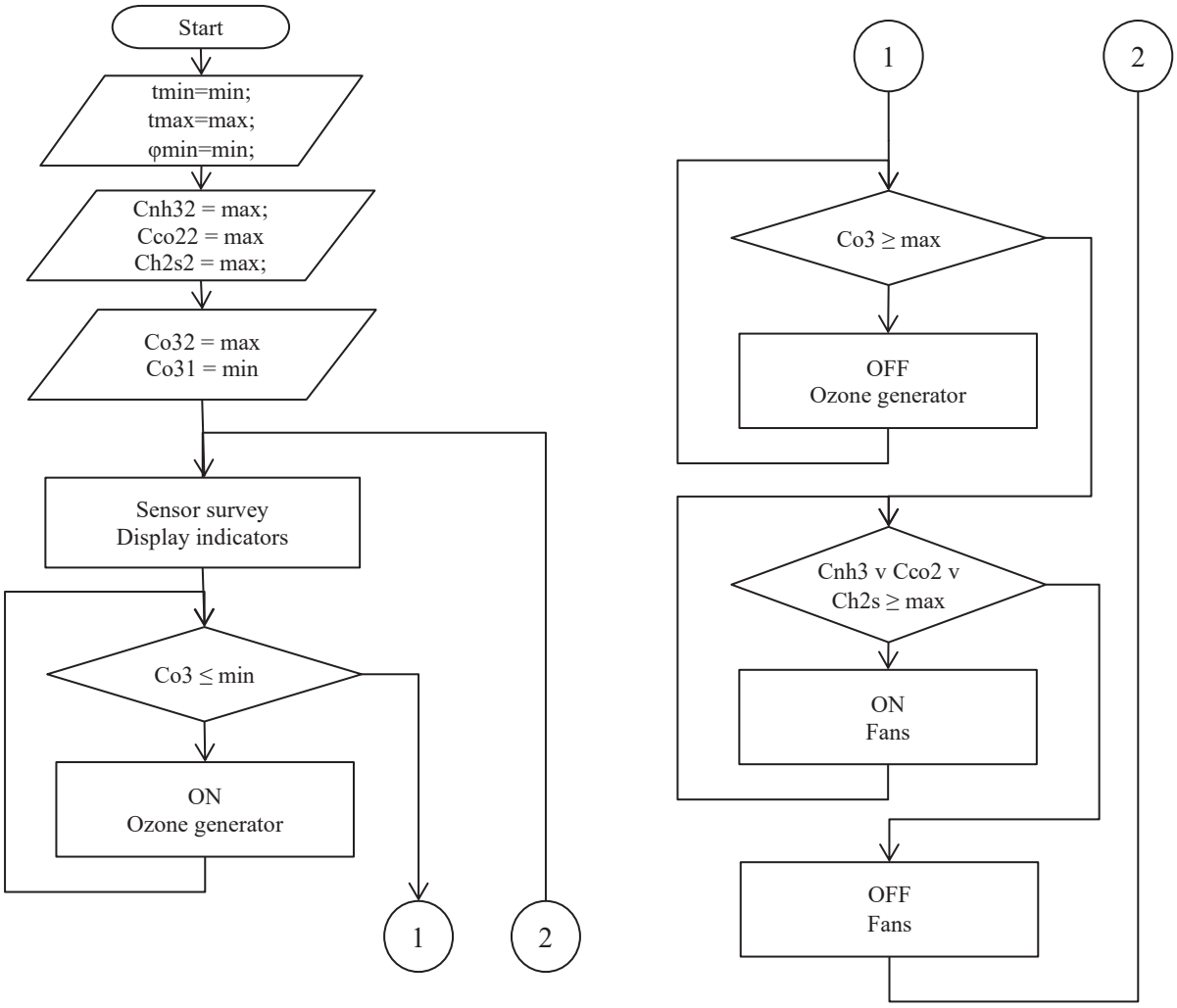

Figure 3. *Algorithm for controlling the system of energy efficient equipment to create an energy efficient microclimate of livestock facilities*

The algorithm works as follows: the minimum and maximum values of temperature and humidity in the room are set by the programme method or using controls according to the accepted technology and animal species, MPC of harmful substances in the air (ammonia, hydrogen sulphide, car-bon dioxide, methane, etc.). If the actual value of any harmful substance in the air of the working area is exceeded, the ozone generator is turned on until the ozone maximum concentration limit is reached. When the maximum concentration limit is reached, the generator is switched off. At the same time if the MPC of any harmful impurity is above permissible value – volumes of the general exchange ventilation of the room are switched on or increased.

To control the energy-efficient microclimate system, according to the developed algorithm (Fig. 3), an experimental sample of the automatic control system (ACS) of the energy-efficient microclimate of livestock premises with the use of air purification system was developed and manufactured (Fig. 4).

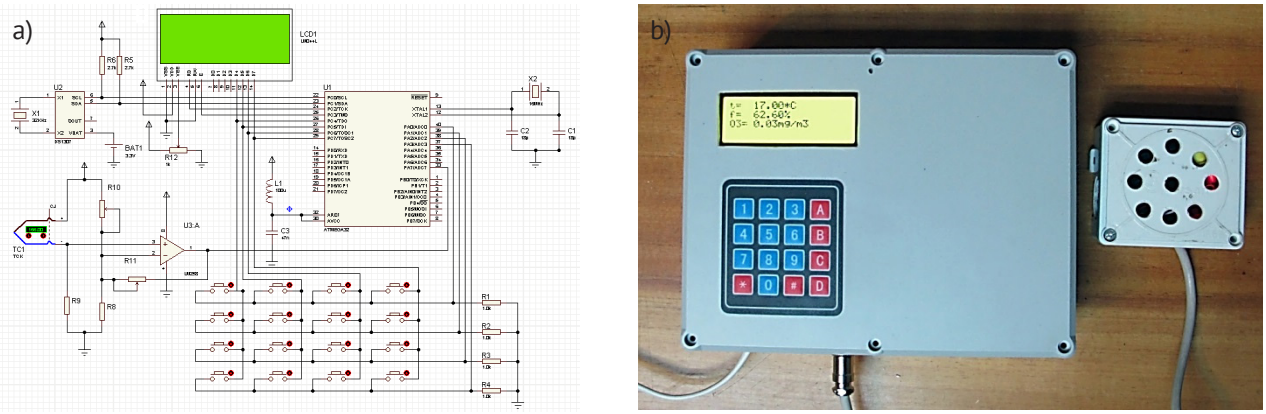

Figure 4. *Schematic electrical diagram (a) and appearance (b) of the experimental ACS unit for the microclimate parameters of livestock premises using an air cleaning system*

The ACS consists of a control and monitoring unit, and a remote sensor unit, provides control of temperature, relative humidity and ozone, and control of general ventilation units. The developed ACS unit provides monitoring of the concentration of ozone and harmful impurities in the air of the working area, automatic control of ozone concentration and general ventilation of the room to minimise energy costs and ensure normalised microclimate performance.

During the test of the RPB 1.0-6/30 bactericidal recirculator with ultraviolet lamps (total power of 180 W) and an ozoniser (capacity of 10 g/h) in a rabbit farm for 120 rabbits with a volume of 380 m^3, it was found that with the air exchange of 1.5-2.0 thsd. m^3/h, ACS provides the ozone concentration in the working area in the range of 0.02-0.2 mg/m^3, with an average value of ozone concentration of 0.15 mg/m^3, and the concentration of ammonia in the working area of the premises during production tests decreased from 14 mg/m^3 to 6 mg/m^3 (Fig. 5).

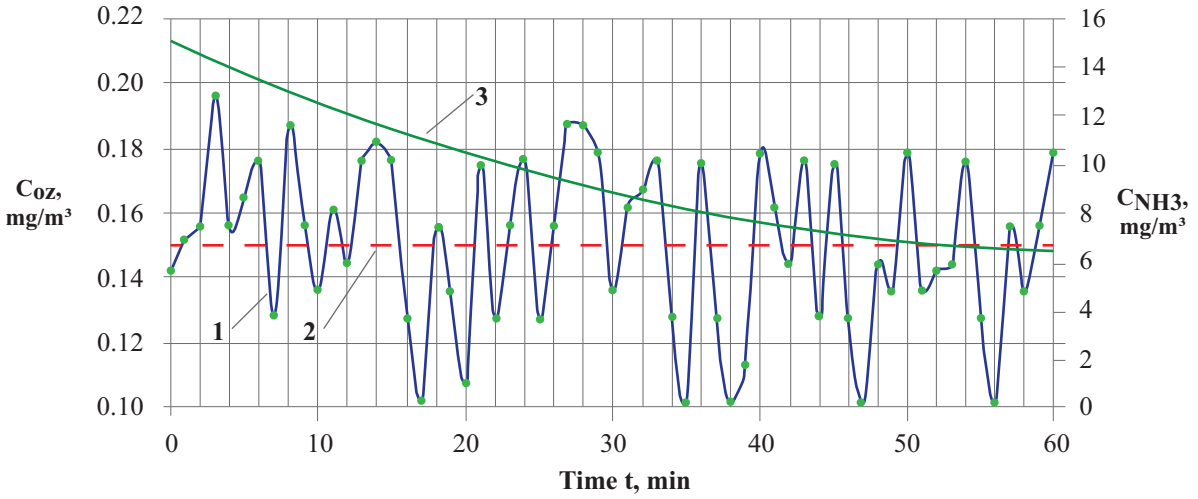

Figure 5. *Dynamics of ozone and ammonia concentration in the rabbit farm when using an energy-efficient system for cleaning the air environment of livestock premises*

Note*: 1 – ozone concentration in the working area of the room; 2 – average value of the concentration of ozone in the room during the test period; 3 – concentration of ammonia in the working area of the room*

CONCLUSIONS

The following conclusions were obtained from the study results:

1. To ensure maximum efficiency of cleaning and disinfection of indoor air from harmful impurities, it is advisable to use ozonisation and ultraviolet radiation in a closed chamber of the recirculator with an automatic control system of air parameters in the working area of the room.

2. When cleaning the air from harmful impurities and pathogenic microflora using the proposed automatic system based on a recirculator, the air exchange of the room can be reduced without violating the specific parameters of the microclimate.

3. Rational values of bactericidal efficiency of UV-c radiation J_{bc}=80-95%, specific power of bactericidal radiation Φ_{bc}=65-121 W/thsd. m^3 of air, the minimum specific productivity of the ozoniser Q_{OZspec}=0.1 mg/h·m^3.

The innovative technology developed in the article and the implemented SOPs are practically significant for the national economy as a whole and specifically for various industries. Their practical use helps to preserve human health, increase productivity in livestock and poultry, and curb the spread of various diseases, especially infectious diseases, including COVID-19. The equipment of all premises where there is a considerable quantity of people for preservation of their health and all premises for animals is perspective.

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Технологічні аспекти енергоефективного високоякісного очищення повітряного середовища приміщень від шкідливих домішок

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Анотація. Приведення до безпечних для здоров'я норм та підтримки у встановлених межах основних параметрів повітряного середовища (мікроклімату) в приміщеннях різного призначення із забезпеченням високого рівня економічності та енергоефективності, надає можливість вирішення проблеми державного значення – збереження громадського здоров'я та необхідних екологічних характеристик оточуючого середовища. Метою роботи є розроблення технології і основ побудови універсальних систем автоматизованого високоякісного очищення повітря в приміщеннях різного призначення. У процесі досліджень використано методи аналізу, синтезу, математичного моделювання та інженерних розрахунків. Розроблено технологію, склад і структуру універсальних систем для автоматизованого очищення та підтримки необхідної якості повітря в приміщеннях, яка забезпечує автоматичний контроль параметрів повітряного середовища і управління засобами очищення та підтримки необхідної якості повітря. Обґрунтовано склад і особливості програмного та апаратного забезпечення, розроблено метод інженерного розрахунку, структуру системи очищення повітря та визначені її технічні параметри. Досліджено та доведено синергетичні ефекти при здійсненні очищення повітря, які досягаються за рахунок комплексної, узгодженої за процедурами та процесами послідовно-паралельної обробки повітря, що нагнітається та фільтрується. Розроблені технологія і системи забезпечують можливість очищувати великі об'єми повітря з високою швидкістю та якістю в приміщеннях з різними рівнями його забрудненості механічними домішками, мікрофлорою, зокрема патогенною, іншими шкідливими домішками, включно з мікроорганізмами, алергенами, небезпечними вірусами, які приводять до інфікувань збудниками захворювань, що характеризуються масовістю та високою швидкістю поширення, наприклад COVID-19. Вперше вирішено проблему створення енергоефективних систем комплексного очищення повітря великої потужності для виробничих приміщень великих розмірів, які в 2,5 – 4 рази більш ефективні за всіма основними показниками у порівнянні з найкращими аналогами

Ключові слова: система очищення повітря, ультрафіолет, озон, знезараження, мікроклімат

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Methods for Measuring the Optimal Time for the Water Residence in the Denitrification Filter

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Abstract. Nitrate filters are widely used in various sectors of the national economy for the purpose of stable degradation of nitrates without complex technological changes and control, as well as for obtaining, for practical use, water free from impurities of various polluting substances. The relevance of the stated research topic is determined by the wide use of filters in various areas of water conditioning in order to improve the quality of consumed water, as well as the need to develop methods for qualitative measurements of the optimal time parameters for the water residence in the denitrification filter when using it. The purpose of this research work is the practical development of methods for measuring the optimal time for the water residence in a denitrification filter, in order to find optimal opportunities for eliminating harmful and polluting substances from water used for domestic and industrial needs. The methodology of this research involves the use of a combination of methods for the systematic study of practical application issues of denitrification filters in water purification systems, using the method of qualitative analysis of water conditioning problems that are important with reference to the need to obtain high-quality water in volumes sufficient to meet the current domestic and industrial needs. The results of this research work are of great importance from the point of view of studying the problematic issues of determining the optimal time parameters for the water residence in modern filters, in order to achieve optimal indicators of the cleaning quality. The results and conclusions of this research are of considerable practical value for water filter designers, solving practical problems of creating high-quality denitrification filters, as well as for ordinary users, for whom the issues of water purification for its further practical application are of great importance

Keywords: aquarium, water conditioning, water purification, wastewater, biological filtration

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INTRODUCTION

The issues of measuring the optimal water residence in the denitrification filter are of considerable practical importance in terms of improving the quality of purification and the consumption of environmentally friendly products [1]. In the current state of the environment, the use of denitrification filters is essential, taking into account the need to obtain water purified from nitrates and its further use. Determination of the optimal time for the water residence in the denitrification filter is an important parameter from the point of view of calculating the indicators of water purification in general and the elimination of nitrates and other polluting substances from it, in particular. The holding time of water in the filter is essential in terms of the quality of its purification, which is extremely important for its subsequent practical use [2]. The issues of water purification and filtration have been studied relatively recently, while they are of considerable importance from the point of view of the state of the ecology of the environment, since water pollution with nitrates and other polluting substances has an extremely negative effect on both the general state of the environment and the prospects for the development of any of the spheres of the national economy in which there is a need for large volumes of purified water [3].

The currently existing technologies for industrial purification of filtration waters of various household waste landfills do not allow an objective assessment of the time required for water to stay in the types of filters used, from the point of view of achieving optimal quality parameters of such purification. At the same time, denitrification filters have recently become more widespread due to their ability to efficiently purify water from nitrates and other polluting substances. Denitrification involves the reduction of nitrates to gaseous oxides and molecular nitrogen, which is important, in particular, in aquaristics, since it is in this area that special attention should be paid to the preparation of water for its use in the aquarium, which requires bringing it to certain parameters [4]. Marine aquaristics involves the widespread use of denitrification filters, moreover, much earlier they were developed and successfully used for wastewater purification. In marine aquaristics, denitrification filters are widely used as part of a filtration system that includes several components. The main task of such devices is the transformation of nitrate into gaseous nitrogen with the help of special bacteria, which leave the aquarium complex during their evaporation.

Denitrification filters have the following operating principle: an oxygen-depleted environment, which contains denitrifying anaerobic bacteria, promotes the extraction of nitrates from oxygen. This happens as a result of a chemical reaction that can be carried out by many types of bacteria, including *Pseudomonas denitrificans, Pseudomonas aeruginosa, Paracoccus denitrificans, or Bacillus licheniformis* [5]. The main condition for the qualitative conduct of such reactions is a weak water inflow, which is no more than 30 liters per hour. A similar rate of water inflow is necessary to establish an anaerobic environment, since a more intense inflow causes a large volume of oxygen to penetrate into the inner space of the filter. Internal circulation in the filter contributes to a more uniform distribution of the anaerobic environment in its space, which, in turn, is necessary for the extraction and elimination of nitrates from the water.

The purpose of the work is the practical development of methods for measuring the optimal time for the water residence in the denitrification filter, in order to find the optimal possibilities for eliminating harmful and polluting substances from the water used for domestic and industrial needs.

MATERIALS AND METHODS

The methodology of the work consists of a combination of methods for systematic study of the issues of practical application of denitrification filters in water purification systems, with the method of qualitative analysis of water conditioning issues, which are important as part of the need to obtain purified water in those volumes that are sufficient to meet current domestic and industrial needs. A full-fledged research involves the study of the technical features of the denitrification filter designs and their operating principles in the implementation of the process of removing nitrates from water. In addition, the selected methods of scientific research combined provide the proper quality of the declared topic coverage due to its scientific and technical complexity and significance for industrial and domestic needs. The theoretical basis of this research work is the analysis of the scientific publications of researchers available within the framework of the stated topic of scientific research on the design of denitrification filters and their practical use in various industries.

In order to facilitate the perception of information and create an optimal, high-quality picture of scientific research, all the authors' developments from other countries, studied in the course of this scientific work and presented in the order of citation, were translated into Russian. The same was done in the section in which the results obtained in the course of this research work are compared with the results and conclusions of foreign researchers specialising in a wide range of issues raised in the subject of this research work or related to it. At the first stage of this research work, a theoretical study of the denitrification filter design features and their operating principle is carried out. This research stage also includes a systematic analysis of practical application issues of denitrification filters in water purification systems, which considerably complements and expands the overall scope of research.

At the second stage of this research work, the method of qualitative analysis of water conditioning issues was practically used, which are important as part

of the need to obtain purified water in volumes sufficient to meet the current domestic and industrial needs. This research stage also included an analytical comparison of the obtained preliminary results with the results and conclusions of other researchers on the issues of determining the water residence time in the denitrification filter, which is optimal from the point of view of its high-quality purification. At the final stage of this research work, the final conclusions on the basis of the results obtained in the process were formulated, summing up the entire range of work performed within the framework of the declared topic, as well as highlighting the most essential research aspects. In general, the results and conclusions of this research work are a qualitative reflection of the entire complex of research carried out and can be effectively used during further research within the framework of the stated topic or related to it.

RESULTS

Denitrification filters play an important role in industrial wastewater purification in different countries and are widely used in the conversion of nitrates in water to nitrogen gas or nitrous oxide [6]. This process runs on the basis of the following chemical reaction:

$$5C + 4NO_{3-} + 4H + = 5CO_2 + 2N_2 + 2H_2O \quad (1)$$

In addition, carbon in the form of lactose is consistently added to denitrification filters, as well as beads used as filter fillers and containing recycled butyric acid in their base. The methods for measuring the optimum time for the water residence in the denitrification filter depend on the filter type and its operating principle. In this context, the following main types of denitrification filters used to remove nitrates from water should be highlighted:

– nitrate reducers used in aquariums with a volume of up to 1000 liters and containing in their design a large-volume reactor chamber, as well as a built-in pump for internal circulation;

– filters without internal water circulation, installed in containers of a relatively small volume (up to 150 liters), subject to intensive circulation and deaeration of water in the aquarium itself.

Taking into account the above, effective methods for measuring the optimal time for the water residence in the denitrification filter involve taking into account a number of parameters that are important from the point of view of the water purification quality:

– operating time of the filter during the release of nitrates and their impurities;

– water volume entering the inner space of the filter per unit of time;

– service life of the denitrification filter at the time of the purification;

– filter type.

The water volume entering the inner space of the filter per unit of time can be determined by the product:

$$V_в = S_г \times T \times V_c \quad (2)$$

where: $S_г$ – the filter throat area through which water enters; T – total time of water entering the filter; V_c – the rate at which water enters the filter.

Knowing the exact value of the water volume entering the denitrification filter during its operation, it is possible to calculate the water residence time in the filter, which is optimal from the point of view of purification quality of water samples. For this, the following ratio is used:

$$Tv = \frac{V_в}{S_в \times V_c} \quad (3)$$

where: $S_в$ – the area of the filter outlet through which the water leaves the filter.

The presented mathematical calculation model forms the basis of the dynamic adsorption method of water samples passing through the denitrification filter during its practical use. The essence of this technique is to perform a mathematical calculation of the dynamic indicators of water movement in the filter, taking into account all the accompanying factors [7]. The parameters of the optimal water residence time in the filter can vary depending on the rate of water entering the filter and the area of the inlet and outlet throats of the filter, which is affected by the specific design option. Figure 1 shows the dependence of the calculated parameter of the water residence time in the filter on the value of the filter inlet neck. Determination of the nature of the dependence under consideration is substantial from the point of view of finding ways to reduce the time value required for water to stay in the filter for its high-quality purification.

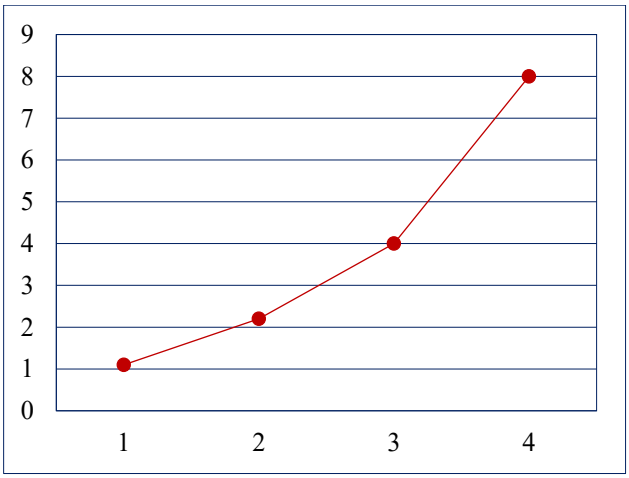

***Figure 1**. Dependence of the calculated parameter of the water residence time in the filter on the area value of the inlet neck of the filter*

In Figure 1, the X-axis shows the time (min) of water residence in the filter during purification, and the Y-axis shows the area of the filter inlet neck (cm^2), depending on its design. The data presented in Figure 1 indicate that there is a direct connection between the

time required for optimal water purification in the denitrification filter and the inlet area through which water is supplied to the filter. This means that a constructive increase in the area of this hole automatically increases the time parameter required for high-quality purification of the water sample that entered the filter through its inlet neck. At the same time, the total volume of water entering the denitrification filter per unit of time also increases, and, therefore, the total volume of nitrates and polluting substances in the filter increases, which must be removed during water sample purification. The above technique is closely related to the comparative analysis method of water samples before and after purification. The practice of using comparative analysis implies the need for laboratory studies of the water quality before entering the filter and after its purification, in order to establish the optimal parameters for the water residence time in the filter, as well as taking into account the main design characteristics of the filter itself. This contributes to a more accurate determination of the amount of time required for the optimal purification from the point of view of the purification quality of the water sample entering the denitrification filter per unit of time.

At the same time, a change in the main design characteristics of the filter itself, as well as the volume of contamination of the water supplied to it, has a tangible effect on the reliability of the results of the comparative analysis, which indicates the relativity of the results obtained through its use and the high errors of its practical application [8]. Removing nitrates from aquarium water by filtering it is an alternative to cleaning aquariums by replacing the water, as well as planting special algae that consume nitrates and other substances in the aquarium water polluting it and preventing fish breeding. In this context, denitrification should be considered an oxidation process, and a denitrification filter is a device in which conditions are created for high-quality water purification entering it by methods of oxidation reaction. At the same time, the nitrates in the water gradually turn into nitrogen, harmless to the aquarium environment, which can be observed in the form of bubbles coming out. The process of sequential conversion of nitrates into nitrogenous compounds involves their sequential conversion into intermediate products: nitrites, nitric oxide, and nitrous oxide. In this case, one should take into account the fact that the multistage denitrification process presupposes the sequential development of a number of toxic products, including nitrites, in particular. Therefore, the need to determine the optimal water residence time in the denitrification filter is largely due to the need to create safe conditions for water purification and its subsequent use.

A high-quality solution to the issues of increasing the efficiency of the use of denitrification filters and carrying out denitrification in aquarium conditions, in general, suggests the need to control all stages of the denitrification process. Effective water filtration is impossible without proper maintenance of all denitrification process stages listed above. It is also required to bring the aquarium ecosystem to a state in which the accumulation of intermediate denitrification products will be completely excluded. The danger of the gradual accumulation of nitrites in the aquarium lies in the considerable pollution of the aquarium environment, as well as the real danger of creating conditions under which the very existence of fish in it will become impossible. The development of methods for measuring the optimal water residence time in the denitrification filter is a promising area of aquaristics and wastewater purification methods since it implies ample opportunities for improving the denitrification processes in general. These filter types have long been successfully used in saltwater aquariums and have recently begun to find widespread use in freshwater aquariums. Research in this area is far from complete and has broad prospects since the issues of effective cleaning of aquariums and wastewater are of great importance both for the functioning of industrial facilities and for ordinary citizens.

DISCUSSION

Changing the modes of wastewater supply helps to reduce the total amount of harmful substances entering the anaerobic zone of the denitrification filter, which negatively affects the purification process intensity. In such a situation, denitrification filters cannot compete with heterotrophs in terms of the rate of organic substances processing, as well as in water purification quality. In addition, the anaerobiosis conditions in the first, anaerobic zone, can be maintained to a much lesser extent, since this area contains not only nitrites and nitrates, but also oxygen dissolved in water [9]. Wastewater purification involves the elimination of the bulk of harmful impurities, as well as high-quality elimination of nitrates, phosphorus, and nitrogenous compounds. The procedure for such a purification involves the course of ammonification processes followed by nitrification and hydrolysis of phosphorus-containing compounds. At the same time, a large amount of these elements regularly enter natural water bodies, which determines the degree of their pollution and the need for regular purification [10]. Water filtration in an aquarium is a rather complex process, consisting of many sequential stages and involving the comprehensive use of mechanisms, both similar to natural methods of wastewater purification, and specially developed modern technological solutions. At the same time, specific filter manufacturers for water purification recommend certain purification methods for practical use, in accordance with the methods of using purifying substrates and filling cleaning filters [11].

In this case, it is implied that mechanical filtration should precede biological one since a sequential increase in the porosity of the filling substances is assumed. Correct

filter filling presupposes the presence of a coarse-porous sponge in its lower compartment, while in some filter models there are special compartments or chambers that can be easily removed and designed to accumulate particularly large polluting substances. In addition, some filter models assume the presence in their design of special elements for the automatic elimination of this kind of contamination with a continuous water flow, which allows the filter to be flushed much less frequently. The coarse-pored sponge in the lower filter compartments of some manufacturers is combined with special ceramic rings, which are placed in a layer directly in front of it. The main purpose of such a structure is to evenly distribute the water flow throughout the entire available area, which contributes to the creation of vortex flows that can delay the water movement, slow down its rotation, resulting in the deposition of the largest possible amount of pollutants. In addition, after the coarse-grained sponge, a sponge with smaller pores can be structurally provided, followed by a padding polyester filler, whose function is to collect smaller particles of impurities [12]. Such a filter design implies a higher quality water purification from harmful impurities and pollutants.

The faster goes the process of biological oxidation of water when passing through the filter, the higher its temperature. Also, from the point of view of nitrates displacement quality, the percentage of oxygen in water is important and should not exceed 70% of the value of its maximum solubility in water at a fixed temperature value for the optimal course of the purification process. In this case, the optimal course of oxidative processes is ensured, since the presence of oxygen in the aquarium is essential not only from the point of view of the need for respiration of plants and fish but also for the high-quality course of biofiltration processes. Nitrified bacteria also need oxygen, and in large quantities [13]. The oxygen demand increases as the temperature and porosity of the substrate used in the filter increase. Oxygen consumption begins already from the first layers of filtration materials, and the rate of oxygen consumption directly depends on the degree of general pollution and the type of denitrification filter used. Nitrates are the end product of the decomposition of organic substances and for this reason, they are practically not removed from the water, gradually accumulating in it. This explains the fact that biological water filtration processes will never replace water changes. Periodic replacement of the aquarium water is in any case necessary, regardless of what kind of filtration system is provided in it.

With an average value of the total biomass of fish in the aquarium, there is a need to replace the aquarium water with fresh water, at least once a week, about a third of the total volume [14]. In the event that the water change stops in a natural reservoir, a swamp will appear in its place after some time. If the water in the aquarium does not change, it will deteriorate much faster than in a natural reservoir. Installing a biofilter does not guarantee immediate effects, the same applies to flushing or replacing it. High-quality filter operation takes time during which bacteria colonies take root and develop in it. Only then it begins to function at full capacity. The efficiency of denitrification filters is determined by the gradual increase in the number of bacteria. Provided that all the necessary conditions are met, this period will be from two to four weeks. Special techniques can help to shorten this period, which is achieved by adding some water from the soil from the old aquarium to the new one. Such procedures requires strict adherence to the principles of hygiene since it is quite easy to introduce new strains of bacteria into the aquarium, which greatly complicates the subsequent reservoir purification [15; 16]. There is often a situation in which some manufacturers' recommendations, declaring the correspondence of any filter to specific water volume in the aquarium, turn out to be unwarranted.

The most essential indicators in determining the feasibility of the practical use of denitrification and biological filters in an aquarium are the activity of fish in it, its total biomass, and the feeding frequency. If we are talking about an aquarium with living plants and relatively low biomass of living organisms, the minimum filter performance indicators are sufficient for a high-quality solution of all water purification tasks. In the event that large fish live in the aquarium and feed relatively often, there is a need to gradually increase the recommendations on the filter performance for purifying such a reservoir several times. Among all filter manufacturers, only Tetra is known for taking the total biomass of aquarium fish into account when calculating filter performance. The filter operating instructions from this manufacturer contain a lot of practical recommendations for keeping and feeding fish, as well as maintaining a high level of the aquarium's entire ecosystem. The optimal parameters of the water residence in the denitrification filter during purification are calculated in order to improve the water quality in the aquarium, as well as the wastewater used in industrial developments. The water residence time in the filter is essential from the point of view of water purification quality and the elimination of nitrate compounds from it.

Depending on the water residence time in the filter, the indicators of the total water purification in the aquarium are determined in the case of an aquarium filter and wastewater with filters of a different type. At the same time, these indicators have a direct impact on the total operating time of the filter, which is essential from the point of view of the duration of maintaining the high quality of water purification. The adsorption method, which involves the use of activated carbon, has become widespread in the process of aquarium water purification. At the same time, the value of activated carbon is somewhat overestimated, since it does not

remove nitrates and nitrogen-containing ions from water. Activated carbon removes large organic molecules from water, as well as individual gases, peptides, and amino acids. Moreover, activated carbon is able to indirectly contribute to the elimination of activated nitrogen, since nitrite and ammonium are products of the decay of protein elements that retain carbon. The use of activated carbon in the aquarium water purification contributes to the water production with a very high degree of transparency, while the charcoal helps to heal fish and removes drugs dissolved in it from the water [17]. The method of aquarium water chemical filtration is used relatively rarely. In the meantime, ion exchange, synthetic resins, as well as minerals of natural origin belonging to the group of zeolites, are usually used as a filtration material.

The chemical filtration method leads to the absorption of nitrates, ammonium, phosphates by resins and zeolites, with the release of sodium ions, which are completely harmless from an environmental point of view. In addition, the definition of the chemical filtration method includes the use of high moor peat as filter media in purifying operations [18]. Peat provides light water acidification and contributes to the addition of biologically active substances. Such cleaning methods should not be combined with each other in the operation of the simplest filter. Films that appear as a result of a high concentration of bacteria and other biologically active substances can be due to using any substrate, while any biological filter is suitable for solving problems of high-quality water purification. At the same time, it is very difficult to develop such a filter design in which it would be impossible to place an insert, zeolite, or carbon. This is despite the fact that the bulk of large external filters are designed to solve complex issues of water regeneration. At the same time, the most common filtration method is biological filtration, in which industrial canister filters are actively used. There are many models of such filters and their varieties. These are mainly filter models with multiple filling layers, such as sponges, zeolites, and other solids [19].

Filters with special ceramics and other highly porous materials as a filler, a large number of pores of which is a favourable environment for bacteria that enter into a chemical reaction, are often used. The more pores in the filter, the more space for bacteria to reside, which qualitatively improves the performance of biological filtration. Methods for measuring the optimal water residence time in denitrification filters are constantly being improved, which determines the development of the industry of creating water purification facilities and contributes to the search for new, more effective ways to purify aquarium and wastewater. At the same time, there is a growing need for new, effective technologies for removing nitrates and harmful impurities from water, improving the water quality used for domestic and industrial needs [20]. The strengthening of this need leads to an intensive search for new opportunities to improve water filtration quality, as well as to the creation of new methods for the optimal water residence time in denitrification filters, which generally meets the needs for improving the quality of waste and aquarium water purification. In the future, the issues of improving the quality of water conditioning and water purification for domestic and industrial needs will not lose their relevance, which will lead to the discovery of new high-quality solutions to the issues considered in this area.

CONCLUSIONS

The optimal water residence time in the filter during purification must be calculated in order to accurately determine the optimal operating modes of the filter when it is in aquarium water or wastewater. This indicator is calculated taking into account the total time of the chemical reaction course for the nitrates elimination, which is described by the corresponding chemical formula. With the knowledge of the exact time required for the optimal elimination of nitrate impurities from the water, it is quite possible to accurately plan the procedure course for purifying an aquarium or wastewater for industrial purposes, which is essential from the point of view of their subsequent economic use. In addition, the water residence time in the filter during purification determines the nature of both the purification itself and the filter quality, since it allows making a preliminary calculation of the possible service life of the filter. Nitrates removal from water occurs as a result of a complex chemical reaction, the flow time of which is essential from the point of view of assessing the water residence time in the filter itself.

This time can be determined using various methods, the most effective of which are the method of dynamic adsorption of water samples and the method of comparative analysis of water samples before and after purification. These methods have approximately the same practical efficiency and can be successfully used in situations where it is required to determine the optimal water residence time in denitrification filters. Water purification quality has a determining impact from the point of view of the safety of its further use, therefore, determining the optimal water purification time in the context of assessing the effectiveness of a particular denitrification filter is essential for understanding the optimal operating conditions and overall service life. This is necessary for a qualitative assessment of the filter overall efficiency and the feasibility of its use in specific situations, implying the need to maintain high efficiency and water purification quality.

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Методи вимірювання оптимального часу утримання води у денітрифікаційному фільтрі

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Анотація. Нітратні фільтри широко використовуються в різних галузях народного господарства з метою стабільної деградації нітратів без складних технологічних змін та контролю, а також з метою одержання води для практичного використання, вільної від домішок різних шкідливих речовин. Актуальність зазначеної теми дослідження визначається широким використанням фільтрів у різних областях кондиціонування води з метою покращення якості споживаної води, а також необхідністю розробки методів якісних вимірювань оптимальних параметрів часу для утримання води у денітрифікаційному фільтрі за його використання. Метою цієї дослідницької роботи є практична розробка методів вимірювання оптимального часу перебування води в денітрифікаційному фільтрі з метою пошуку оптимальних можливостей для усунення шкідливих і забруднюючих речовин з води, що використовується для побутових та промислових потреб. Методологія цього дослідження передбачає використання комбінації методів для систематичного вивчення питань практичного застосування денітрифікаційних фільтрів у системах очищення води, з використанням методу якісного аналізу проблем кондиціонування води, що є важливими з огляду на необхідність отримання високої якості води в обсягах, достатніх для задоволення актуальних побутових та промислових потреб. Результати цієї дослідницької роботи мають велике значення з точки зору вивчення проблемних питань визначення оптимальних параметрів часу перебування води в сучасних фільтрах, з метою досягнення оптимальних показників якості очищення. Результати та висновки цього дослідження мають значну практичну цінність для розробників водяних фільтрів, які вирішують практичні задачі створення високоякісних фільтрів денітрифікації, а також для звичайних користувачів, для яких питання очищення води для подальшого практичного застосування мають велике значення

Ключові слова: акваріум, кондиціонування води, очищення води, стічні води, біологічна фільтрація

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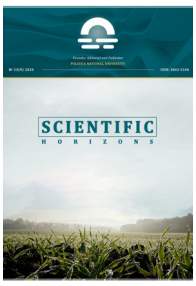

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Comparative Analysis of Rabbit Meat Quality when Using Modular Raising Technologies and Eco-Farm

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Abstract. The nutritional value and organoleptic evaluation of rabbit showed that the meat of rabbits raised on the eco-farm and in the modular rabbit house did not differ from each other and had the best nutritional and biochemical qualities, indicating the prospects of using modular farms to produce high quality products. A high percentage of fresh meat yield was found – 53.6 and 53.9% in rabbits raised in the module and on the eco-farm. Rabbit carcasses from the module had more fat by 1.1% and slightly enlarged kidneys due to the peculiarity of the equipment. Changes in the chemical composition – a slight increase in moisture and fat content (by 0.2%) in the meat, which was obtained by raising in the modular rabbit house compared to the meat of rabbits raised on the eco-farm – were founded. At the same time there was 0.3% less protein and 0.1% less sol. In general, the difference in chemical composition was insignificant, which indicated the identity of the analyzed samples. The organoleptic characteristics of rabbit meat in the carcass at slaughter and after heat treatment were studied. Muscle consistency was dense, elastic, when pressed the formed hole was quickly leveled; fat was dense. The aroma was specific for fresh meat. All samples taken from sampling of "Hy-plus" hybrid rabbits raised in the modular rabbit house and those raised on the eco-farm had the highest scores. The studied samples by organoleptic evaluation did not differ from each other and corresponded to high quality rabbit. Carcasses of hybrids in the experimental groups had a high content of saturated, monounsaturated and polyunsaturated fatty acids and the lowest content of cholesterol (0.04 g/100 g). The difference between the amino acid composition of meat and the lipid composition of fat in the study groups was insignificant

Keywords: rabbit, carcass, aroma, color, consistency, biochemical composition

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INTRODUCTION

Providing the population with high quality foodstuff at the present stage of society evolution is one of the most important tasks. The main role in solving this problem is played by the intensive development of animal husbandry, including rabbit breeding. Rabbit breeding is one of the most promising branches of animal husbandry, which allows to provide the population with high-quality raw meat in a short time. The high content of sustainable proteins and extracts, a small amount of fat and cholesterol favorably distinguishes rabbit from beef, pork and lamb. Rabbit protein is absorbed by the human body by 90%. Cholesterol in rabbit meat is 2.4-2.7 times less than in chicken and veal [1]. Therefore, rabbit meat is considered a high-value dietary product, its consumption helps to prevent cardiovascular and gastrointestinal diseases [2].

Rabbit meat is characterized by a delicate texture, finely-fibred structure with evenly spaced thin layers of adipose tissue, which gives the meat marbling. Fat is deposited mainly in the abdomen, near the kidneys, stomach, as well as on the neck between the shoulder blades. Fat is almost not deposited on the surface of the carcass. The carcass of a fattened rabbit (mainly in the abdomen) can contain up to 400-500 g of fat, rabbit belongs to the white meat, the color of which is pale pink [3].

The biological value of rabbit meat is determined by a high content of sustainable proteins (myosin, globulin) and a favorable ratio of amino acids. The largest amount of sustainable protein and reserve fat is found in the meat of 100-120-day-old rabbits [4]. With the increase in fat, the caloric content of rabbit meat increases. Rabbit carcasses contain sufficient and at the same time moderate amount of lipids. Meat does not lose moisture during cooking [5].

The meat productivity of rabbits is determined primarily by heredity, as well as a number of paratypic factors, which primarily include raising technology. Recently, there is a growing demand for dietary meat, which includes rabbit, so much attention should be paid not only to quantitative but also qualitative features [6]. The quality of meat is assessed by consumer on such indicators as color, water-absorbing capacity, succulence, texture and tenderness, taste and smell. Rabbit meat has a high nutritional value. The high content of digestible sustainable protein and essential amino acids distinguishes it from other types of meat. The meat productivity of rabbits is significantly affected by many factors – breed characteristics, direction of breeding, breeding method, housing conditions, intensity and duration of fattening, time and age of slaughter of rabbits [7; 8].

The development of meat productivity is different at different ages in different breeds of rabbits. Rabbits of specialized meat breeds have the highest meat productivity. In their researches, A.O. Pohorielova and G.A. Kotsiubenko [9], proved that rabbits change the amount of meat and internal fat with age. The ratio of the specific weight of physiological systems of the body is almost unchanged during the life of the animal. Regarding the study of the morphological composition of carcasses in animals of different sexes, the advantages of female rabbits over male rabbits should be noted. They probably outscore them in fresh meat yield and internal fat for all studied age periods up to 120 days of age. The ratio of physiological systems does not differ significantly.

Most often, the results of organoleptic evaluation become decisive and final in determining the nutritional value of livestock products, but important in this case biochemical studies are not conducted because they are considered expensive and long [10]. Rabbit muscle tissue proteins are complex. They are diverse in structure, physico-chemical properties and biological functions. The most biologically valuable are proteins of the myogen group A and B, which perform mainly enzymatic functions. With the age of rabbits, the level of oxyproline in the muscles increases (most intensely up to 120 days of age). There is also a tendency to decrease the content of arginyl, alanine, glycine, proline and increase histidine, phenylalanine, norleucine, tyrosine and aspartic acid [11; 12].

The biological value of rabbit meat is primarily due to its high protein content and has advantages over other animals [13]. The amino acid composition can vary significantly. The protein-quality index (the ratio of oxyproline and tryptophan amino acids) of 4-5-month-old rabbits reaches maximum values, and then gradually decreases [14]. High productivity in rabbit breeding can be provided by hybrid young animals, which have higher growth energy in the first months of life, which is used in broiler and intensive rabbit breeding [15]. The chemical composition and quality of rabbit meat depend on the breed, conditions and intensity of rabbit breeding [16]. At different ages, the ratio of internal, subcutaneous and intramuscular fat is different, adults have an excess of adrenal fat [17].

Many scientists are studying the quality of meat, since intensive selection for early maturity shows some deterioration. The quality of meat deteriorates even if the technological conditions are not observed [18]. The significant impact of raising technology on the quality of rabbit meat emphasized G.A. Kotsiubenko and O.I. Petrova [19], in their researches. Of the three technologies studied, eco-technology was recognized as the best for obtaining the highest quality rabbit. The worst indicators of rabbit quality were found in industrial technology (mechanized rabbit house).

Considering the application of these technologies from an economic point of view, industrial technology is more profitable than raising rabbits on eco-farms. Specialists of Mykolayiv national agrarian university developed technology of rabbit raising on modular farms which combined all the best elements of both technologies. Therefore, the main objective of the research was to compare the meat quality of "Hy-plus" hybrid rabbits raised in the module and on the eco-farm.

MATERIAL AND METHODS

The material of the research was carcasses of rabbits slaughtered at the age of 90 days (10 rabbits raised in the modular rabbit house (Fig. 1) developed by the specialists of Mykolayiv NAU and 10 ones raised on the eco-farm "Rabbitax-8" (Fig. 2).

***Figure 1**. Modular rabbit house*

***Figure 2**. Eco-farm "Rabbitax-8"*

Young animals were slaughtered mechanically (with a struck on the back of the head with a stick) after a mandatory 12-hour fasting. The following weights were taken into account (to within 0.01 g): live body weight before slaughter, weight of fresh carcass with and without offal, head, ears, paws, tail, heart, kidneys, lungs, liver, spleen, fat mass (intermuscular, intra-abdominal), the mass of the offal and the mass of the gastrointestinal tract with chyme. In all cases, the hind and forelegs were separated from the carcass (front by elbow, and hind by hocks). Weighing was performed on electronic scales (MK-15.2-AB20) with a measurement accuracy of ± 1 g.

The morphological composition of the carcasses was determined by separating the muscle tissue together with the connective tissue from the bone. When viscerating carcasses of rabbits raised by various technologies, identified the most valuable parts of them – meat, viscerating products and fat. The weight of the viscera was estimated by weighing on electronic scales (MK-15.2-AB20) with a measurement accuracy of ± 1 g. Post-slaughter inspection of carcasses was controlled in accordance with the requirements of the "Rules of Veterinary Inspection of Slaughter Animals and Veterinary and Sanitary Examination of Meat and Meat Products" [4].

The chemical composition of meat, such as moisture, fat, protein, sol, was determined. For laboratory analysis, the flesh obtained by separating the muscle tissue together with the connective tissue from the bone was mechanically grinded twice in a meat grinder, then thoroughly mixed and the average sample was taken for chemical analysis. The quality of meat was determined in the regional sanitary-veterinary laboratory for assessing the quality of feed and products of animal origin in Mykolayiv. The chemical composition (mass fraction of dry matter, fat was determined according to State Standard GOST 23042-86, mass fraction of protein was determined according to State Standard GOST 25011-85, water content was determined according to the Method of Crau R., Hamm F.) was indicated [7].

Qualitative and quantitative amino acid composition of the protein was determined by ion exchange chromatography on the automatic analyzer AAA-339. The calculation of the quantitative content of amino acids was performed on the calibration scale constructed using a mixture of standard solutions. Fatty acid composition in g per 100 g of protein in muscle tissue was determined on the automatic analyzer according to conventional methods.

Meat was evaluated on the basis of organoleptic characteristics: color, aroma, texture of rabbit meat. Whole rabbit carcasses were used for cooking without stripping from surface fat. When assessing the quality of cooked meat and broth, the carcasses were placed in a pan with cold water (ratio of water and meat was 1:3), covered, brought to a boil and cooked for 1.5 hours. After cooking, the meat was removed from the broth and cooled to 30-40°. The cooled meat was cut into pieces of 50 g for each taster. All the results of the evaluation were entered in special tasting forms, which were distributed to the members of the tasting commission before the tasting. The number of tasters for evaluation on a 9-point scale was ten people.

Amino acid and fatty acid composition was determined in g per 100 g of muscle protein (hip cut) in the laboratory of biochemical analysis of livestock products in Mykolayiv.

RESULTS AND DISCUSSION

The average percentage of the rabbits' carcass components are shown in Table 1.

***Table 1**. Yield of slaughter products of rabbits raised under different conditions, (n=10)*

Product name	Yield, % to the carcass weight of rabbits	
	Eco-farm	Modular rabbit house
Fresh meat including:	53.9	53.6
Internal fat	7.1	8.2
Kidneys	0.6	0.7
Head	7.0	6.9
Skin	13.5	13.4
Ears, paws, tail	4.8	4.5
Blood	2.0	2.0
Liver	3.5	3.4
Offal	1.2	1.2
Entrails	6.4	6.3
Illiquid waste	8.7	8.7

Based on the data in Table 1, it should be noted that there is the high yield of fresh meat – 53.6 and 53.9%. Although this figure is 0.3% higher in the carcasses of the rabbits raised in the module, the difference is insignificant. There was also no significant difference in the amount of illiquid waste and offal of rabbits raised in different conditions.

The carcasses of rabbits from the module had 1.1% more fat and slightly enlarged kidneys. This can be explained by the peculiarities of the equipment. The size of the cages in the standard module is 80×40 cm to keep 6 rabbits, and the size of the eco-farm is 100×50 cm for 6 rabbits. The animals in the module move less due to the small space and accumulate fat. Therefore, this fact must be taken into account when improving the modular farm. Namely, increase the size of the cages. The chemical composition of meat determines its nutritional value. High quality rabbit depends on the optimal balance of protein, fat, sol elements, moisture and other substances.

We studied the chemical composition of meat of the rabbits raised under different conditions. Research data are shown in Table 2.

***Table 2**. Chemical composition of rabbit, (%)*

Indexes	Eco-farm	Modular rabbit house
Moisture	73.0	73.2
Fat	3.0	3.2
Protein	22.7	22.4
Sol	1.3	1.2

The analysis of the obtained results shows changes in the chemical composition – a slight increase in moisture and fat content (by 0.2%) in the rabbit meat, which was obtained by raising rabbits in the modular rabbit house compared to the rabbit meat obtained by raising rabbits on the eco-farm. At the same time there was 0.3% less protein and 0.1% less sol. In general, the difference in chemical composition was insignificant, which indicates the identity of the analyzed samples.

It was found that on the surface of rabbits' carcasses in all experimental groups after maturation a drying crust of pale pink color was formed in time, the serous membrane of the thoracic and abdominal cavities remained moist and shiny for some time. Subcutaneous and internal adipose tissues were white. The serous membranes of the thoracic and abdominal cavities were moist and shiny. The muscles in the cross-section of the rabbits' carcasses were slightly moist (leaved no wet spots on the filtered paper), pale pink with a red tinge. Their consistency was dense, elastic, when pressed the formed hole was quickly leveled; fat was dense. The aroma was specific for fresh meat. Therefore, the studied samples by organoleptic evaluation did not differ from each other and corresponded to high quality rabbit meat. More complete information about the organoleptic qualities of rabbit meat was obtained after cooking. The results of the tasting evaluation of meat and broth are shown in Table 3.

***Table 3**. Tasting evaluation of meat and broth*

Indexes	Rising technology	
	Eco-farm	Modular rabbit house
	M±m	M±m
	Rabbit meat	
Appearance	8.7±0.22	8.6±0.31
Aroma	8.3±0.18	8.5±0.21
Taste	9.0±0.19	9.0±0.23
Consistency	7.9±0.28	7.8±0.11
Succulence	7.8±0.15	7.7±0.24
General assesment	8.3±0.19	8.3±0.26
	Broth	
Appearance	8.5±0.24	8.5±0.34
Aroma	8.0±0.28	8.1±0.26
Taste	8.4±0.22	8.3±0.25
Richness	8.9±0.21	8.9±0.21
General assesment	8.5±0.24	8.5±0.29

The general tasting evaluation of meat and broth from hybrid rabbit carcasses raised on the eco-farm and in the modular rabbit house showed fairly high scores (meat – 8.3 points, broth –8.5 points on a 9-point scale). The top rating for meat was taste – 9.0 points, and for broth it was richness (8.9 points) according to the technology. The lowest score of meat was given to succulence – 7.8, 7.7 points respectively.

When evaluating the broth, the lowest score was given to aroma – 8.0, 8.1 points. It was noted that the appearance of rabbit resembles chicken meat. The consistency of all samples' meat was characterized as tender. The tasting evaluation of rabbit meat raised indoors (in the modules) was probably no different from the evaluation of hybrids' meat raised on the eco-farm. The broth during cooking was clear, flavorful, with nice smell. The quality of the broth was very good on all indicators and was rated quite high.

The biological value of rabbit meat proteins was assessed by the amino acid composition in which the presence of all essential amino acids was established. Research data are shown in Table 4.

***Table 4**. The content of essential amino acids in muscle tissue (g per 100 g of protein)*

Amino acids	Research groups	
	Eco-farm	Modular rabbit house
Valine	1.098	1.088
Isoleucine	0.982	0.989
Leucine	1.678	1.652
Lysine	1.789	1.698
Methionine + cystine	0.745	0.699
Threonine	1.099	1.089
Tryptophan	0.427	0.415
Phenylalanine	0.995	0.988

The data in Table 4 indicate the high quality of carcasses of rabbits raised under both housing conditions. Thus, the high content of lysine (1.789, 1.698), valine (1.098, 1.088), threonine (1.099, 1.089), phenylalanine (0.995, 0.988) and isoleucine (0.982, 0.989) indicates the protein value of meat of rabbits raised by means of the studied technologies without the use of growth stimulants during fattening. The difference in amino acid composition between the experimental groups was insignificant.

Obtaining information about the chemical, amino acid, lipid composition of rabbit meat allows us to substantiate feasibility of the most complete use of meat products of high biological value. The lipid composition of rabbit meat is characterized by a high content of polyunsaturated fatty acids: linoleic, linolenic, arachidonic. It should be noted that the cholesterol content in rabbit meat is much lower than in other species of farm animals.

Data on the lipid composition of carcasses of rabbits raised under different conditions are shown in Table 5.

Table 5. *Fatty-acid composition of meat of the rabbits raised by different technologies*

Indexes	Content, g per 100 g of product	
	Eco-farm	Module
Cholesterol	0.04	0.04
Fatty acids	2.78	2.71
Saturated, including:	1.33	1.28
Myristic	0.09	0.08
Pentodecanoic	0.04	0.03
Palmitic	0.71	0.69
Margaric	0.03	0.03
Stearic	0.46	0.45
Monounsaturated, including:	1.19	1.18
Myristoleic	0.17	0.16
Palmitoleic	0.11	0.13
Oleic	0.91	0.89
Polyunsaturated, including:	0.26	0.25
Linoleic	0.09	0.09
Linolenic	0.09	0.08
Arachidonic	0.08	0.08

Saturated fatty acids are in the lead. In percentage terms, their composition is almost 45-48%. Polyunsaturated acids occupy 8-9% of the total. Thus, the carcasses of hybrids from the experimental groups have a high content of saturated, monounsaturated and polyunsaturated fatty acids and the lowest content of cholesterol (0.04g/100g).

CONCLUSIONS

Thus, the nutritional value and organoleptic evaluation of rabbit showed that the meat of rabbits raised on the eco-farm does not differ from the meat of rabbits raised in the modular rabbit house and has the best nutritional and biochemical qualities, indicating the prospects of using modular farms to produce high quality products. The rabbits raised in the module and on the eco-farm showed an almost equal percentage of fresh meat yield – 53.6 and 53.9%. Rabbit carcasses from the module had 1.1% more fat and slightly enlarged kidneys due to the particular equipment. The difference in chemical composition was insignificant, which indicated the identity of the analyzed samples. The carcasses of the hybrids of the experimental groups had a high content of saturated, monounsaturated and polyunsaturated fatty acids and the lowest cholesterol content (0.04g/100g). The difference between the amino acid composition of meat and the lipid composition of fat in the study groups was insignificant.

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Порівняльний аналіз якості м'яса кролика при використанні технологій модульного вирощування та екоферми

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Анотація. Харчова цінність та органолептична оцінка кроликів показали, що м'ясо кроликів, вирощене на екофермі та в модульному кролятнику, не відрізняється одне від одного і має найкращі харчові та біохімічні якості, що вказує на перспективи використання модульних ферм для виробництва продукції високої якості. Виявлено високий відсоток виходу свіжого м'яса – 53,6 та 53,9 % у кроликів, вирощених у модулі та на екоферме. Тушки кроликів з модуля мали більше жиру на 1,1 % і дещо збільшені нирки через особливості обладнання. Спостерігаються зміни хімічного складу – незначне збільшення вологості та вмісту жиру (на 0,2 %) у м'ясі, що було отримано шляхом вирощування в модульному кролятнику порівняно з м'ясом кроликів, вирощеним на екоферме. Водночас було на 0,3 % менше білка і на 0,1 % менше золю. Загалом, різниця в хімічному складі була незначною, що вказувало на ідентичність аналізованих зразків. Досліджено органолептичні характеристики м'яса кролика в туші під час забою та після термічної обробки. М'язова консистенція була щільною, еластичною, під час натискання утворений отвір швидко вирівнювався; жир був щільним. Аромат був специфічним для свіжого м'яса. Усі зразки, взяті з вибірки гібридних кроликів «Ну-plus», вирощених у модульному кролячому будиночку, та тих, які вирощені на екоферме, мали найвищі бали. Досліджені зразки за органолептичною оцінкою не відрізнялися один від одного і відповідали кролику високої якості. Тушки гібридів в експериментальних групах мали високий вміст насичених, мононенасичених та поліненасичених жирних кислот і найнижчий вміст холестерину (0,04 г/100 г). Різниця між амінокислотним складом м'яса та ліпідним складом жиру в досліджуваних групах була незначною

Ключові слова: кролик, тушка, аромат, колір, консистенція, біохімічний склад

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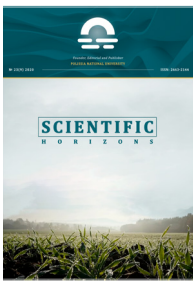

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Productivity of Short-Rotary Crop Cultivation under Different Systems of Basic Tillage in Organic Agriculture of the Steppe of Ukraine

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Abstract. Long-term reform of the agricultural sector in Ukraine is taking place under difficult economic and natural conditions. In modern agriculture, the most relevant ones are biologized measures and technologies for growing crops and resource- and energy-economic restoration of soil fertility. Studies of the impact of the system of basic tillage and the use of straw bio-decomposers and postharvest residues in organic farming were conducted in the most common and typical for the southern region of the steppe of Ukraine short-rotation crop cultivation with the following alternation of crops: peas – winter wheat – winter barley – ½ sunflower fields + ½ corn fields. During the years of the first cultivation, the experiment showed the advantages of a system of differentiated tillage, where even without the use of bio-decomposers, the highest yield of cereals was obtained – 3.64 tons/ha and sunflower – 2.20 tons/ha (check experiment). The application of the planar-free system combined with multi-depth and especially planar-free shallow soil processing, main tillage caused a decrease in grain yields by 0.11-0.39 tons/ha and sunflower by 0.28-0.42 tons/ha, respectively. With the use of bio-decomposers provided by brands Ecostern and Cellulad, yields' growth is in the range of 0.13-0.25 t/ha or 4.5-8.7% for cereals and 0.10-0.23 t/ha or 5.4-12.4% for sunflower. The application of the Ecostern bio-decomposer 1.5 l/ha provided an increase in the yield from 1 ha of crop rotation area of grain, fodder, fodder-protein units and digestible protein on average in all systems of basic tillage by 4.7, respectively; 4.5; 4.3 and 5.4%, and with the introduction of Cellulad 2.0 l/ha, these figures increased by 9.5, respectively; 8.9; 8.6 and 10.8% compared to options without the introduction of bio-decomposers

Keywords: farming, bio-decomposers, economic and natural conditions, restoration of soil fertility, yields' growth

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INTRODUCTION

At the current stage of development of Ukraine, as a country with a strong agro-industrial complex aimed at integration into the European Community, increasing the production of agricultural products is impossible without improving the agricultural sector. The main goal of reforming the agricultural sector of the country's economy is to obtain from each hectare of land the largest amount of high quality, environmentally friendly products with minimal production costs, while maintaining and increasing soil fertility and environmental protection. The past decade for Ukraine's agriculture has been characterized with a high rate of intensification of the industry, which is opposite in the background of excessive anthropogenic pressure on agricultural landscapes and their high level of depletion [1]. In today's world, more and more people are thinking about the excessive chemicalization of agricultural production, contributing to high level of total harvests. All of it has an extremely negative impact on the environment and human health. The first in the world to face the negative consequences of the intensification of agriculture were the advanced economies of Western Europe, such as the United States, Canada, Great Britain, and others. Progress in the modern world not only brings material welfare to mankind, but also causes an ever-increasing ecological load on the biosphere – soil, natural and artificial reservoirs, rivers, atmosphere, living organisms, etc. [2]. Opinions of scientists and producers of agricultural products have appealed to the alternative farming systems, including biological.

The ultimate goal of alternative agriculture is ecologically balanced agriculture and animal husbandry in order to provide people with ecologically clean food. Alternative agriculture does not mean a return to the old extensive technology, although it does not preclude the use of some of its elements. However, new systems must be competitive, i.e. highly productive [3]. However, at the present stage of agricultural development, the idea of organic farming requires a new approach, new technical solutions for the maximum possible returning to the soil of nutrients in the form of straw, manure, compost, municipal waste, green manure. The key to the effective development of agriculture around the world is the development and implementation of innovative, adapted farming systems. According to the National Standard of Ukraine [4] the term "biological system of agriculture" is a system of agriculture without the use of chemical fertilizers and pesticides. In Ukraine, as well as around the world, the demand for quality and safe food is growing, and the term "organic products" and "organic production" has recently become especially popular. In the nearest future, Ukraine should become a European leader in the production of organic food, as it has a large area of highly fertile land in Europe. Organic farming is a promising way of agricultural development in the world and in Ukraine. In agricultural science, sufficient experimental experience has been accumulated of the crucial importance of tillage in the system of agriculture. It is under the action of tillage that the agrophysical and agrobiological properties of the soil, its water, air, heat and nutrient regimes are regulated, the number of weeds, pests and the spread of pathogens in agrophytocenoses of field crops are regulated. Tillage ensures that the seeds and fertilizers are wrapped to the required depth, and other additional conditions are created for normal plant growth and development and crop formation [5-7].

In recent decades, Ukraine has carried out an extensive work to improve existing system and developing new one, more efficient tillage systems in accordance with specific soil and climatic conditions. Appropriate systems of basic, pre-sowing tillage and crop care have been developed, the need for differentiation of depth and number of tillage in crop rotation has been substantiated, and a system of soil protection tillage has been proposed for areas where wind and water erosion are observed [8-10]. Ukrainian modern agriculture uses differentiated tillage for individual crops in crop rotations using the latest equipment and technologies: a combination of plowing, tilting the soil without or before ploughing, chiseling, surface tillage (discs and cultivators) and the method of direct sowing without tillage. Studies conducted in recent years have shown that mechanical tillage, which aims to create optimal conditions for growth, development and crop formation of agricultural plants, occupies a leading place in the agricultural system. The main tillage, which uses 60-75% of the total fuel consumption and funds intended for tillage throughout the growing season is a major element in the overall process cycle. The variety and features of existing methods and systems of tillage solve its main task in creating optimal conditions in the arable layer, where a significant part of the absorbing surface of the root system of plants is concentrated and it is in this layer of soil should be sufficient for germination and further development of plants. and organic compounds. Only by scientifically-based cultivation adapted to a specific group of agroecological soil conditions are favorable for the life of field crops [11-13].

The leading link in any system of agriculture is the rational structure of areas under cultivation and the system of crop rotations. This link acquires special significance under the conditions of the biological system of agriculture. It is responsible for the process of self-regulation of soil fertility and expanded reproduction of soil fertility. In Ukraine, crop rotations have a classic ecological basis. One crop rotation includes a large composition of crops from different families, i.e. they can simultaneously grow crops with different biological properties. Agrotechnical and biological basis of crop rotations with a wide range of crops is provided by the annual change of different plants in the field. The sharper the difference between crops and the greater the period

between the return to the same field of the corresponding group of plants, the higher the effect of the entire crop rotation. Due to the rotation of crops with different biological properties, better conditions are created for the growth and development of plants and increase in the collection of ecologically clean products of organic farming. However, the productivity of crop rotations in organic farming is inferior to crop rotations with organo-mineral fertilizer system by 16-22% [14]. The main performance by increasing their crop rotation is optimal saturation of high-yielding crops while maintaining, restoring and improving soil fertility. Different crop rotation, as well as the use of optimal fertilization and tillage system significantly affect crop productivity in general: grain and oilseed yields from 1 ha of crop rotation area, yield of grain, fodder, feed-protein units and digestible protein from 1 ha of arable land. After all, the productivity of crop rotations is determined in kind by the collection of basic products, and for the general assessment of crop rotation – in the conversion of all products (main and secondary) into grain, feed, feed protein units and digestible protein [15; 16].

The aim of the research. The research envisages: to establish the influence of different systems of basic tillage and application of bio-decomposers of straw Ecostern 1.5 l/ha and Cellulad 2 l/ha in short-rotation crop rotation on the yield of individual crops and overall crop rotation productivity in organic farming of the Southern Steppe of Ukraine.

MATERIALS AND METHODS

Evaluation of crop rotation efficiency should be carried out comprehensively, taking into account a number of indicators. To compare the productivity of short-rotation field crop rotation, depending on the factors studied in the experiment, the indicators of grain and seed production of oilseeds, yield of grain, feed, feed protein units and the availability of digestible protein were taken into account. Conducting organic farming in the arid Southern Steppe of Ukraine has certain features and weaknesses and therefore the focus should be on the implementation of elements of biologization of agriculture, based on specific soil and climatic conditions of farms management and specialization. Undoubtedly, the best conditions for the biologization of agriculture and the production of environmentally friendly products are created in farms of mixed type with the presence of certain livestock industries. In farms of grain or grain-oil specialization, which is the vast majority of farms in the Southern Steppe, there are problems with the implementation of biologization measures. Of particular importance, this problem is in terms of global warming and the conditions for the growth of harmful effects of drought in the southern region. It is the lack of precipitation, and sometimes the complete absence of them in the second half of the growing season, makes it impossible to obtain seedlings of green crops, low share of by-products of field crops in drought, low productivity of legumes and low share in the structure of sown areas, all worsens balance of nutrients in the soil. Thus, according to Ye. Yurkevych [17-20], for four years of research in the Southern Steppe, not even seedlings of post-harvest green manure crops were obtained, due to the lack of productive moisture in the soil. The research is carried out in a grain-rotating short-rotation 4-field crop cultivation with the following alternation of crops: peas – winter wheat – winter barley – ½ sunflower fields + ½ corn fields. The soil of the experimental plot is chernozem(blacksoil) ordinary, low-humus, medium-thick, heavy loam in the forest. Place of research: Ivaniv district of Odesa region of Ukraine. Scheme of the experiment: two-factor experiment:

Factor A – main tillage systems:
a_1 differentiated – check;
a_2 – planar-free multi-depth;
a_3 – planar-free shallow;
Factor B – bio-decomposers of by-products:
b_1 – without bio-decomposers
b_2 – Ecostern 1.5 l / ha;
b_3 – Cellulite 2.0 l / ha.

Variants of the experiment are placed in 3 repetitions by the method of split sections. The total area under experiment – 7.78 ha land area in the experiment: soil tillage – 2158 m^2, bio-decomposers – 2160 m^2. In the experiment, zoned varieties and hybrids of crops were sown (Table 1).

***Table 1**. Scheme of basic tillage systems in the experiment*

Variants of basic tillage systems	No. crops in crop rotation			
	1	2	3	4
	Peas for grain	Soft winter wheat	Winter barley	½ corn for the grain ½ sunflower
Differentiated (check)	Planar deep, 23-25 cm	Shallow, 10-12 cm	Planar-free shallow, 10-12 cm	Planar deep, 25-27 cm Planar deep, 25-27 cm
Planar-free different-depth	Planar-free shallow, 12-14 cm	Planar-free shallow, 10-12 cm	Planar-free shallow, 10-12 cm	Planar-free shallow, 12-14 cm Planar-free shallow, 12-14 cm
Planar-free shallow	Planar-free shallow, 10-12 cm	Planar-free shallow, 10-12 cm	Planar-free shallow, 10-12 cm	Planar-free shallow, 10-12 cm Planar-free shallow, 10-12 cm

Agricultural techniques for growing crops in the experiment, in addition to the options studied, were recommended for the study area, taking into account the requirements of organic farming. The total crop rotation productivity was determined in kind by the volume of main and by-products from 1 ha of crop rotation area, as well as in the conversion of these products into grain units by V. Grevtsov [21] coefficients, feed, feed protein units and digestible protein according to M. Tomme [22] tables. The obtained results were subjects to statistical analysis of variance according to B. Dospekhov [23].

RESULTS AND DISCUSSION

In addition to economic, energy and agro-technical assessment of the effectiveness of any crop rotation, farmers and scientists are largely interested in its productivity. This indicator makes it possible to assess the agro-technical impact of predecessors, the system of basic tillage, fertilizers, ameliorants, biostimulants, etc., on increasing soil fertility, which determines the yield of each crop and crop rotation in general. Table 2, Figures 1 and 2 shows the average data for assessing the productivity of short-rotation oilseed crop rotation for the first rotation, depending on the implementation of different systems of basic tillage in crop rotation and the use of bio-decomposers of crop by-products of crop rotation.

LSD (Least Significant Difference). The scheme of short-rotation crop rotation for research of the impact of the system of basic tillage and the use of bio-decomposers of straw and after harvest residues in organic farming was chosen on purpose. Crops grown in crop rotation are typical are the most common and the most typical for agriculture in the arid southern region of the Steppe of Ukraine. The development of measures aimed at increasing the productivity of this crop rotation will improve the market supply of agricultural products with grain and oil.

***Table 2**. Productivity of short-rotation crop cultivation depending on the studied factors, average 2015-2018 [t/ha]*

Tillage system	Crops rotation in rotation	Crop capacity, [t/ha]		Yield of arable land, [t/ha]			
		Cereals	Oilseeds	Grain units	Feed units	Feed and protein units	Digestible protein
Without bio-decomposers							
Differentiated (check)	Peas	2.41		3.90	3.85	4.83	0.58
	Winter wheat	3.61		4.12	5.35	5.04	0.48
	Winter barley	2.87		2.64	4.73	3.74	0.28
	Sunflower		2.20	2.51	0.65	1.36	0.21
	Corn	5.68		3.81	6.19	4.85	0.35
Total in crop rotation				**16.99**	**20.77**	**19.81**	**1.89**
Average in crop rotation		**3.64**	**2.20**	**4.25**	**5.19**	**4.95**	**0.48**
Planar-free Multi-depth	Peas	2.33		3.79	3.74	4.68	0.57
	Winter wheat	3.60		4.11	5.34	5.03	0.47
	Winter barley	2.95		2.71	4.85	3.83	0.28
	Sunflower		1.92	2.20	0.57	1.19	0.18
	Corn	5.21		3.49	5.67	4.44	0.32
Total in crop rotation				**16.30**	**20.16**	**19.17**	**1.82**
Average in crop rotation		**3.53**	**1.92**	**4.08**	**5.04**	**4.80**	**0.46**
Planar-free shallow	Peas	2.21		3.58	3.54	4.43	0.53
	Winter wheat	3.22		3.67	4.77	4.50	0.42
	Winter barley	2.58		2.37	4.24	3.35	0.25
	Sunflower		1.78	2.03	0.53	1.10	0.17
	Corn	4.97		3.34	5.43	4.25	0.31
Total in crop rotation				**14.99**	**18.59**	**17.68**	**1.68**
Average in crop rotation		**3.25**	**1.78**	**3.75**	**4.64**	**4.42**	**0.42**

Table 2, Continued

Tillage system	Crops rotation in rotation	Crop capacity, [t/ha]		Yield of arable land, [t/ha]			
		Cereals	Oilseeds	Grain units	Feed units	Feed and protein units	Digestible protein
Bio-decomposer Ecostern 1.5 l/ha;							
Differentiated (check)	Peas	2.63		4.26	4.20	5.27	0.63
	Winter wheat	3.86		4.41	5.72	5.39	0.51
	Winter barley	3.01		2.78	4.97	3.93	0.29
	Sunflower		2.32	2.64	0.69	1.43	0.22
	Corn	6.01		4.03	6.56	5.14	0.37
Total in crop rotation				**18.12**	**22.13**	**21.15**	**2.01**
Average in crop rotation		**3.88**	**2.32**	**4.53**	**5.54**	**5.29**	**0.50**
Planar-free Multi-depth	Peas	2.51		4.07	4.02	5.03	0.60
	Winter wheat	3.86		4.40	5.72	5.39	0.51
	Winter barley	3.08	2.16	2.83	5.06	4.00	0.30
	Sunflower		1.98	2.31	0.61	1.25	0.19
	Corn	5.49		3.69	6.00	4.69	0.34
Total in crop rotation				**17.30**	**21.39**	**20.36**	**1.93**
Average in crop rotation		**3.73**	**2.02**	**4.33**	**5.35**	**5.09**	**0.49**
Planar-free shallow	Peas	2.37		3.84	3.79	4.75	0.57
	Winter wheat	3.46		3.95	5.12	4.83	0.46
	Winter barley	2.72		2.50	4.47	3.53	0.26
	Sunflower		1.86	2.12	0.56	1.15	0.17
	Corn	5.23		3.51	5.71	4.47	0.32
Total in crop rotation				**15.97**	**19.74**	**18.80**	**1.79**
Average in crop rotation		**3.44**	**1.86**	**3.99**	**4.94**	**4.70**	**0.45**
Bio-decomposer Cellulad 2.0 l/ha;							
Differentiated (check)	Peas	2.67		4.32	4.26	5.34	0.64
	Winter wheat	4.03		4.59	5.96	5.62	0.53
	Winter barley	3.15		2.90	5.19	4.10	0.30
	Sunflower		2.38	2.72	0.71	1.47	0.22
	Corn	6.10		4.09	6.65	5.20	0.38
Total in crop rotation				**18.63**	**22.77**	**21.73**	**2.09**
Average in crop rotation		**3.99**	**2.38**	**4.66**	**5.70**	**5.43**	**0.52**
Planar-free Multi-depth	Peas	2.54		4.13	4.08	5.10	0.61
	Winter wheat	4.01		4.57	5.94	5.60	0.53
	Winter barley	3.18		2.92	5.22	4.12	0.30
	Sunflower		2.11	2.41	0.63	1.30	0.20
	Corn	5.55		3.72	6.05	4.74	0.34
Total in crop rotation				**17.75**	**21.91**	**20.86**	**1.98**
Average in crop rotation		**3.82**	**2.11**	**4.44**	**5.48**	**5.21**	**0.50**

Table 2, Continued

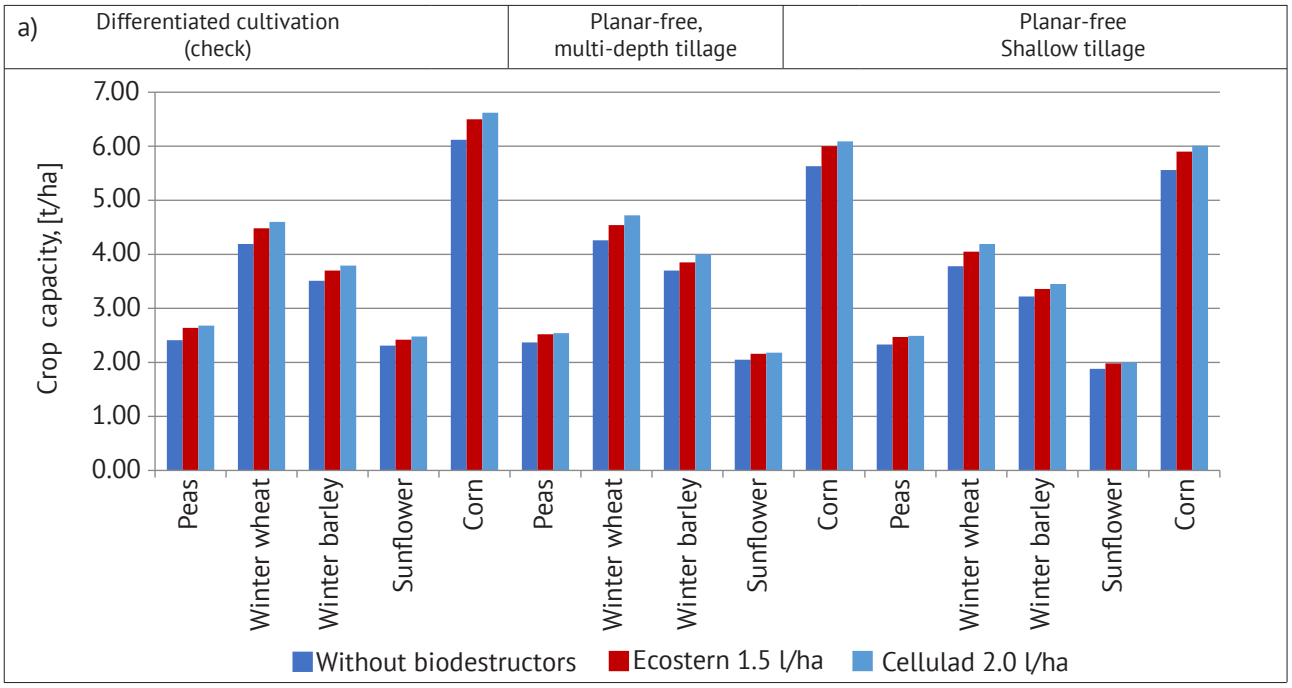
Tillage system	Crops rotation in rotation	Crop capacity, [t/ha]		Yield of arable land, [t/ha]			
		Cereals	Oilseeds	Grain units	Feed units	Feed and protein units	Digestible protein
Planar-free shallow	Peas	2.39		3.88	3.83	4.80	0.58
	Winter wheat	3.66		4.18	5.42	5.11	0.48
	Winter barley	2.81		2.59	4.62	3.65	0.27
	Sunflower		1.90	2.17	0.57	1.17	0.18
	Corn	5.30		3.55	5.77	4.52	0.33
Total in crop rotation				**16.36**	**20.20**	**19.25**	**1.83**
Average in crop rotation		**3.54**	**1.90**	**4.09**	**5.05**	**4.81**	**0.46**
LSD_{05}	Factor A	0.03-0.06	0.03-0.08	0.02	0.01-0.03	0.02-0.03	0.02-0.09
	Factor B	0.03-0.06	0.03-0.08	0.02	0.01-0.03	0.02-0.03	0.02-0.09
	Interaction of AB factors	0.05-0.11	0.04-0.14	0.04	0.02-0.05	0.03-0.06	0.03-0.15

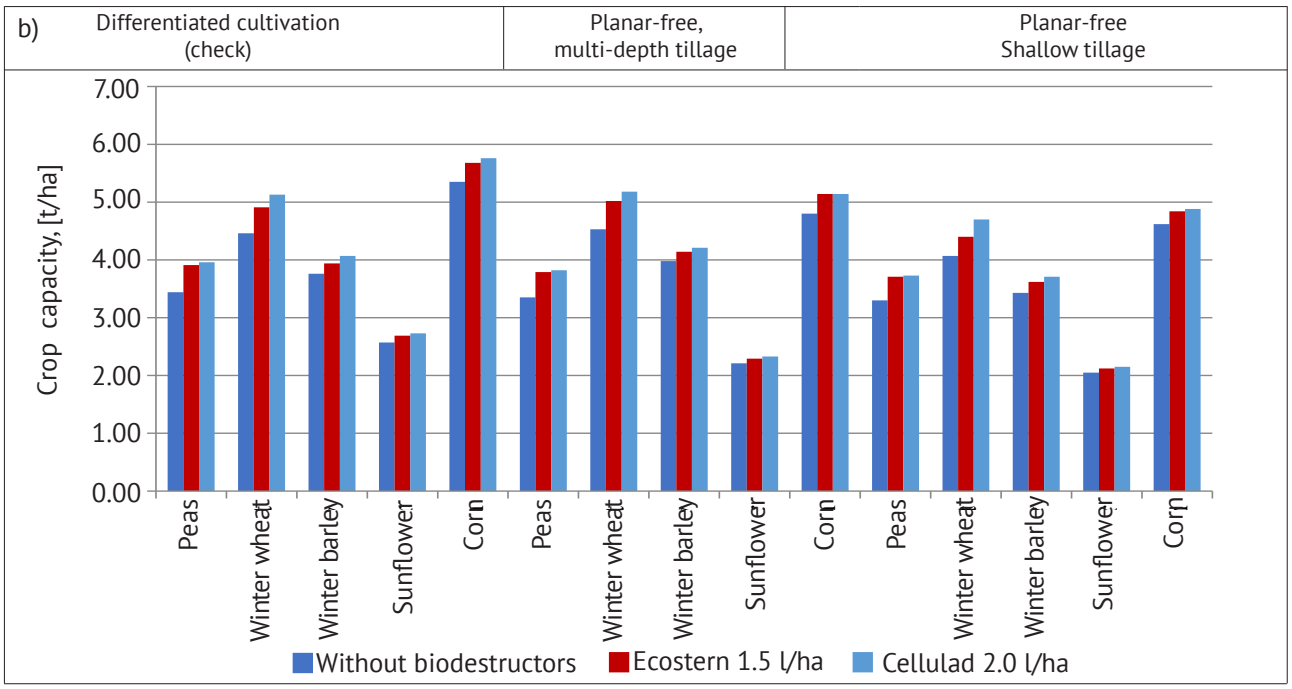
During the years of the first rotation (Table 2, Fig. 1, 2), the experiment showed the advantages of a system of differentiated tillage, where even without the use of bio-decomposers, the highest crop capacity of cereals was obtained – 3.64 t/ha and sunflower – 2.20 t/ha (check). The application of the system of planar-free shallow tillage caused a slight decrease in the yield of grain crops by 0.11 t/ha and sunflower by 0.28 t/ha. An even greater decrease in the crop capacity occurred in the experiment in the version with a system of planar-free shallow main tillage, where the yield of cereals was – 3.25 t/ha, or 0.39 t/ha less than the check experiment, and sunflower respectively – 1.78 t/ha, or 0.42 t/ha less.

The productivity of the group of both grain and oilseeds as a whole, as well as individual crops of short-rotation field crop cultivation, changed under the influence of factors that were studied in the experiment and the weather conditions of the research years. It was found that without the use of straw bio-decomposers, the highest grain crop capacity was obtained in the experiment in the version with a system of differentiated basic tillage in crop rotation in 2016 – 4.25 t/ha (Fig. 1). This year is characterized as very favorable in terms of hydrothermal parameters (hydrothermal coefficient = 2.18). Some decrease in grain yield occurred in variants with a system of planar-free multi-depth and planar-free shallow main tillage in crop rotation, respectively, by 0.08-0.39 t/ha, or 1.9-9.2% (LSD_{05}=0.05 t/ha). Similarly, for oilseeds – sunflower, the yield in the version with a system of differentiated basic tillage in crop rotation was – 2.57 t/ha, which is 0.36-0.52 t/ha, or 14.0-20.2% more in comparison with the systems of planar-free multi-depth and planar-free shallow main tillage (LSD_{05}=0.09 t/ha). The yield of grain and oilseeds was slightly lower in 2015, although this year was generally favorable for the growth and development of field crops and hydrothermal indicators exceeded the average long-term data (hydrothermal coefficient = 1.06), but elevated temperatures during filling and grain formation winter crops led to its ignition and the formation of lean grain with a low mass of 1000 grains. The grain yield without the introduction of straw bio-decomposers this year was – 4.06 t/ha in the version with a system of differentiated main tillage in crop rotation and significantly exceeded the options with a system of planar-free shallow and pl nar-free shallow main tillage by 0.07-0.3, or 1.9-8.4% (LSD_{05}=0.03 t/ha). The cultivation of oilseeds – sunflower on the system of planar-free shallow main tillage led to a decrease in seed crop capacity, respectively, by 0.26-0.43 t/ha, or 11.3-18.6% (LSD_{05}=0.05 t/ha). in comparison with the control variant, with the system of differentiated tillage, where the seed yield was at the level of 2.31 t/ha.

In the conditions of 2017 (hydrothermal coefficient = 0.91) and 2018 (hydrothermal coefficient = 0.42) years, which according to weather conditions, namely the level of moisture and temperature were characterized as sufficiently unfavorable for the growth and development of cereals and oilseeds, the authors observed significant reduction of the total productivity of cultivated crops in short-rotation crop cultivation. But even in these years, the highest yields of cereals and oilseeds were obtained without the use of bio-decomposers of straw, in the version with a system of differentiated basic tillage: 2017 – 3.09 t/ha of grain and 2.08 t/ha – sunflower; 2018, respectively – 3.17 t/ha of grain and 1.83 t/ha of sunflower. It is the difficult weather conditions of these years, insufficient moisture and abnormal heat, did not allow plants to realize their potential productivity. Thus, compared to the best 2016, in the version without the use of straw bio-decomposers, with a system of differentiated basic tillage in crop rotation, the productivity of cereals decreased by 1.16-1.08 t/ha, respectively, or 27.3-25.4%, and for sunflower by 0.49-0.74 t/ha, or 19.1-28.8%. The response of cereals and sunflower to the minimization of basic cultivation in extreme years was also not the same. In 2017, the introduction of systems of planar-free

multi-depth and planar-free shallow main tillage led to a decrease in grain yields without the introduction of straw bio-decomposers by 0.19-0.43 t/ha, or 6.1-13.9% (LSD_{05}=0.06 t/ha), and oil – sunflower by 0.27-0.41 t/ha, or 13.0-19.7% (LSD_{05}=0.08 t/ha). The same pattern was revealed in the studies of V. Tsikov [24] and S. Tanchyk et al. [25] under the conditions of the ecological system of agriculture. Similar changes took place in 2018, where the use of systems of planar-free shallow multi-depth and planar-free shallow main tillage without the use of straw bio-decomposers, led to a decrease in grain yields by 0.13-0.43 t/ha, or 4.1-13.6% (LSD_{05}=0.05 t/ha). A similar pattern of the influence of systems of minimization of basic tillage in crop rotation on the yield of oilseeds – sunflower, where its yield in the version with a system of differentiated basic tillage was – 1.83 t/ha, and in options with a system of non-planar tillage it significantly decreased by 0.21-0.33 t/ha, respectively, or by 11.5-18.0% (LSD_{05}=0.04 t/ha). The reaction of individual cereals crop rotation to the systems of basic tillage in crop cultivation was different depending on their biological characteristics and weather conditions of the year. Over the years of research, the best soil conditions were observed in the case with a system of differentiated basic tillage. However, in the case of winter wheat and winter barley crops, the experiment did not observe a clear advantage of the system of differentiated basic tillage for yield formation in comparison with the systems of planar-free deep and shallow main tillage. On the contrary, in winter barley, slightly higher grain yield was in the variant with the system of planar-free multi-depth basic tillage, while in winter wheat grain crop capacity decreased under such a system of basic tillage. But these crops significantly reduced the capacity in the option with a system of planar-free shallow main tillage in short-rotation crop cultivation.





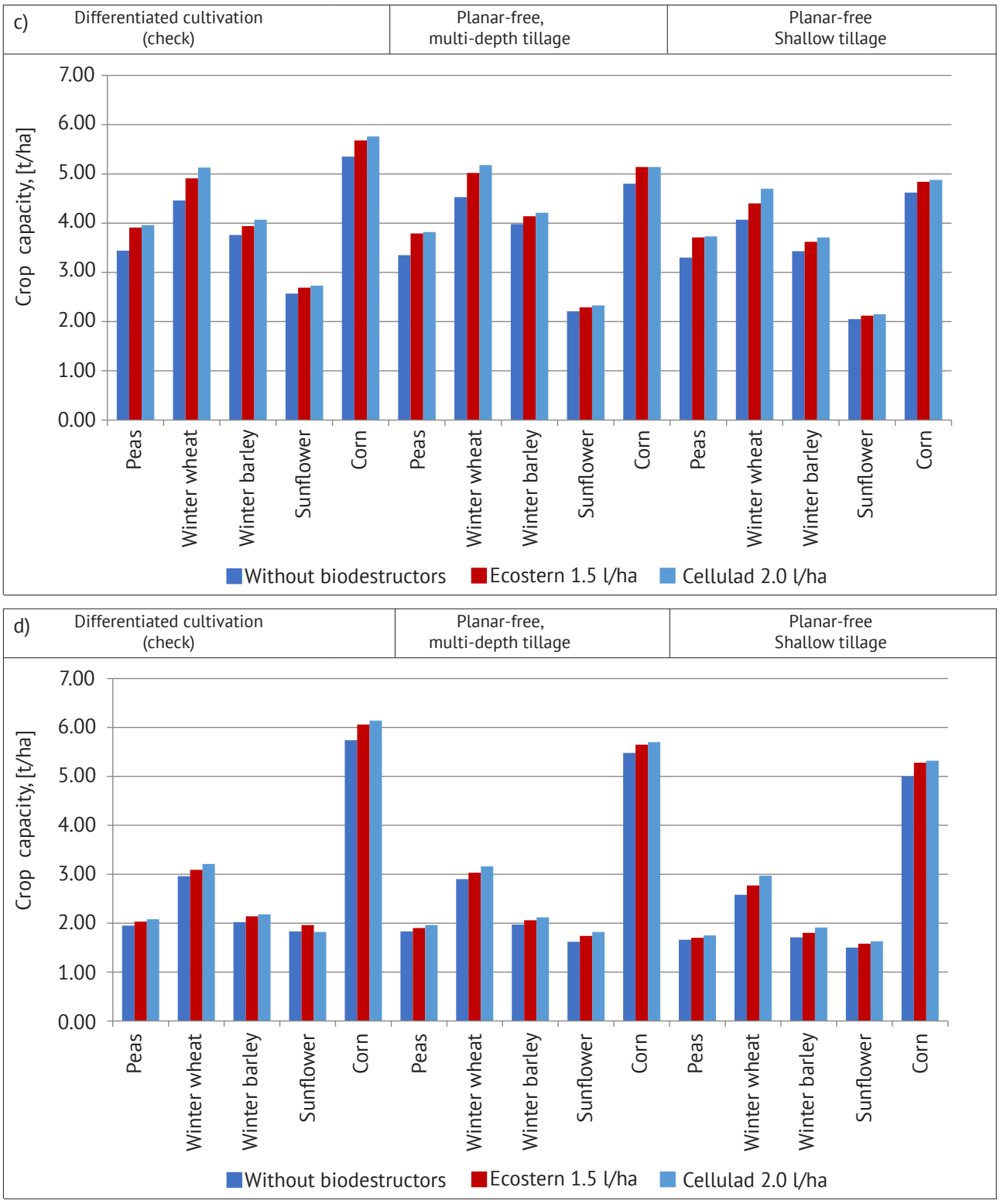


Figure 1. *Crop capacity of cereals and oilseeds depending on tillage and used bio-decomposers for 2015-2018: a) 2015, b) 2016, c) 2017, d) 2018*

Thus, over the years of research, for winter wheat grain change for systems of planar-free multi-depth and planar-free shallow main tillage in short-rotation crop cultivation in comparison with the check variant – system of differentiated main tillage compared to the background without bio-decomposers within straw:

2015, +0.09 and -0.41 t/ha, (LSD_{05}=0.03 t/ha);
2016, +0.07 and -0.39 t/ha, (LSD_{05}=0.04 t/ha);
2017, -0.12 and -0.40 t/ha, (LSD_{05}=0.06 t/ha);
2018, -0.06 and -0.38 t/ha, (LSD_{05}=0.05 t/ha).

The same applies for winter barley, respectively:
2015, +0.19 and -0.29 t/ha, (LSD_{05}=0.03 t/ha);
2016, +0.22 and -0.33 t/ha, (LSD_{05}=0.04 t/ha);
2017, -0.04 and -0.23 t/ha, (LSD_{05}=0.06 t/ha);
2018, -0.05 and -0.31 t/ha, (LSD_{05}=0.05 t/ha).

The reaction of spring crops of peas and especially

corn and sunflower to the use of systems of planar-free shallow multi-depth and planar-free shallow main tillage in short-rotation crop cultivation was extremely negative. Thus, the following decrease in yield was observed in the experiment, respectively:

2015, -0.04 and -0.08 t/ha, (LSD_{05}=0.03 t/ha);
2016, -0.09 and -0.14 t/ha, (LSD_{05}=0.04 t/ha);
2017, -0.05 and -0.33 t/ha, (LSD_{05}=0.06 t/ha);
2018, -0.12 and -0.29 t/ha, (LSD_{05}=0.05 t/ha).

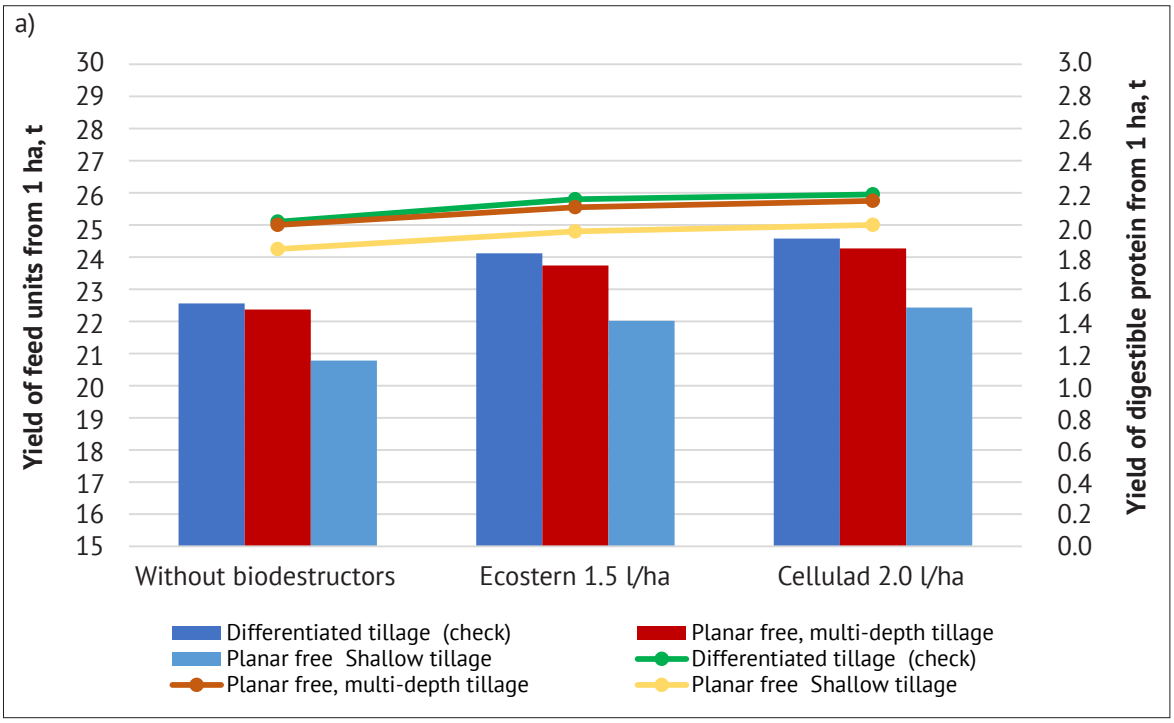
The reaction of sunflower culture was much greater to the use of planar-free systems of different depths and shallow basic tillage in crop rotation, namely:

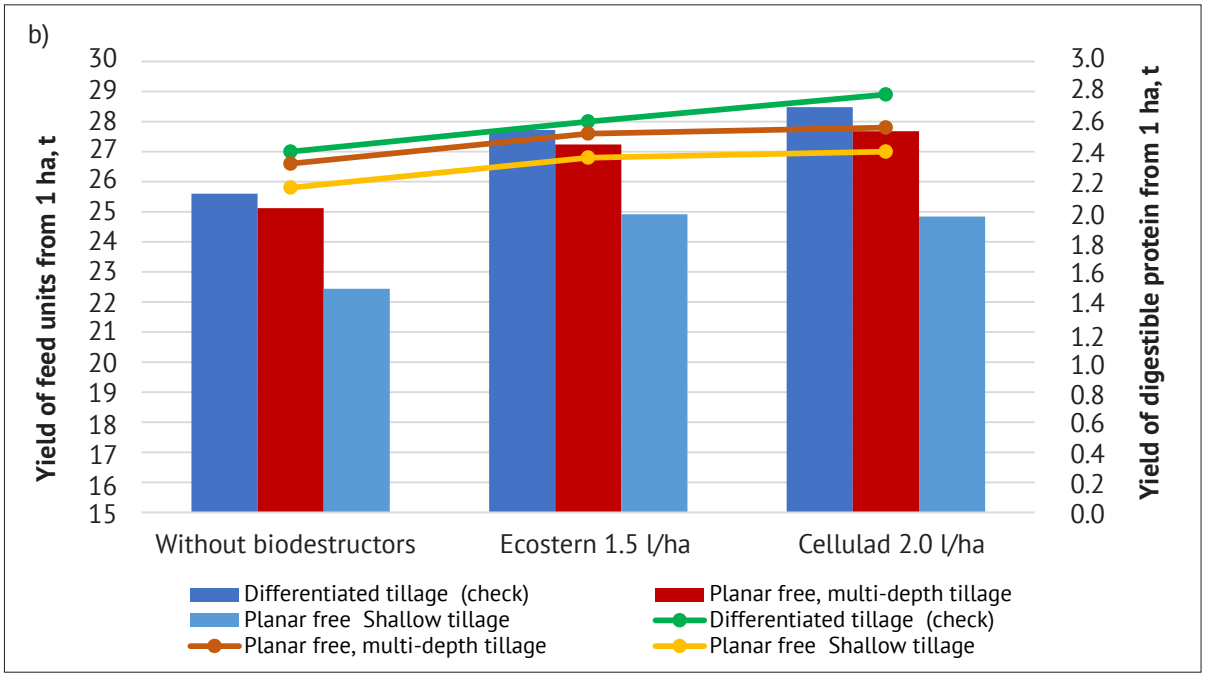
2015, -0.26 and -0.43 t/ha, (LSD_{05}=0.03 t/ha);
2016, -0.36 and -0.52 t/ha, (LSD_{05}=0.05 t/ha);
2017, -0.13 and -0.41 t/ha, (LSD_{05}=0.08 t/ha);
2018, -0.21 and -0.33 t/ha, (LSD_{05}=0.04 t/ha).

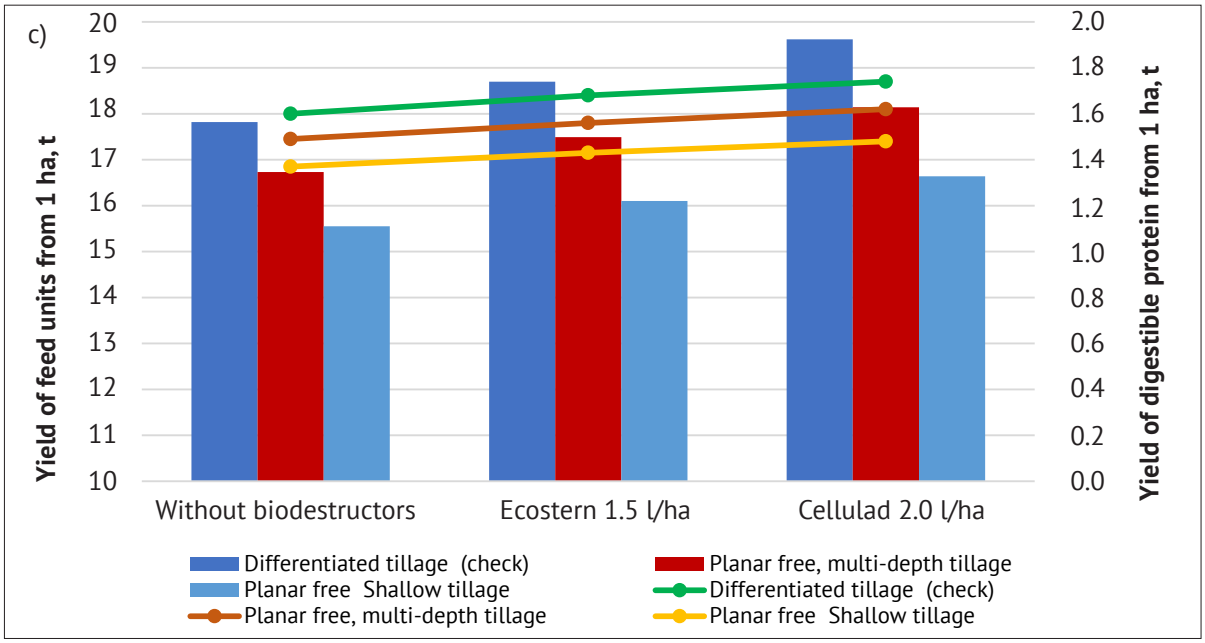
And the corn crop reacted the most to the minimization of the system of basic tillage in crop rotation:

2015, -0.49 and -0.56 t/ha, (LSD_{05}=0.03 t/ha);
2016, -0.55 and -0.73 t/ha, (LSD_{05}=0.04 t/ha);
2017, -0.61 and -0.81 t/ha, (LSD_{05}=0.06 t/ha);
2018, -0.26 and -0.74 t/ha, (LSD_{05}=0.05 t/ha).

According to the results of the research it is revealed that not only the systems of basic tillage in short-rotation crop cultivation, but also the use of various bio-decomposers of straw Ecostern and Cellulad significantly affected the yield of individual crops and overall crop rotation productivity as a whole. The efficiency of straw bio-decomposers was determined by the conditions of the year, as well as by different ways of post-harvest residues entering the soil depending on the system of basic tillage in short-rotation crop cultivation. However, it was found that the bio-decomposer Cellulad, in terms of efficiency, exceeds the bio-decomposer Ecostern. Thus, on average, for all variants of the main tillage systems in 2015, the application of the bio-decomposer Ecostern 1.5 l/ha increased the yield capacity of grain crops by 0.25 t/ha, or 6.4% (LSD_{05}=0.03 t/ha), and sunflower – by 0.11 t/ha, and 5.3% (LSD_{05}=0.03 t/ha). When using the bio-decomposer Cellulad 2.0 l/ha, the yield increased by 0.41 t/ha, or by 9.7% (LSD_{05}=0.03 t/ha), and 0.13 t/ha and 5.7 by sunflower, respectively (LSD_{05}=0.03 t/ha). Deterioration of plant moisture conditions due to lack of precipitation in 2017 significantly reduced the effectiveness of straw bio-decomposers. Against the background of the introduction of the bio-decomposer Ecostern 1.5 l/ha on average for all systems of basic tillage in crop rotation, the increase in grain yield was only 0.13 t/ha, or 4.5% (LSD_{05}=0.06 t/ha), and for sunflower 0.10 t/ha, or 4.5% (LSD_{05}=0.08 t/ha). Against the background of the application of the bio-decomposer Cellulad 2.0 l/ha, the increase in grain yield was 0.25 t/ha, or 8.7% (LSD_{05}=0.06 t/ha), and for sunflower, respectively, 0.23 t/ha and 12.4% (LSD_{05}=0.08 t/ha).




b)
Yield of feed units from 1 ha, t
Yield of digestible protein from 1 ha, t
30
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Without biodestructors
Ecostern 1.5 l/ha
Cellulad 2.0 l/ha
Differentiated tillage (check)
Planar free Shallow tillage
Planar free, multi-depth tillage
Planar free, multi-depth tillage
Differentiated tillage (check)
Planar free Shallow tillage


c)
Yield of feed units from 1 ha, t
Yield of digestible protein from 1 ha, t
20
19
18
17
16
15
14
13
12
11
10
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Without biodestructors
Ecostern 1.5 l/ha
Cellulad 2.0 l/ha
Differentiated tillage (check)
Planar free Shallow tillage
Planar free, multi-depth tillage
Planar free, multi-depth tillage
Differentiated tillage (check)
Planar free Shallow tillage

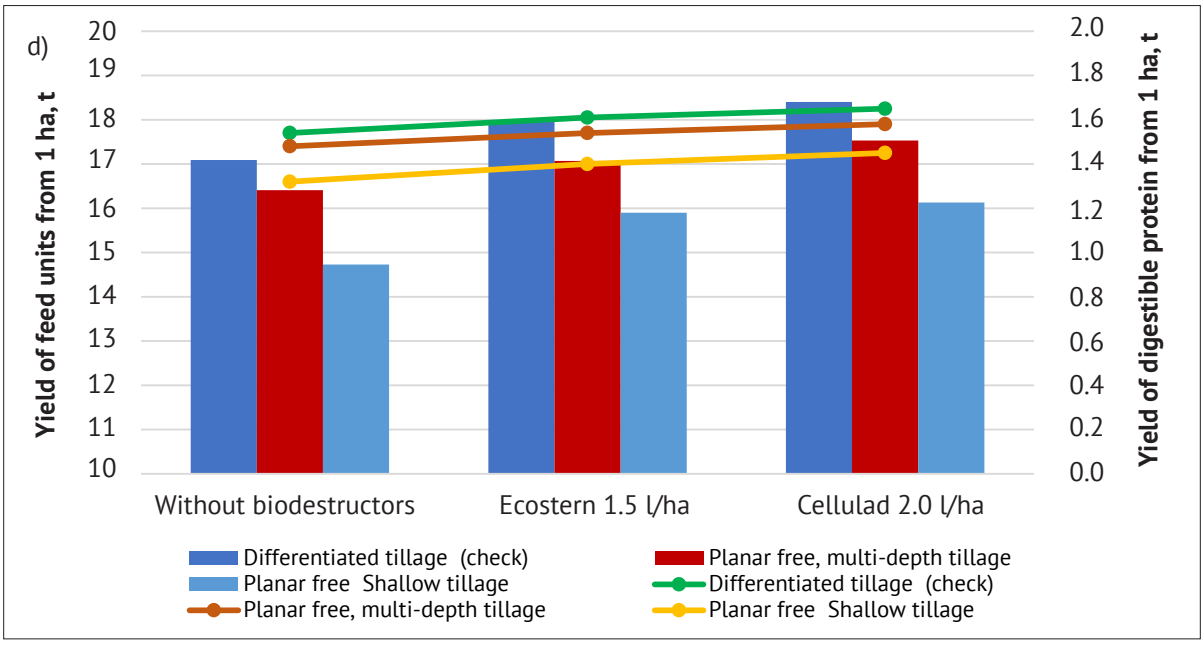


***Figure 2**. Total productivity of short-rotation crop cultivation depending on tillage and used bio-decomposers for 2015-2018: a) 2015, b) 2016, c) 2017, d) 2018*

In 2018, the use of Ecostern straw bio-decomposer 1.5 l/ha provided an increase in grain yield for all systems of basic tillage in crop rotation at the level of 0.15 t/ha or 5.0% (LSD_{05}=0.05 t/ha) and sunflower by 0.11 t/ha, or 6.7% (LSD_{05}=0.04 t/ha). But the largest increase in yield this year was observed against the background of the application of the bio-decomposer Cellulad 2.0 l/ha and averaged on all systems of basic tillage, on cereals 0.23 t/ha, or 7.7% (LSD_{05}=0.05 t/ha), and for oilseed sunflower – 0.17 t/ha, or 10.3% (LSD_{05}=0.04 t/ha). Also, in the researches of V. Malyarchuk and M. Starodubtseva [26], A. Kushnaryov et al. [27] they proved the effectiveness of bio-decomposers with the background of a system of differentiated basic tillage in crop rotation. According to the results of research conducted during 2015-2018. The experiment showed a clear pattern of the advantage of the system of differentiated tillage in grain plowing short-rotation crop cultivation in comparison with planar-free multi-depth and planar-free shallow systems of basic tillage (Table 2). Thus, without the use of straw bio-decomposers in the differential system of basic tillage, the aver-age crop capacity of cereals was – 3.64 t/ha, which exceeded the options with planar-free multi-depth and planar-free shallow tillage, respectively, 0.11-0.39 t/ha (LSD_{05} A=0.03-0.06), or 3.0-10.7%. The same pattern was observed for the influence of basic tillage systems on the productivity of oilseeds – sunflower, where the yield of seeds according to the system of differentiated tillage without the use of bio-decomposers – 2.20 t/ha, which is 0.28-0.42t/ha (LSD_{05} A=0.03-0.08), or by 12.7-19.1% more in comparison with variants with the system of planar-free different depth and planar-free shallow tillage.

The scientific works of A. Kuznetsov [28], V. Loshakov [29], O. Tsyuk [30] proved that the productivity of crop rotation largely depends on its structure, selection of crops, fertilization system, system of basic tillage. A similar pattern can be traced in studies on other indicators of crop rotation productivity, namely grain units, feed, feed protein units and digestible protein, which are derived from the productivity of individual crops in crop rotation (Table 2). Thus, high yields of cereals and sunflower on the background of the system of differentiated main tillage during the first rotation of crop rotation provided the highest yield from 1 ha of arable land grain units – 4.25 t/ha, feed units – 5.19 t/ha, feed and protein units – 4.95 t/ha and 0.48 t/ha of digestible protein. In the case with the system of planar-free multi-depth basic tillage in crop rotation, the productivity was lower per 1 ha of arable land by 0.17 tons of grain units, 0.15 tons of feed units, 0.15 tons of feed-protein units, and digestible protein not significant only by 0.02t compared to the check experiment (LSD_{05}=0.06 t/ha). The lowest crop rotation productivity was in the experiment, which used a system of planar-free shallow main tillage. In this embodiment, the yield from 1 ha of arable land grain units decreased by 11.8%, feed units by 10.6%, feed protein units by 10.7% and digestible protein by 12.5%. The use of bio-decomposers Ecostern and Cellulad for all cases of the system of basic tillage in crop rotation has increased the crop capacity of cereals and sunflower and crop rotation productivity in general. However, the effectiveness of these bio-decomposers was different. Thus, the yield of cereals and sunflower from the use of bio-decomposer Ecostern at a dose of 1.5 l/ha on the background of planar-free shallow tillage increased by

0.19 t/ha (LSD_{05} B=0.03-0.06) and 0.08 t/ha LSD_{05} B=0.03-0.08).

In the variant with the system of planar-free multi-depth main tillage, the application of the bio-decomposer Ecostern 1.5 l/ha provided an increase in grain yield by 0.20 t/ha (LSD_{05} B=0.03-0.06), and sunflower by 0.10 t/ha (LSD_{05} B=0.03-0.08), but the greatest effect from the use of this bio-decomposer was obtained for the system of differentiated main tillage, where the yield of cereals increased by 0.24 t/ha, respectively (LSD_{05} B=0.03-0.06), and sunflower – by 0.12 t/ha (LSD_{05} B=0.03-0.08). A similar trend is observed in the change in crop rotation productivity under the influence of the application of the bio-decomposer Ecostern at a dose of 1.5 l/ha and other indicators, which is due to changes in crop yields in crop rotation. The largest yield from 1 ha of arable land of grain units was on the background of the system of differentiated main tillage – 4.53t, feed units – 5.54t, feed-protein units – 5.29t and digestible protein – 0.50t, which significantly exceeded the control option (without the use of the bio-decomposer Ecostern), respectively, by 0.28; 0.35; 0.34; and 0.02t. The smallest increase in crop rotation productivity in the experiment from the use of Ecostern bio-decomposer 1.5 l/ha was observed in the variant using shallow planar-free main tillage, where crop rotation productivity at the yield of 1 ha of arable land grain units increased by only 0.24t (LSD_{05} B=0.02), feed units at 0.30t (LSD_{05} B=0.01-0.03), feed protein units at 0.28t and digestible protein at 0.03t (LSD_{05} B=0.02-0.09). An option of the experiment with a system of different depth planar main tillage in crop rotation occupied an intermediate position in terms of crop rotation productivity, where the increase from the use of bio-decomposer Ecostern 1.5 l/ha was grain units – 0.25t (LSD_{05} B=0.02), feed units – 0.31t (LSD_{05} B=0.01-0.03), feed protein units – 0.29t (LSD_{05} B=0.02-0.03) and digestible protein – 0.03t (LSD_{05} B=0.02-0.09), which is confirmed statistically.

Comparing the effect of the use of different bio-decomposers in the experiment, the authors found that the bio-decomposer Cellulad at a dose of 2.0 l/ha was characterized with increased efficiency compared to the bio-decomposer Ecostern at a dose of 1.5 l/ha. Thus, with its application, the yield of cereals and sunflower significantly increased against the background of the system of differentiated main tillage, respectively, by 0.35 (LSD_{05} B=0.03-0.06) and 0.18 t/ha (LSD_{05} B=0.03-0, 08), thus provided the highest level of crop capacity increase in the experiment. In the options of the experiment with the system of planar-free multi-depth and planar-free shallow main tillage in crop rotation with the application of bio-decomposer Cellulad at a dose of 2.0 l/ha, there was also an increase in grain and sunflower yields compared with the application of bio-decomposer Ecostern, but it tillage. The increase in yield from the use of bio-decomposer Cellulad at a dose of 2.0 l/ha in these variants was approximately the same and was cereals and sunflower – 0.29 and 0.19 t/ha and 0.29 and 0.12 t/ha, respectively, and at a significant level. The same pattern is observed in the improve-ment of crop rotation productivity in general with the use of bio-decomposer Cellulad at a dose of 2.0 l/ha. The best option in the experiment on the yield from 1 ha of arable land of grain, feed, feed-protein units and digestible protein was the option using a system of differentiated basic tillage in crop rotation where the yield of grain units was – 4.66 t/ha, feed units – 5.70 t/ha, feed and protein units – 5.43 t/ha and digestible protein, respectively – 0.52 t/ha.

Thus, under the differential system of basic tillage, the average yield of cereals without the use of bio-decomposers was – 3.64 t/ha, which exceeded the options with planar-free shallow and planar-free shallow tillage, respectively, 0.11-0.39 t/ha (LSD_{05} A=0.03-0.06), or 3.0-10.7%. The same pattern was observed for the influence of basic tillage systems on the productivity of oilseeds – sun-flower, where the yield of seeds according to the system of differentiated tillage without the use of bio-decomposers – 2.20 t/ha, which is 0.28-0.42 t/ha (LSD_{05} A=0.03-0.08), or by 12.7-19.1% more in comparison with variants with the system of planar-free different depth and planar-free shallow tillage. This indicates that in the conditions of the Southern Steppe of Ukraine, heavy soils in the system of basic tillage in crop rotations require periodic application of shelf plowing, especially for crops such as peas, corn and sunflower. Considering the impact of the introduction of bio-decomposers of straw External 1.5 l/ha and Cellulad 2.0 l/ha on the level of yield of cereals and sun-flower in crop rotation, it was found that its growth is in the range of 0.13-0.25 t/ha or 4.5-8.7% for cereals and 0.10-0.23 t/ha or 5.4-12.4% for sunflower. The introduction of the bio-decomposer Ecostern 1.5 l/ha provided an increase in the yield from 1 ha of crop rotation area of grain, feed, feed protein units and digestible protein on average in all systems of basic tillage, respectively, by 4.7; 4.5; 4.3 and 5.4%, and with the introduction of Cellulad 2.0 l/ha, these figures increased by 9.5, respectively; 8.9; 8.6 and 10.8% compared to options without the introduction of bio-decomposers.

CONCLUSIONS

The conducted research claimed the possibility and certain efficiency of introduction of the system of organic agriculture in the zone of risky agriculture of the arid Steppe of Ukraine. On the basis of scientific research and the results obtained, the following preliminary conclusions can be made that in the years of research the system of basic tillage in grain-row short crop rotation in organic farming have different efficiencies, which largely depends on the conditions of the year. The experiments did not confirm the effectiveness of the system of systematic shallow non-planar basic tillage in crop rotation, as one of the main substantive aspects of organic farming. Considering the influence of different systems of main tillage in short-rotation grain crop cultivation, the advantage of the system of differentiated main tillage over the

systems of planar-free multi-depth and planar-free shallow main tillage.

Thus, the highest average grain yield in the experiment, with a differentiated system of basic tillage on the background of the application of the bio-decomposer Cellulad 2.0 l/ha was – 3.99 t/ha, which exceeded the options with planar-free shallow and planar-free tillage, respectively, by 0.17-0.45 t/ha, or 4.3-11.3%. The same pattern was observed for the influence of basic tillage systems on the productivity of oilseeds – sunflower, where the yield of seeds according to the system of differentiated basic tillage and the use of bio-decomposer Cellulad 2.0 l/ha was – 2.38 t/ha, which is 0.27-0.41 t/ha, or 11.3-20.2% more in comparison with the options with the system of planar-free shallow and planar-free shallow tillage. That is necessary statistically. Applying the technology of accelerated destruction of straw and plant residues using bio-decomposers Ecostern and Cellulad, the experiment showed higher efficiency of bio-decomposer Cellulad at a dose of 2.0 l/ha.

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Продуктивність короткороторного вирощування сільськогосподарських культур за різних систем базового обробітку ґрунту в органічному землеробстві Степу України

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Анотація. Довгострокове реформування аграрного сектору в Україні відбувається у складних економічних та природних умовах. У сучасному сільському господарстві найбільш актуальними є біологізовані заходи й технології вирощування сільськогосподарських культур, ресурсо- та енергоекономічного відновлення родючості ґрунтів. Дослідження впливу системи базового обробітку ґрунту та використання біорозкладачів соломи й залишків після збору врожаю в органічному землеробстві були проведені в найпоширенішому та типовому для південного регіону степу України, короткооборотному вирощуванні сільськогосподарських культур із наступним чергуванням посівів: горох – озима пшениця – озимий ячмінь – ½ полів соняшника + ½ полів кукурудзи. За роки першого вирощування експеримент показав переваги системи диференційованого обробітку ґрунту, де навіть без використання біорозкладачів було отримано найвищий урожай зернових – 3,64 т/га та соняшнику – 2,20 т/га (перевірка експерименту). Застосування комбінованого різноглибинного обробітку у поєднанні з ґрунту, основний обробіток ґрунту спричинив зниження врожайності зернових на 0,11–0,39 т/га та соняшнику відповідно на 0,28–0,42 т/га. З використанням біорозкладачів, що надаються марками Ecostern та Cellulad, зростання врожайності знаходиться в діапазоні 0,13–0,25 т/га або 4,5–8,7 % для зернових культур та 0,10–0,23 т/га або 5,4–12,4 % для соняшнику. Застосування біорозкладача Ecostern 1,5 л/га забезпечило збільшення врожайності з 1 га площі сівозміни зерна, корму, кормово-білкових одиниць та засвоюваного білка в середньому у всіх системах базового обробітку ґрунту на 4,7 відповідно; 4,5; 4,3 та 5,4 %, а з внесенням Cellulad 2,0 л/га ці показники зросли відповідно на 9,5; 8,9; 8,6 і 10,8 % порівняно з варіантами без впровадження біорозкладачів

Ключові слова: землеробство, біорозкладачі, економічні та природні умови, відновлення родючості ґрунтів, зростання врожайності

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Growth and Development of Seedlings of Scots Pine and European Spruce Container Seedlings Using Various Materials to Neutralise the Substrate

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Abstract. The article analyses the features of growth and development of seedlings of Scots pine and European spruce on substrates in which various materials were used to neutralise them, affecting the reaction of the environment. According to the research results, the highest germination of seeds of both woody species was established on substrates with a ratio of dolomite flour of 30% and chalk of 70%, while in the case of using pure chalk, seed germination was significantly lower. Scots pine seeds germination in the substrate ranged from 77.6% to 90.1%, and European spruce seeds – from 66.4% to 94.3%. During the cultivation of seedlings of Scots pine and European spruce container seedlings, differences in the content of mobile forms of phosphorus are noted in all variants of the experiment. However, no definite pattern was found depending on the share of participation of various types of lime material. In the substrate of seedlings of Scots pine at the end of the growing season, the content of nitrate nitrogen naturally increases from 1069.1 to 1323.6 mg/100 g of absolutely dry substrate with a decrease in the proportion of dolomite and an increase in the proportion of chalk in the lime neutralising material. Another pattern is manifested when growing seedlings of European spruce container seedlings: the lowest content of nitrate nitrogen (412.1 mg/100 g of absolutely dry substrate) is established in the case of mixing dolomite flour and chalk in equal proportions (option 3). Differences in the content of mobile forms of iron were revealed in all experimental versions of the substrate of both woody species. For the cultivation of Scots pine, its amount ranges from 16.67 to 28.81 mg/100 g of absolutely dry substrate, and European spruce – from 18.40 to 20.99 mg/100 g of absolutely dry substrate. In general, low content of mobile iron was observed in the substrate of growing pine and spruce seedlings in containers. In all experimental variants, the height of seedlings of Scots pine container seedlings exceeds the required average height of the aboveground part in accordance with national standard by 1.3-2.0 times, and for seedlings of European spruce the excess was 1.2-1.5 times. In seedlings of Scots pine and European spruce, according to the variants of the experiment, the average height of the aboveground part rises with an increase in the concentration of dolomite in the mixture of neutralising material from 50% and higher

Keywords: container planting material, container seedlings, substrate composition, peat substrate, medium reaction, seed germination

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INTRODUCTION

Optimal conditions for the growth and development of plants are determined by a whole complex of factors, including the reaction of the environment. Scientific research and practical experience have established that high values of environmental reaction parameters (acidity and alkalinity) have a negative impact on the growth of the root and stem parts of plants [1]. The development of the direction of growing planting material container seedlings (PMCS) dates back to the 60s of the last century, when almost simultaneously in many countries (Scandinavian countries, Northern Europe, South America, Canada, USA) industrial cultivation and research of the growth characteristics of planting material in individual and multi-chamber containers of various types and sizes were started. To date, many types of insulating materials are known – peat and ceramic pots, briquettes, paper honeycombs, plastic bags, and others [2].

At the end of the 1960s, research was started at the St. Petersburg Scientific Research Institute of Forestry and the Latvian Scientific Research Institute of Forestry Problems, as a result of which a technology for growing seedlings using the "Briquette" method was developed. According to this method, the root systems of annual seedlings of coniferous species grown in a greenhouse were placed between two pressed peat plates measuring 2×5×20 cm each. The volume of the root-forming briquette or lump was 400 cm^3. Briquettes were tied, stacked 50 pcs. between two polyethylene tapes, rolled up and placed in containers with a nutrient liquid medium. After impregnation, the rolls were sent to the greenhouse, and then, after a week, to an open area for growing for one year [1].

In Belarus, Plantek 64F and 35F reusable hard plastic cassettes are used for the cultivation of annual seedlings of coniferous tree species. 64F cassettes, as a rule, are designed for the cultivation of Scots pine for one year, while seedlings of European spruce are recommended to be grown to obtain standard sizes within a 2-year period [3]. The technology of growing PMCS in Belarus began to be used in the late 70s of the last century when a line for obtaining seedlings from the CRS was set up on the basis of the Glubokoe experimental forestry. The next stage of the implementation of this technology was the installation of the line in the Republican Forest Breeding and Seed Production Centre. Currently, the development of technology for growing PMCS is determined by the sectoral program for growing PMCS in the organisations of the Ministry of Forestry of the Republic of Belarus [3], which provides for the construction of four modern and modernisation of two outdated industries.

The production of PMCS is associated with higher costs for growing seedlings, a significant part of which falls on the preparation of the substrate. The size and quality of seedlings depend on the composition and quality of the substrate [3-5], the safety of the substrate coma during transportation [6-8], as well as the growth and development of seedlings in the first years after transplanting to the forest area [9-11]. In foreign countries, over the past more than 20 years, the production of PMCS has been further developed and in practice it has been proven that its production and introduction into forestry production is a more promising direction compared to the use of planting material with an open root system [12-14]. PMCS is increasingly being used in the forestry practice of forest reproduction and afforestation in many countries [15-17].

Indisputable is the fact of the use of various types of PMCS in the forestry production of Belarus, however, the issue of choosing the optimal type of substrate for the production of seedlings of Scots pine and European spruce container seedlings with the selection of the most suitable materials for its neutralisation is still relevant [12].

Many scientists have been engaged in the selection of the optimal substrate for growing plants container seedlings, the selection of various materials for its neutralisation, the evaluation of the effectiveness and prospects of using container plants in forestry production in various countries. In Russia, these studies were conducted by G. Kovalenko and M. Kovalenko [18], in the North-West of Russia – D.S. Burtsev [19], in the North – S.V. Bobushkina and B.A. Mochalov [20], in Karelia – A.V. Zhigunov, A.I. Sokolov and V.A. Kharitonov [16], in Finland – N.V. Landis, R.K. Dumrose, J.R. Pinto [21], in Poland – K. Szabla and R. Pabian [22], in the USA – J.P. Barnett, J.M. McGilvrary, K.D. Howell and T.B. Harrington [23; 24], in Belarus – V.V. Nosnikov [25; 26], O.A. Selishcheva, A.M. Granik, A.V. Romanchuk, A.A. Domasevich, A.V. Yurenia [27], N.I. Yakimov, I.V. Sokolovsky, V.V. Tsai [28], and S.V. Suraviev [29], in Ukraine – V.V. Gupal [15], I.M. Boboshko-Bardin [30], O.I. Lyalin [31].

The purpose of this study is to determine the effect of materials neutralising peat substrate on the growth and development of seedlings of Scots pine and European spruce when growing them container seedlings.

The object of research is the planting material of Scots pine and European spruce container seedlings. *The subject of the study* is the special features of the growth and development of container seedlings of Scots pine and European spruce with the use of various substrate neutralising materials.

MATERIALS AND METHODS

In order to determine the degree of influence of peat-based substrates with the introduction of various combinations of neutralising materials on the growth and development of container seedlings of Scots pine and European spruce an experiment was carried out in the spring of 2020. The substrates were prepared on the basis of separated top peat of a milling billet, into which lime materials (dolomite flour, chalk and their combinations) were introduced to create an optimal acidity regime for these woody species according to national standard [26].

The substrates were thoroughly mixed and moistened with water to a relative humidity of 60-70%, then the cassettes were filled with them and compacted.

The quality of the planting material of coniferous tree species with CRS is determined according to national standard [26]. Planting material should have lignified shoot tips with fully formed dormant buds that are in a dormant state at the end of the growing season.

For growing seedlings of Scots pine and European spruce, were used Plantek 35F and 64F cassettes, respectively, which are widely used for the industrial cultivation of seedlings of these tree species in the Republic of Belarus, as well as in other neighbouring countries with a solid nursery base.

To create optimal conditions for seed germination and seedling cultivation, cassettes were placed in the greenhouse of the Republican Forest Breeding and Seed Production Centre with controlled microclimate parameters. For an active experiment, 6 cassettes for pine and 4 for spruce were used in experimental versions. In the spring of 2020, seeds of Scots pine and European spruce of the 1st quality class were sown in cassettes filled with substrate. The germination of seeds was established on June 7 – on the 30th day after sowing them in cassettes – by analysing the state of seedlings in all variants of the experiment.

The share of various types of lime fertilisers in the total mass of lime material in the substrate according to the variants was:

1) milling peat + lime material (100% dolomite flour);
2) milling peat + lime material (70% dolomite flour 30% chalk);
3) milling peat + lime material (50% dolomite flour 50% chalk);
4) milling peat + lime material (30% dolomite flour, 70% chalk);
5) milling peat + lime material (100% chalk).

In autumn (September 20), measurements of the main biometric indicators (height of the aboveground part and diameter at the root neck) of container seedlings of the studied tree species were made. Also, at the end of the growing season, pH measurements were carried out.

RESULTS AND DISCUSSION

Seed germination is its ability to produce normal seedlings (in the laboratory) or seedlings (in the field) for a certain period of time. It is affected by the quality of seeds, from which trees they are collected, the conditions of their storage and germination. Indicators of germination of seeds of Scots pine and European spruce according to the variants of the experiment are shown in Figure 1. The germination rate of Scots pine seeds ranged from 77.6 to 90.1%, and European spruce – from 66.4 to 94.3%. With an increase in the share of chalk up to 70% in the composition of lime material, the germination of seeds both species naturally increases.

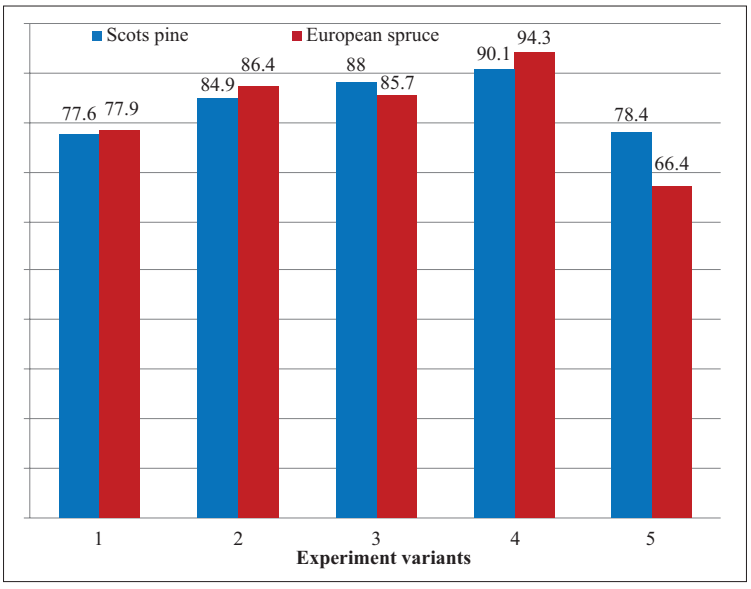

Figure 1. *Germination of seeds of Scots pine and European spruce in cassettes according to the variants of the experiment, %*

The greatest germination was established in experiments with a ratio of dolomite flour of 30% and chalk of 70%. When using 100% chalk, germination was significantly lower. The results of measurements of biometric indicators of pine and spruce seedlings are presented in Table 1.

Table 1. *Biometric indicators of seedlings container seedlings on substrates using different materials to neutralise them (in the denominator – statistical indicators for the height of the stem of the seedling (cm), in the numerator – statistical indicators for the diameter at the root neck of the seedling (mm))*

Variant	χ±m	$\bar{x}$	min	max
		Scots pine		
1) milling peat + lime material (100% dolomite flour)	15.4±0.2 / 2.66±0.04	4.2 / 0.66	2.5 / 0.89	29.3 / 5.14
2) milling peat + lime material (70% dolomite flour 30% chalk)	13.2±0.2 / 2.25±0.03	3.2 / 0.56	4.2 / 0.68	24.1 / 3.61
3) milling peat + lime material (50% dolomite flour 50% chalk)	16.1±0.2 / 2.70±0.03	4.1 / 0.59	5.1 / 0.76	30.6 / 5.24
4) milling peat + lime material (30% dolomite flour, 70% chalk)	11.9±0.2 / 2.21±0.03	3.4 / 0.52	3.8 / 0.67	20.5 / 4.05
5) milling peat + lime material (100% chalk)	10.3±0.2 / 2.03±0.04	3.0 / 0.62	2.6 / 0.56	19.2 / 3.82
		European spruce		
1) milling peat + lime material (100% dolomite flour)	20.8±0.5 / 2.69±0.05	6.3 / 0.61	4.0 / 0.76	33.0 / 3.90
2) milling peat + lime material (70% dolomite flour 30% chalk)	20.5±0.6 / 2.55±0.05	6.0 / 0.52	4.8 / 0.94	37.5 / 3.69
3) milling peat + lime material (50% dolomite flour 50% chalk)	20.4±0.6 / 2.69±0.05	6.8 / 0.50	4.0 / 1.20	34.3 / 3.88
4) milling peat + lime material (30% dolomite flour, 70% chalk)	17.3±0.6 / 2.48±0.06	6.0 / 0.63	3.9 / 0.72	30.6 / 3.90
5) milling peat + lime material (100% chalk)	18.5±0.6 / 2.74±0.06	5.7 / 0.32	3.2 / 1.13	31.5 / 4.19

Note: *χ is the average value, m is the error of the average value, x is the standard deviation, min is the minimum value of the indicator, max is the maximum value of the indicator*

Figures 2 and 3 are shown for a visual comparison of seedling height and diameter at the root neck on the different variants.

The height of experimental seedlings of Scots pine exceeds the required average height of the aboveground part according to national standard by 1.3-2.0 times, and the height of annual seedlings of European spruce – by 1.2-1.5 times. The average height of the aboveground part increases with an increase in the concentration of dolomite in the neutralising material from 50% or more (Fig. 2).

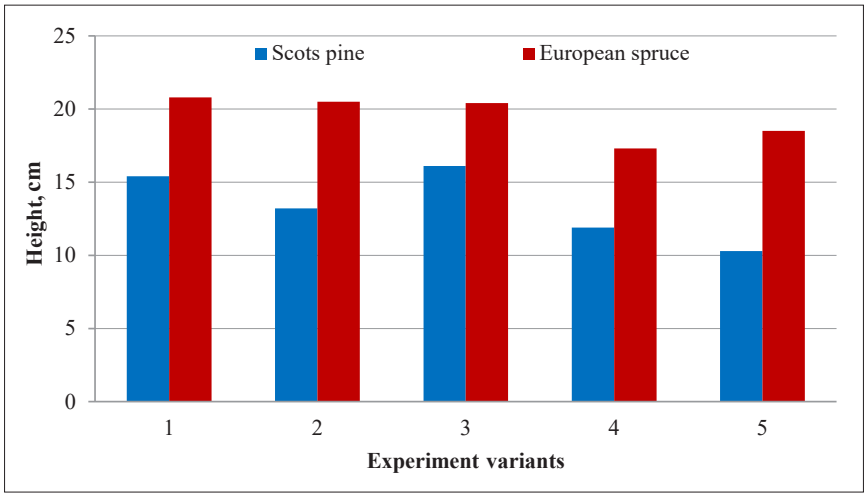

Figure 2. *The average height of container seedlings of Scots pine and European spruce according to the variants of the experiment*

At the same time, seedlings of Scots pine have the highest average height in variant 1, where the lime material consisted of 100% dolomite flour; seedlings of European spruce in variant 3, where the lime material consisted of dolomite flour and chalk in equal parts.

The best diameter of seedlings of Scots pine was found when using 100% chalk, and European spruce when using dolomite flour and chalk in equal parts. The results of determining the mobile forms of phosphorus and the reaction of the medium in the substrate samples at the end of the growing period of seedlings of Scots pine and European spruce container seedlings are presented in Table 2.

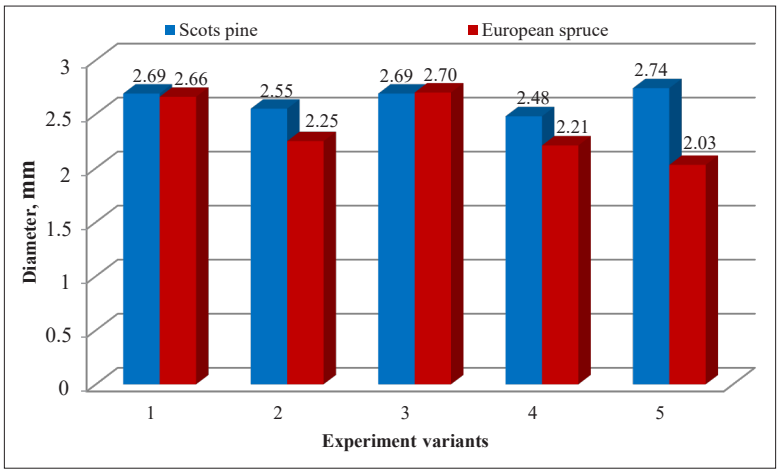

Figure 3. *The average diameter of the root neck of seedlings of Scots pine and European spruce in cassettes according to the variants of the experiment*

Table 2. *The number of mobile forms of phosphorus and the reaction of the medium in the substrate samples at the end of the growing season of the first year of growing seedlings in cassettes*

Experiment variant	P_2O_5 mg/100 g of absolutely dry substrate	Medium reaction (pH kcl)
Scots pine		
1) milling peat + lime material (100% dolomite flour)	446.2	4.34
2) milling peat + lime material (70% dolomite flour 30% chalk)	540.8	4.49
3) milling peat + lime material (50% dolomite flour 50% chalk)	450.2	4.45
4) milling peat + lime material (30% dolomite flour, 70% chalk)	456.8	4.65
5) milling peat + lime material (100% chalk)	474.9	4.40
European spruce		
1) milling peat + lime material (100% dolomite flour)	382.8	4.07
2) milling peat + lime material (70% dolomite flour 30% chalk)	288.8	4.13
3) milling peat + lime material (50% dolomite flour 50% chalk)	345.1	4.27
4) milling peat + lime material (30% dolomite flour, 70% chalk)	338.9	4.23
5) milling peat + lime material (100% chalk)	340.9	4.56

Differences in the content of mobile forms of phosphorus and the reaction of the medium (pH) are noted in all variants of the experiment. However, no definite pattern was found depending on the change in the share of participation of various types of lime material. As a result of the research, the following change in the reaction of the medium in the substrate during the cultivation of Europe-an spruce was established: the pH value increases from 4.07 to 4.56 with a decrease in the proportion of dolomite in the initially added neutralising material and an increase in the proportion of chalk. A similar pattern is manifested in the cultivation of Scots pine, with the exception of the experimental variant 5 using pure chalk, where the pH value decreased to 4.40.

The results of determining the amount of ammonia, nitrate nitrogen, exchangeable potassium and mobile forms of iron at the end of the growing season in substrate samples when growing seed-lings of Scots pine and European spruce with CRS are presented in Table 3.

Table 3. *Chemical composition of substrates at the end of the growing season*

Experiment variant	Ammonia nitrogen (NH_4+)	Nitrate nitrogen (NO_3–)	Exchangeable potassium K_2O	Iron Oxide Fe_2O_3
	mg/100 g of absolutely dry substrate			
Scots pine				
1) milling peat + lime material (100% dolomite flour)	35.4	1069.1	491.6	28.81
2) milling peat + lime material (70% dolomite flour 30% chalk)	75.3	1170.5	487.9	16.67
3) milling peat + lime material (50% dolomite flour 50% chalk)	65.9	1211.4	603.3	18.24
4) milling peat + lime material (30% dolomite flour, 70% chalk)	83.3	1274.2	489.3	17.18
5) milling peat + lime material (100% chalk)	133.8	1323.6	553.8	21.41
European spruce				
1) milling peat + lime material (100% dolomite flour)	20.4	532.9	327.1	18.40
2) milling peat + lime material (70% dolomite flour 30% chalk)	35.0	459.8	305.5	19.46
3) milling peat + lime material (50% dolomite flour 50% chalk)	106.7	412.1	372.1	18.87
4) milling peat + lime material (30% dolomite flour, 70% chalk)	16.2	464.2	311.2	19.22
5) milling peat + lime material (100% chalk)	10.3	473.1	376.2	20.99

According to Table 3, it follows that when growing Scots pine, the content of ammonia nitro-gen increases from 35.4 to 133.8 mg/100 g of absolutely dry substrate with a decrease in the propor-tion of dolomite and an increase in the proportion of chalk in the composition of lime material. A different pattern was established when growing European spruce: the highest content of ammonia nitrogen (106.7 mg/100 g of absolutely dry substrate) is observed when mixing dolomite flour and chalk in equal proportions (experiment version 3).

Regarding nitrate nitrogen in the substrate, the following has been established: when growing Scots pine, its content naturally increases from 1069.1 to 1323.6 mg/100 g of absolutely dry sub-strate with a decrease in the proportion of dolomite and an increase in the proportion of chalk in the lime material. When growing European spruce, the lowest content of nitrate nitrogen is observed when mixing dolomite flour and chalk in equal proportions (experiment variant 3), and the highest – in the absence of chalk in the substrate (experiment variant 1).

Analysis of the content of nitrate nitrogen in substrates at the end of the growing season showed that the substrate in which seedlings of Scots pine are grown contains a much larger amount of it (2-3 times more) compared with the substrate where the seedlings of European spruce were grown.

According to the content of exchangeable potassium in Scots pine, the highest value is at an equal dose of chalk and dolomite flour, and the lowest – at 30%

dolomite flour and 70% chalk. For European spruce, the situation is different, exchangeable potassium is presented to a greater extent in the variant with 70% dolomite flour and 30% chalk, and the least – in the variant with 100% chalk. The situation is reversed only with iron oxide being higher at 100% dolomite meal and the lowest at 100% chalk.

On the contrary, iron oxide had a higher value with a content of 100% dolomite flour and 30% chalk. This, in turn, suggests that with an increase in the iron content, the seedlings of Scots pine have a better height and diameter of the root neck.

CONCLUSIONS

At the initial stage of germination of seeds of Scots pine and European spruce, the main nutrition of seedlings is provided by the endosperm of seeds. The obtained results of the influence of substrates of different structural composition and using various neutralising materials, such as dolomite flour and chalk, indicate high seed germination rates. Germination of Scots pine seeds in substrates using various neutralising materials ranged from 77.6% to 90.1%, and seeds of European spruce – from 66.4% to 94.3%. In experimental versions using different neutralising materials, the average height of seedlings of Scots pine exceeds the required average height of the aboveground part according to national standard by 1.3-2.0 times, and seedlings of European spruce – by 1.2-1.5 times. In seedlings of Scots pine and European spruce, according to the variants of the experiment, the average height of the aboveground part rises with an increase in the concentration of dolomite in the mixture of neutralising material from 50% and higher. It should also be borne in mind that the European spruce should reach standard indicators (in accordance with the technical conditions) in the second year of cultivation, while in the experimental versions, plants of one-year age were measured.

The content of nitrate nitrogen increases from 1069.1 to 1323.6 mg/100 g of absolutely dry substrate with a decrease in the proportion of dolomite and an increase in the proportion of chalk in the lime material. Analysis of the content of nitrate nitrogen in substrates at the end of the growing season showed that the substrate in which seedlings of Scots pine are grown contains a much larger amount of it (2-3 times more) compared with the substrate where the seedlings of European spruce were grown.

The exchange potassium for Scots pine has the highest value with an equal dose of chalk and dolomite flour, and the least – with 30% dolomite flour and 70% chalk, the situation is quite different for European spruce – the content of exchange potassium is higher in the variant of 70% dolomite flour and 30% chalk, and least of all – with 100% chalk. The highest iron oxide content is in the 100% dolomite flour variant, and the lowest is at 100% chalk. The iron oxide content is higher with 100% dolomite flour and 30% chalk. This, in turn, suggests that with an increase in the iron content, seedlings of Scots pine reach higher height and diameter at the root neck.

When growing seedlings of Scots pine and European spruce container seedlings in variants with pure chalk with equal proportions of chalk and dolomite flour, the content of exchangeable potassium was 13-24% higher than in other experiments. The content of exchangeable potassium in the substrate when growing Scots pine is 1.6 times higher on average compared to the substrate when growing European spruce. According to the content of mobile forms of iron in the substrate, there are absolutely insignificant differences in all variants of the experiment. The iron content in the substrate when growing Scots pine is from 16.67 to 28.81 mg/100 g of absolutely dry substrate, in the substrate when growing European spruce – from 18.40 to 20.99 mg/100 g of absolutely dry substrate. In general, low content of mobile forms of iron in substrates is observed when growing seedlings of the tree species under study.

The obtained research results show that these requirements for growing container seedlings of the studied coniferous species in the closed root system in the Republican Forest Breeding and Seed Production Centre are observed with a slight deviation for seedlings of Scots pine.

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Ріст і розвиток сіянців сосни звичайної і ялини європейської із закритою кореневою системою за використання різних матеріалів для нейтралізації субстрату

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Анотація. У статті проаналізовано особливості росту і розвитку сіянців сосни звичайної та ялини європейської на субстратах, у яких було використано різні матеріали для їх нейтралізації, що впливають на реакцію середовища та хімічний склад. За результатами досліджень найбільша схожість насіння обох деревних видів встановлена на субстратах із співвідношенням доломітового борошна 30 % і крейди 70 %. Однак у разі застосування чистої крейди схожість насіння була значно нижчою. Схожість насіння сосни звичайної в субстраті становила від 77,6 % до 90,1 %, а насіння ялини європейської – від 66,4 % до 94,3 %. Під час вирощування сіянців сосни звичайної та ялини європейської із закритою кореневою системою по всіх варіантах досліду відзначаються відмінності у вмісті рухомих форм фосфору. Однак певної закономірності залежно від частки участі різних видів вапняного матеріалу не виявлено. У субстраті сіянців сосни звичайної в кінці періоду вегетації закономірно підвищується вміст нітратного азоту від 1069,1 до 1323,6 мг/100 г абсолютно сухого субстрату при зниженні частки участі доломіту та збільшенні частки крейди у вапняному нейтралізуючому матеріалі. Інша закономірність проявляється за вирощування сіянців ялини європейської із закритою кореневою системою: найменший вміст нітратного азоту (412,1 мг/100 г абсолютно сухого субстрату) встановлено у випадку змішування доломітового борошна та крейди в рівних пропорціях (варіант 3). Відмінності за вмістом рухомих форм заліза виявлено по всіх дослідних варіантах субстрату обох деревних видів. За вирощування сосни звичайної його кількість коливається від 16,67 до 28,81 мг/100 г абсолютно сухого субстрату, а ялини європейської – від 18,40 до 20,99 мг/100 г абсолютно сухого субстрату. Загалом можна говорити про низький вміст рухомого заліза в субстраті вирощування сіянців сосни і ялини в контейнерах. У всіх дослідних варіантах висота сіянців сосни звичайної з із закритою кореневою системою перевершує необхідну середню висоту надземної частини по національному стандарту в 1,3–2,0 рази, а висота сіянців ялини європейської – в 1,2–1,5 рази. У сіянців сосни звичайної і ялини європейської по варіантам досліду збільшується середня висота надземної частини із збільшенням концентрації доломіту в суміші нейтралізуючого матеріалу від 50 % і більше

Ключові слова: посадковий матеріал із закритою кореневою системою, контейнерні сіянці, склад субстрату, торф'яний субстрат, реакція середовища, схожість насіння

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The Integrated Approaches to the Productivity Management of the Grape Plantations of Different Ages

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Abstract. The article highlights the generalized research data of the Department of Horticulture, Viticulture, Biology and Chemistry of Odessa State University. The main direction of its work is to maintain the productivity of existing plantations and the formation of high-yielding plantations of grapes of technical varieties in the Northern Black Sea region of Ukraine. Based on many years of research, the productivity of vineyards of Aligote, Traminer pink, White fetish, Chardonnay, Pinot Noir, Cabernet Sauvignon and many others has been established, as well as complex schemes of impact on young grape bushes and plantations older than 25 years. As a result of researches, the basic optimum terms for conditions of the South of Ukraine in which it is necessary to carry out processing by growth stimulators and root and foliar feeding are established. These terms are: the first treatment before flowering, the second when the berries reach the size of a pea and the third at the beginning of ripening berries. It is proved that the after-effect of application of fertilizing elements is intensified on old plantations after the renewal of the plantation and can last up to three years, depending on the wet supply of the territory. The main conclusions and proposals for the use of complexes of agricultural technology elements based on root and foliar nutrition with different substances, irrigation, periodic deep tillage is given. Based on the obtained results, a mathematical model of quality management of grape products and products of its processing is developed

Keywords: grape plants, productivity increase, replantation, local nutrition, phenylalanine, microelements

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INTRODUCTION

The grape plantations in Ukraine are very different in quality both in the condition and age. In a number of obvious economic, technological and other advantages obtained from growing grapes, this industry in Ukraine began to revive. At the same time, we are confronted with such a problem as resuscitation of existing plantings that were launched during the transition period of management. For the revival of viticulture, along with the laying of new highly productive plantings, it is necessary to prolong the life of existing ones and improve their productivity and ensure the quality of the obtained products. At this stage, it is possible to resuscitate the existing grape plantations only through the combined effect on the above-ground and below-ground parts of the grape plant. In our point of view, such tools of influence are the replantation of the grape plants with fertilization to a considerable depth and also foliar and root nutrition (using a hydroborer) of grape plants with biologically active exo- and endogenic substances with a strict interpretation of varietal agriculture.

Our assumptions are confirmed by the work of various scientists, but all of them studied the above-mentioned techniques separately. That's why a number of scientists [1-9] confirm the positive effect of the replantation with simultaneous fertilization, while the staff of the Department of horticulture and viticulture (until 2009, the Department of viticulture and winemaking) at Odesa State Agrarian University suggests the feasibility of using in foliar and root nutrition the biologically active substances and also using of specific agricultural techniques for each of the varieties [10-30].

In the literature, there is no data concerning the combined effect of foliar and root nutrition on young and bearing bushes with different substances on the productivity of the grape plant, and even less so on the quality of table and sparkling wines. Therefore, the chosen research direction is quite relevant and timely. Based on the above-mentioned information, the purpose of these studies was to establish the influence of agricultural combinations on the development and productivity of different technical varieties and age categories of grape plants. The main limiting factor in the development of the grape and wine industry in the steppe regions of the Odessa, Mykolaiv, Kherson and the Autonomous Republic of Crimea is the lack of sugar accumulation, that is why it is impossible to get a desired annual harvest for preparing different types of wines [31; 32].

Since the industrial vineyards in these areas are located in the zone of hazardous agriculture, new ways of the exposure routs for the grape plant are needed that could reveal its potential. It is necessary to create favorable conditions for more intensive life processes in the plant, namely to better take place photosynthesis, respiration, transpiration and better work the root system in the conditions in which plants are located during the year. Thus, it is necessary to influence on the foliar apparatus and root system of the grape plant during the vegetation. There are some decisions, namely the foliar and root nutrition, regulation of the narrow habit of the plant, the point-of-care effects on a bush green part.

Foliar nutrition should be combined with a pest and disease protection system in order to protect the plant from diseases and pests simultaneously at no additional cost and carry out foliar nutrition. It is more difficult to carry out root nutrition, because it's effective only if it gets into the optimal soil horizon, i.e. to a depth of 45-50 cm. This task can be solved by the deep tillage at a specified depth and by the local nutrition using a hydroborer. The replantation should be carried out in the autumn, when the second wave of root growth is observed and in the spring before the beginning of vegetation when the first wave of root growth is. Local nutrition using a hydroborer can be carried out several times during the vegetation.

Unconventional physiologically active substances, namely organic acids of the Krebs cycle, amino acids, pyridine compounds have been proposed in order to achieve these objectives at the Department of Viticulture and Winemaking of the OSAU [21]. For solving this problem, firstly, we should grow high-quality grafted planting material, so that the plants have the same vigor and productivity after planting the vineyard. The quality of the grafted planting material depends on the choice of rootstock and scion stalks. It is currently necessary to use clones of rootstock and scion varieties. Clones of rootstock varieties must be grown on a mother plantation of rootstock vines with a management system that would ensure good stalks ripening with a diameter of 7 to 12 mm with a high carbohydrate content, for example, a T-shaped horizontal trellis.

Clones of scion varieties must be grown on a mother plantation of intensive scion vines with a management system that would ensure good stalks ripening with a diameter of 7 to 12 mm with a high carbohydrate content. It is possible to improve the quality of wine materials in the process of their production via selecting yeast strains by various technological methods before, during and after fermentation (Fig. 1).

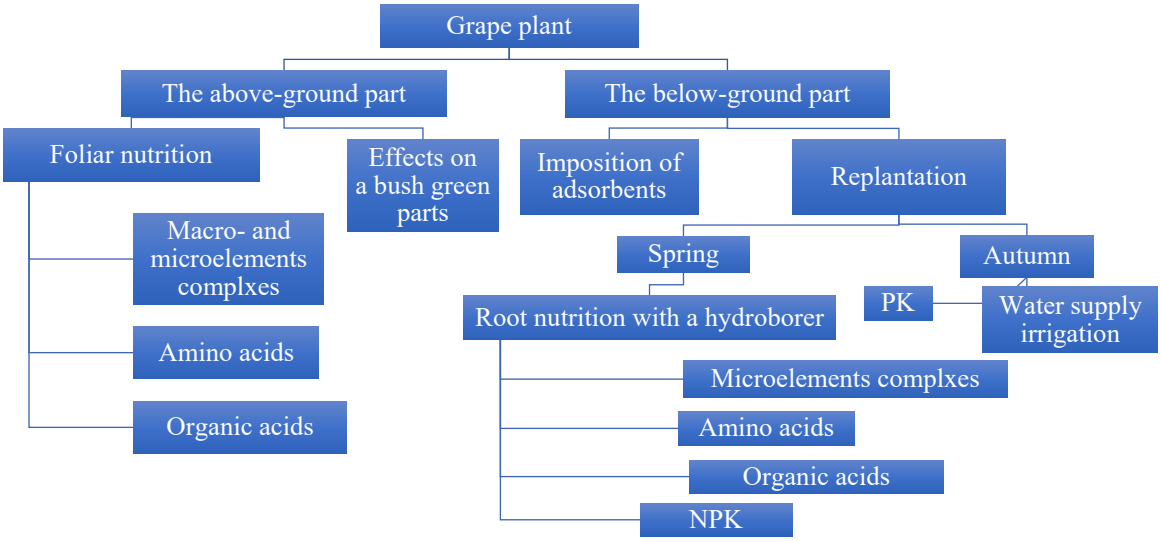

Figure 1. *Modification techniques for a grape plant*

MATERIALS AND METHODS

Since 2001, the Department of Viticulture and Winemaking (now the Department of Horticulture, Viticulture, Biology and Chemistry) in various farm types of the Odesa and Mykolaiv Region (Southern Ukraine) has laid a number of experiments:

1. During 2001-2005, in the agricultural production cooperative "Limanskii", Ochakovskii Region, Mykolaev Oblast carried out Experiments on the productivity of grape plants influenced by the microelements complex nutrition (Ni, Cr, Mn, Ti) on Chardonnay and Pinot noir on the plantations starting between 3 and 7 years. Planting scheme 3x1 m, the grape plant shape – double Guyot. Experiments were conducted using two schemes.

Experiment 1. The influence of root and foliar nutrition of grape plants with a microelements complex on the productivity of Chardonnay and Pinot noir. Option 1 – control – without nutrition. Option 2 – foliar nutrition of grape plant with a microelements complex 0.03% (Ni, Cr, Mn, Ti). Option 3 – root grape plants nutrition with a microelements complex 0.03% (Ni, Cr, Mn, Ti) using a hydroborer. Option 4 – foliar and root nutrition of grape plant with a microelements complex 0.03% (Ni, Cr, Mn, Ti). The establishment scheme of the experiment on the land plot: 2001 – vineyard 3 years of vegetation; 2002 – vineyard 4 years of vegetation; 2003 – vineyard 5 years of vegetation; 2004 – vineyard 6 years of vegetation. In each of the named years, in separate land plots, the experiment was conducted according to the indicated experimental scheme, the microelements complex was studied. The aftereffect was studied at the same land plots in 2002-2005.

Experiment 2. The influence of different yeast strains against the implementation of root and foliar nutrition of grape plants of Chardonnay and Pinot noir on the quality of sparkling wines. Option 1 – control. Option 2 – foliar grape plants nutrition with a microelements complex 0.03% (Ni, Cr, Mn, Ti) + yeast strain 1. Option 3 – foliar grape plants nutrition with a microelements complex 0.03% (Ni, Cr, Mn, Ti) + yeast strain 2. Option 4 – root grape plants nutrition with a microelements complex 0.03% (Ni, Cr, Mn, Ti) using a hydroborer + yeast strain 1. Option 5 – root grape plants nutrition with a microelements complex 0.03% (Ni, Cr, Mn, Ti) using a hydroborer + yeast strain 2. Option 6 – foliar and root grape plants nutrition with a microelements complex 0.03% (Ni, Cr, Mn, Ti) + yeast strain 1. Option 7 – foliar and root grape plants nutrition with a microelements complex 0.03% (Ni, Cr, Mn, Ti) + yeast strain 2.

Foliar grape plants nutrition with a microelements complex is conducted in 3 terms: at the beginning of a blossom time, when the size of a berry is about a pea and at the beginning of berries ripening. Root grape plant nutrition with a microelements complex is carried out using a hydroborer in 3 terms: at the beginning of a sap flow, at the beginning of a blossom time and when the size of a berry is about a pea. Two wells are made 50 cm from the grape plant on both sides along the row using a hydroborer. The microelements complex included salts of Ni, Cr, Mn and Ti, namely: nickel chloride, manganese chloride, ammonium chromate and titanium 4-chloride. The spray material is prepared as follows: nickel chloride – 24 g, ammonium chromate – 27 g, manganese chloride – 20 g are dissolved in 10 liters of water, well mixed, and then it is added 16 g of titanium 4-chloride, well mixed again and then the volume is brought to 100 liters of water.

In the second experiment, different yeast strains are added to the wine material in 0.75-liter bottles during the fermentation. For each variant and variety, wine material is made using the micro-winemaking method, and then sparkling wines are made in bottles of 0.75 liter by the bottle method.

2. In the agricultural production cooperative "Kristo Botev", Artsyzsky Region, Odesa Oblast carried

out experiments on Sukholimansky white and Cabernet Sauvignon. Experiments were conducted using 3 schemes.

Experiment 1. The using of phenylalanine against the implementation of different soil cultivation with local introducing of phenylalanine using a hydroborer. Option 1 – the plowing to a depth of 25-30 cm in the autumn – control; Option 2 – the implantation to a depth of 45-50 cm in the spring; Option 3 – the introducing of phenylalanine for the plowing using a hydroborer; Option 4 – the introducing of phenylalanine using a hydroborer after the replantation.

Experiment 2. The use of mineral fertilizers and Super Humisol separately and jointly while the top-dressing using a hydroborer during the plowing. Option 1 – the plowing to a depth of 25-30 cm – control; Option 2 – the introducing of 80 gr. p.n. (primary nutrients) mineral fertilizers (NPK) per 100 liters of water using a hydroborer; Option 3 – the introducing of 160 gr. p.n. NPK per 100 liters of water using a hydroborer; Option 4 – the introducing of Super Humisol in a dilution of 1:10 liter of water using a hydroborer; Variant 5 – the introducing of 80 gr. p.n. NPK per 100 liters of water with Super Humisol using a hydroborer; Option 6 – the introducing of 160 gr. p.n. NRK per 100 liters of water with Super Humisol using a hydroborer.

Experiment 3. The introducing of mineral fertilizers, Super Humisol separately and jointly using a hydroborer after the replantation. Option 1 – the replantation to a depth of 45-50 cm using a root plow RFG-2 in the spring – control; Options 2-6 are the same as in the experiment 2, only when the replantation. According to the adopted method, phenylalanine, NPK and Super Humisol were introduced three times during the vegetation using a hydroborer: at the beginning of bud opening, before a blossom time and when the size of a berry is about a pea. Phenylalanine concentration was 0.003%, Super Humisol was in a dilution of 1:10. The replantation was carried out one row over to a depth of 45-50 cm, 50 cm from the grape plant using a root plow RFG-2 in the spring.

According to the best options and control, wine materials were made of Sukholimansky White based on the "white" method and Cabernet Sauvignon according to the "red" method. Wine materials were analyzed after 3 months annually. In the conditions of public corporation "Koblevo", the third block of studies was started to develop a set of methods for increasing the productivity of bearing grape plantations based on the replantation in the south of Ukraine. The experiments were carried out for four years on grape kinds Traminer rosso and Feteaska white grafted on the Kober 5BB rootstock, with a planting scheme of 4x2 m, forming a double-sided horizontal cordon. The experiments were carried out according to three schemes:

Experiment 1. "The replantation effect and the use of phenylalanine with 4-titanium chloride on biometric indicators, yield and quality of berries of the grape kinds Feteaska white and Traminer rosso". The experiment included options: 1. Control-plowing to a depth of 25-30 cm; 2. Replantation to a depth of 50-60 cm; 3. Plowing to a depth of 25-30 cm + phenylalanine in combination with 4-titanium chloride; 4. Replantation to a depth of 50-60 cm + phenylalanine in combination with 4-titanium chloride.

Experiment 2. "The phenylalanine effect in combination with titanium during the foliar nutrition and introducing of Ammoium Nitrate Phosphate (ANP) fertilizer against the replantation on biometric indicators, yield and quality of grape kinds Traminer rosso and Feteaska white". Options: 1. Control – plowing with the introducing of NPK; 2. Fertilizing with NPK when the replantation to a depth of 50-60 cm; 3. The grape plants processing with a phenylalanine in the complex with 4-chloride titanium + root fertilizing with NPK when the replantation to a depth of 50-60 cm.

Experiment 3. "The influence of load of grape plants with eyes on biometric indicators, yield and quality of grape kinds Feteaska white and Traminer rosso against the different tillage methods". Options: 1. The load is 60-70 buds the length of vines is 8-10 buds when the plowing (control); 2. The load is 60-70 buds; the length of vines is 8-10 buds when the replantation using a rootplow. 3. The load is 80 buds, the length of vines is 8-10 buds when the plowing; 4. The load is 80 buds, the length of vines is 8-10 buds when the replantation; 5. The load is 90 buds the length of vines is 8-10 buds when the plowing; 6. The load is 90 buds, the length of vines is 8-10 buds when the replantation.

The replantation was carried out in the spring before budding at the distance of 50 cm from the grape plant. At the same time, nitroammofoska fertilizer was added at the rate of 500 kg per hectare. The replantation was carried out one row over to a depth of 50-60 cm using a rootplow. Grape plants were sprayed with phenylalanine with 4-titanium chloride (at a concentration of 0.003%): the first – before blossom time; the second – when the size of a berry is about a pea; the third – at the beginning of berry maturation.

3. The fourth block of tests was carried out during 2003-2008 on the theme "Complex of agro-farms for increasing the productivity and quality of technical grape varieties in the South of Ukraine" in public corporation "Champagne of Ukraine" Artsizsky Region, Odesa Oblast. For experiments, the following grape kinds were taken: Aligote, Feteaska white, Chardonnay, Sauvignon green grafted on rootstock Riparia x Rupestris 101-14, the planting scheme 3.0x1.5 m and 4.0x2.0 m, a grape plant forming – two-sided horizontal cordon. The experiments were carried out according to two schemes:

Experiment 1. Study of the influence of NPK fertilizer and irrigation against the different methods of tillage and nutrition areas on the growth and productivity of technical grape kinds. Option 1 – control-plowing to a depth of 25-30 cm. Option 2 – the replantation using a rootplow to a depth of 45-50 cm in a row in the spring.

Option 3 – deep tilling in two rows to a depth of 45-50 cm one row over in the spring. Option 4 – the replantation using a rootplow to a depth of 45-50 cm one row over in the spring with the introducing of nitroammophoska fertilizer 500 kg/ha. Option 5 – deep tilling in two lines to a depth of 45-50 cm one row over in the spring with the introducing of nitroammophoska fertilizer 500 kg/ha. Option 6 – the replantation using a rootplow to a depth of 45-50 cm one row over in the spring with the introducing of nitroammophoska fertilizer 500 kg/ha and irrigation along the furrows three times during the growing season of 500 m^3/ha. Option 7 – deep tilling in two lines to a depth of 45-50 cm one row over in the spring with the introducing of nitroammophoska fertilizer 500 kg/ha and irrigation along furrows three times during the growing season of 500 m^3/ha. This scheme was used in vineyards with a planting scheme of 3.0x1.5 and 4.0x2.0 m. The effect of techniques was studied in 2003-2006, the aftereffect was studied in 2004-2007. This scheme was used on Aligote and Chardonnay kinds.

Experiment 2. The identification of the optimal load against the nitroammophoska fertilizer application, irrigation and deep row tilling spacing for technical grape kinds. Option 1 – control-load is 40-50 buds, length of vines is 3-4 buds, deep tilling in two rows to a depth of 45-50 cm one row over. Option 2 – load is 40-50 buds and trimming vines for 5-6 buds. Option 3-load is 60-70 buds and trimming are 3-4 buds. Option 4 – load is 60-70 buds, trimming is 5-6 buds. Option 5 – load is 80-90 buds; trimming is to 3-4 buds. Option 6 – load is 80-90 buds, trimming is 5-6 buds. Option 7 – load is 40-50 buds; trimming is 3-4 buds tilling in two rows to a depth of 45-50 cm one row over with the introducing of NPK fertilizer 500 kg/ha and irrigation three times during the growing season of 500 m^3/ha. Options 8, 9, 10, 11, 12 repeat options 2, 3, 4, 5, 6, respectively, similarly to option 7. This scheme was used in vineyards with a planting scheme of 4.0x2.0 m., the effect was studied on Aligote and Fetyaska white kinds in 2003-2006, and the aftereffect was studied on Aligote and Fetyaska white kinds in 2004-2007.

From 2012 to date, the study of the influence of these techniques on various grape kinds growing in different relief conditions (plains, slopes, terraces) is being carried out. Many substances pass from the introduced kinds. Generalizing experiments are carried out by the staff of the department from 2001 to 2020, and will be used to build mathematical models for managing the quality of grapes.

All experiments in all studies were performed in triple analyses by the method of randomization. In each replication was 15 accounting grape plants in a row. Two protective rows were left between the experimental rows. Separately, according to varieties and variants we carried out counts, analyzes and observations generally accepted in viticulture [7].

RESULTS AND DISCUSSION

As a result of the experiments carried out to study the effect and aftereffect of a microelements complex consisting of Ni, Cr, Mn, Ti during the foliar and root nutrition of young grape plants and bearing vineyards and the subsequent use of different yeast strains during the production of sparkling wines of Chardonnay and Pinot noir kinds, it is possible to make the following conclusions.

In young vineyards the root and foliar grape plants nutrition with a microelements complex should be carried out before full bearing. At the same time, the foliage surface area during the year increases by 0.114 m^2, and in the aftereffect year increases by 1.098 m^2 in Chardonnay on average over two years compared with the control. The volume of one-year growth also increases during the year by 25.2 cm^3, and in the aftereffect year by 568.3 cm^3. For Pinot noir, such increases were recorded in foliage surface area, respectively, by 0.244 m^2 and 1.074 m^2, in terms of annual growth, respectively, by 78.5 cm^3 and 443.6 cm^3. Under the influence of a microelements complex, the following increases: the mass of the bunch, the yield from 1 grape plant until full bearing during the year and especially in the aftereffect year, respectively, for Chardonnay by 10.4 g; 0.08 kg and 12.5 g; 0.48 kg, for Pinot, respectively, during the year by 15.7 g 0.23 kg, in the aftereffect year by 11.3 g; 0.55 kg.

In bearing vineyards, the best option is the combined use of foliar and root grape plants nutrition with a microelements complex. In comparison with the control, on average, for two years, during the year of operation on the Chardonnay, the foliar area was increased by 0.625 m^2, in the aftereffect year by 1.144 m^2; the volume of one-year growth was increased in the year of operation by 280.0 cm^3, in the aftereffect year by 375.0 cm^3. For the Pinot noir, in the year of operation, the foliar surface area was increased by 1.205 m^2 and the aftereffect year was increased by 1.583 m^2; the volume of one-year was increased in the year of operation by 380,2 cm^3 and the aftereffect year 439.6 cm^3. The microelements complex, with joint use, provides a yield increase in bearing vineyards for the Chardonnay by 36.7% per year of operation and by 35.9% per year of aftereffect and for Pinot noir, respectively, by 30.7% and 24.2% compared to control. At the same time, the highest quality indicators are observed such as the berries sugar level in the year of operation on young plantations was in the range of 17.6-17.9 g/100, and within 18.0-18.1 g/100 cm^3 on bearing plantations.

The option can be distinguished with the combined use of a microelements complex based on the chemical and organoleptic analyzes of wine materials made from Chardonnay and Pinot noir. The mass fraction of alcohol for Chardonnay was increased in the year of operation by 0.38%, and in the aftereffect year by 0.57%; the mass fraction of alcohol for Pinot noir was increased, respectively, by 0.37% and 0.27%. The

degustation evaluation was increased in the year of operation and aftereffect year for Chardonnay by 0.3-0.4 points, and for Pinot Noir, respectively, by 0.4-0.2 points. Foliar and root nutrition of grape plants Chardonnay and Pinot Noir with a microelements complex and the use of yeast of different strains helps to improve the foamy, sparkling wine properties, increases the taste and degustation evaluation. For both kinds, the best yeast is the Abrau-Durso strain.

The tested techniques are economically proved in bearing vineyards. In the best option (combined use of a microelements complex), the profit was increased by UAH 4312.5 per year of operation, and by UAH 3372.8 per aftereffect year for the Chardonnay and the profit was increased by UAH 3855.7 and UAH 2507.4, respectively, for the Pinot Noir compared to the control.

As a result of the experiments carried out to study the effect of phenylalanine, NPK, Super Humisol against the different tillage during root nutrition using a hydroborer on low-yielding bearing vineyards of Sukholimansky White and Cabernet Sauvignon kinds, the following results were obtained:

– local introducing of biologically active substances and mineral fertilizers using a hydroborer provides a significant increase in the foliage surface area and volume of annual growth of grape plants in the year of operation and especially the next year in both kinds, the reaction of Sukholimansky white is more constant; local introducing of phenylalanine using a hydroborer after the replantation contributes to an increase in the number of roots in the soil layer 40-60 cm, both in the year of operation and in the aftereffect year; under the influence of phenylalanine, the yield increases by 6.3% against the plowing and replantation – 16.1%. In this case, the sugar level increases (by 0.3 g/100 cm^3 – 1.0 g/100 cm^3). The next year, after the introducing of phenylalanine against the replantation, the yield increases by 36.2%, and the sugar level increases by 0.8 g/100 cm^3;

– in a series of experiments on the use of mineral fertilizers (NPK) and Super Humisol (jointly and separately), an increase in the foliar surface area, the volume of annual plant growth, both in the year of operation and in the second and third years after the introducing of NPK separately or jointly with Super Humisol was experimentally proved; in the year of operation of mineral fertilizers and Super Humisol in the eyes, especially in the central buds, there is a deeper differentiation according to well-formed acrospires and the amount of a acrospires up to the eighth eye, which subsequently shows itself in an increase in the number of bunches and yield; root nutrition with mineral fertilizers (NPK) jointly with Super Humisol using a hydroborer against the replantation has a positive effect on the development nature of the root system in the optimal soil horizon from 20 to 60 cm. At the same time, the tendency of wine materials quality improvement is noted. The techniques that have been studied are economically proved. In the option where the replantation was held in the spring and phenylalanine was added three times during the growing season, the profit was increased for Cabernet Sauvignon in the year of operation by UAH 932 and in the aftereffect year by UAH 2335. In a series of experiments, where the root nutrition of NPK 160 g per 100 liters of water jointly with Super Humisol using a hydroborer was used against the replantation, the profit was increased by UAH 1,649.5. from 1 ha per year of operation and by UAH 649.8. from 1 ha per year of aftereffect for Sukholimansky white.

As a result of the experiments carried out to study the effect of a set of methods: foliar nutrition with phenylalanine with 4-titanium chloride, introducing nitroammofoska fertilizer for plowing in the autumn or replantation in the spring, different loads of grape plants on old bearing vineyards of Traminer rosso and Feteasca white, we can make the following conclusions:

– the techniques that were studied separately and in combination affect the biometric indicators in the year of operation: the foliar surface area and the volume of one-year growth decrease while the replantation separately or jointly with nitroammofoska fertilization; he foliar surface area and the volume of one-year growth increase with the use of phenylalanine with titanium 4-chloride, both against the plowing and the replantation in both kinds, especially with the use of nitroammofoska fertilizer against the replantation in the year of aftereffect, the foliar surface area and the volume of one-year growth increase in all experimental variants;

– under the influence of phenylalanine with titanium 4-chloride against the plowing in the year of operation, the yield increases by 16% for Traminer rosso and by 8.5% for Feteaska white; against the replantation by 23.1% for the Traminer rosso and by 6.1% for the Fetyaska. In the year of aftereffect, the yield increases, respectively, by 68.2 and 75.8% for Traminer rosso and by 20.9 and 41.0% for Fetyaska white;

– under the influence of phenylalanine jointly with titanium 4-chloride and the introducing of nitroammofoska fertilizer during the replantation compared to plowing and the introducing of nitroammofoska fertilizer in the year of operation, the yield increases by 6.5% for Traminer rosso and by 7.5% for Feteaska white. In the aftereffect year Traminer rosso increases the yield by 16.4%, and Feteaska white by 29.1%. The yield rising trend persists in the second year of aftereffect in both kinds;

– the sugar level of berry juice is always higher both in the year of operation and in the year of aftereffect in the options where foliar nutrition with phenylalanine with 4-titanium chloride was carried out separately or jointly with root nutrition with nitroammofoska fertilizer, with the load increase in both kinds;

– the use of replantation in combination with spraying the grape plants with phenylalanine jointly with titanium 4-chloride, or replantation with the introducing of ANP fertilizer and spraying the grape plants three times

with phenylalanine jointly with titanium 4-chloride provides a deeper differentiation of inflorescences, especially along the acrospires of the buds and it was also found that there is an increase in the root mass (number, length, weight) under the influence of replantation when NPK(16:16:16) fertilizer is introduced jointly with phenylalanine in combination with titanium 4-chloride and during the increase in eye load in both experimental kinds. At the same time, there is a close correlation between the development of the root system and the foliar surface area. In the year of action, the correlation coefficients are 0.78, and in the year of aftereffect – 0.94, which is expressed by the equation *y=485.96+39.13x*;

– calculations of energy efficiency confirm the feasibility of using phenylalanine in combination with 4-titanium chloride and the combined use of phenylalanine with 4-titanium chloride with the introducing of nitroammofoska fertilizer against the replantation, since the total energy consumption with the highest energy efficiency for three years here was lower compared to options where the specified substances were used for plowing, but more than in the control, but high energy costs are compensated by the high productivity of the plantings in the named options. Thus, higher energy costs in viticulture are more efficient. In addition, the marked options have a level of economic profitability according to Traminer rosso when using phenylalanine in combination with 4-titanium chloride in the year of operation by 149.8%, and in the year of aftereffect by 201.8%; when phenylalanine is used jointly with titanium 4-chloride, and nitroammofoska fertilizer is added against the replantation by 134.8 and 180.1%, respectively, over the years.

As a result of the experiments carried out to study the effect of an agricultural practices complex, namely: the replantation using different devices, root nutrition with ANP fertilizer, tilling and foliar with crystalon due to the different planting schemes on the industrial varieties productivity, the following results were obtained:

– the complex of agricultural practices and individual fragments significantly affect the biometric indicators of grape plants in the year of application and especially in the year of aftereffect, and the reaction of the studied kinds is different;

– the use of a rotter or rootplow for replantation provides approximately the same increments in a number of growth and development indicators of grape plants;

– the individual agricultural practices provide a certain yield increase in the year of their application and in the year of aftereffect, regardless of the planting patterns of grape plants, devices used for the replantation, grape kinds. For Chardonnay, in the year of operation, the yield was increased within 0.83-4.00 t/ha, and in the year of aftereffect in the range of 1.78-3.53 t/ha; for Aligote within 0.7-0.83 t/ha and 1.91-1.53 t/ha, respectively;

– the complex of agricultural practices both in the year of application and in the year of aftereffect provides a significant increase in yield, regardless of the planting schemes, studied kinds. For Chardonnay, in the year of operation, the yield increased within 2.57-3.54 t/ha, and in the aftereffect year within 3.58-5.72 t/ha; for Aligote within 1.56-2.13 t/ha and 2.05-3.1 t/ha, respectively;

– depending on the joint application of a number of agricultural practices or a whole complex, the load and length of trimming of bearing vines are changed. For Fetyaska white, the best growth and bearing indicators were established at a load is 80-90 eyes and a length of bearing vines is 5-6 eyes against the replantation: the foliar surface area was increased by 3.33 cm^2, the volume of annual growth by 1675.98 cm^3, the yield by 6.31 t/ha per year of operation, and in the year of aftereffect these increases are: 6.57 m^2, 2451.36 cm^3, 69.3 t/ha. The optimal load is 80-90 eyes with the length of bearing vines 5-6 eyes against the agricultural practices complex per year of their application provided an increase in the foliar surface area by 6.8 m^2, the volume of annual growth by 3347.9 cm^3, and the yield by 7.13 t/ha, and in the year of aftereffect by 7.56 cm^2, 3556.89 cm^3, 7.53 t/ha, respectively;

– the use of replantation, root nutrition with ANP fertilizer and tilling along furrows, regardless of planting schemes, especially in the year of aftereffect provides a deeper differentiation of inflorescences, bearing rates of central buds by the sum of inflorescence acrospires are increased in all junctures;

– as a result of long-term experiments in studying the development of the root system, it was found that the use of the studied agricultural practices, separately and especially in combination, provide a significant increase in the number of roots in the year of application and year of aftereffect in the soil horizon from 20 to 80 cm, regardless of the planting patterns;

– the proposed agricultural methods, separately and in a certain combination provide an increase in the quality indicators of the studied technical kinds with a high yield both in the year of their application and in the year of aftereffect;

– the developed complex allows to change the quality indicators of wine materials for the better. To obtain wine materials with a mass fraction of alcohol 10.45% and degustation evaluation 7.6 points for the production of ordinary wines, it is necessary to use the whole complex of agricultural practices. To obtain wine materials with a volume fraction of alcohol 11.54% and degustation evaluation 7.7-7.8 points, suitable for the production of vintage wines, against the developed complex, carry out foliar nutrition with special crystalon;

– calculations of economic efficiency confirm the feasibility of using such expensive techniques as replantation, root nutrition with ANP fertilizer, tilling. In the year of application, the level of profitability is ensured at the control level, although energy costs increase almost twice, and in the year of aftereffect with a planting pattern of 3.0x1.5 m for Chardonnay, the level of

profitability increases by 77%, and for Aligote by 59.2%; with a planting pattern of 4.0x2.0 m, 135.5% for Chardonnay and 40.17% for Aligote. At the same time, the efficiency of additional energy cost was greater than one – 1.17-1.31.

CONCLUSIONS

Based on the above-mentioned information, we offer a quality management system for grape and wine products of the specified conditions: cultivation of high-quality grafted planting material based on the use of clones of rootstock and scion varieties; use of physiologically active substances for the root nutrition using a hydroborer against the replantation; use of these substances for foliar nutrition separately or jointly with a pest and disease protection system; use of root and foliar fertilizing simultaneously on young vineyards before starting bearing and on already bearing implantations; development of differentiated agricultural equipment for grape varieties in a separate agrocenosis (area); improving the wine materials quality in the process of their production via selecting yeast strains by various technological methods before, during and after fermentation.

Thus, in order to increase the productivity of plantings of different ages, it is necessary to use a set of techniques that are most appropriate in relation to the age and condition of the plantings, as well as the available material and technological capabilities. And this is possible thanks to a large selection of complexes of techniques mentioned in this article.

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Комплексні підходи до управління продуктивністю виноградних насаджень різного віку

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Анотація. У статті висвітлено узагальнені дані дослідження кафедри садівництва, виноградарства, біології та хімії Одеського державного університету. Основним напрямом її роботи є підтримка продуктивності наявних насаджень та формування високопродуктивних насаджень винограду технічних сортів у Північному Причорномор'ї України. На основі багаторічних досліджень було встановлено врожайність виноградників Aligote, Traminer pink, White fetish, Chardonnay, Pinot Noir, Cabernet Sauvignon та багато інших, а також складні схеми впливу на молоді кущі винограду та насадження віком від 25 років. Унаслідок досліджень встановлено базові оптимальні умови для умов Півдня України, в яких необхідно проводити обробку стимуляторами росту та кореневе, позакореневе підживлення. Такими термінами є: перша обробка перед цвітінням, друга, коли ягоди досягають розміру горошини, і третя – на початку дозрівання ягід. Доведено, що ефект від внесення добрив посилюється на старих насадженнях після оновлення насадження і може тривати до трьох років, залежно від вологості території. Наведено основні висновки та пропозиції щодо використання комплексів елементів агротехніки на основі кореневого та позакореневого живлення різними речовинами, зрошення, періодичного глибокого обробітку ґрунту. На основі отриманих результатів розроблено математичну модель управління якістю виноградної продукції та продуктів її переробки

Ключові слова: виноградні рослини, підвищення продуктивності, пересадка, місцеве живлення, фенілаланін, мікроелементи

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Imperatives of Efficient Use of Land and Resource Potential of the Agricultural Enterprises of Ukraine

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Abstract. The article considers the institutionalization of land relations and the imperatives of efficient use of land and resource potential of agricultural enterprises of Ukraine. Within the institutionalization of land relations, the methodical approach to complex estimation of effective use of land and resource potential of agricultural enterprises is substantiated, by definition of an integral indicator of efficiency (quantitative and qualitative characteristics of involved resources, productivity and efficiency) of basic kinds of activity of economic entities on agricultural lands. Indicators of transparency in the assessment of land and resource potential and indicators of land policy according to the level of their use in agriculture are proposed. Comprehensive criteria for assessing the components of the efficiency of the use of land and resource potential of agricultural enterprises are presented. The amount of rent for land shares and the amount of fertilizer application per 1 ha of sown area of agricultural enterprises of Ukraine are analyzed. The productive capacity of natural and potential yields for grain and legumes (excluding corn for grain) in Ukraine has been determined. The normative monetary value of 1 ha of arable land in rural areas is calculated on average for one region of Ukraine, adjusted for the natural yield of cereals and legumes, without taking into account the application of fertilizers. The forecast level of technical, social and economic efficiency of the use of land and resource potential of agricultural enterprises is presented

Keywords: land and resource potential, land relations, rent, yield, costs, cost price, income, profitability

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INTRODUCTION

Institutional changes in land relations in the conditions of uncertainty in the development of agricultural entities require comprehensive characterization in the system of targeted land use and differentiation of the functional purpose of land and resources potential. At the same time, modern stereotypes of the formation of land and resource potentialare focused on the requirements of the institution of land ownership along with the need for resource provision of agricultural enterprises. Within the framework of institutional changes, the formation of new trends in the accumulation of land resources and their distribution among enterprises of a particular rural area are due not only to material but also to public goods, because in the process of decentralization and creation of united territorial communities certain restrictions of the state on land ownership are taken into account.

As part of the intensification of the initiative of territorial communities on their possible development and ability to independently solve the problem of the mobilization of internal reserves, in relation to the strategic imperatives of efficient use of land and resource potential, the land use within agglomerations of large cities sometimes ends with the futility. Therefore, to solve this problem, along with theoretical and methodological aspects of institutional support of land and resource potential of agricultural enterprises, it is necessary to distinguish between qualitative and quantitative assessment of efficient and rational land use, taking into account the growing social orientation of economic entities to economic development. This is especially true for the diversification of the rural economy, which involves the development of production, services, recreation. This is a guarantee of improving the quality of life of the rural population, preserving the natural environment in the spatial location of agricultural enterprises, which play a leading role in ensuring sustainable development of the village as a whole.

Theoretical and methodological principles of building a system of land resources distribution are widely studied by the European community: C. Barnard, G. Whittaker, D. Westenbarger, M. Ahearn [1], S. Blancard, J. Boussemart, W. Briec, K. Kerstens [2], H. Guyomard, C. Mouël, A. Gohin [3], L. Khan [4], Yu. Khvesyk, R. Busel [5]; the application of institutional provisions of the economy in the practice of land and resource potential formation is reflected in the works by P. Ciaian, d'A. Kancs, J. Swinnen, H. Van, L. Vranken [6], M. Fedorov and V. Mesel-Veseliak [7], O. Khodakivska and I. Yurchenko [8], H. Sharyi [9]. Modern problems of improving the efficiency of the use of land and resource potential, including in agriculture were solved by – V. Andriichuk and S. Sas [10], V. Dankevych [11], S. Kay, J. Peuch, J. Franco [12], M. Shchuryk [13], N. Ulitskaya and L. Semerkova [14], I. Yasinetska [15], O. Yatsenko [16]. Noting the value of scientific work for the theory and practice of the use of land and resource potential and opportunities for modernization of land relations through institutional mechanisms, it should be noted that some aspects of this problem remain insufficiently studied. Transparency and institutionalization of land relations in rural areas, substantiation of methodological support for a comprehensive assessment of the sectoral distribution of land resources within the territory need in-depth study.

The priority of our study is to substantiate within the institutionalization of land relations methodological approach to comprehensive assessment of effective use of land and resource potential of agricultural enterprises, by determining an integrated indicator of effectiveness (quantitative and qualitative characteristics of resources, productivity and efficiency) of basic activities of economic entities on agricultural lands.

MATERIALS AND METHODS

Institutionalization of land relations in the state is regulated by the behavior of land agents and their relationship with agricultural enterprises to attract land to a particular type of economic activity. Acquisition of their status, capacity and profitability according to legal, economic and environmental norms in the market situation of land demand is due to the established foundation of the institutional environment, which has a direct and indirect impact (through the state) on sustainable land use and protection in agriculture and its industries. In the global context, the management of regulators of rational distribution of land and resource potential between enterprises in rural areas is justified by the attractiveness and competitiveness of agricultural land resources.

Given the principles of transparency and openness of the economic system of agricultural enterprises for the formation of environmentally friendly and efficient land use, modern strategic imperatives for the use of land and resource potential operate in accordance with three main provisions. First, they operate in the context of the economic regime of balancing the land and financial goals of the participants in land relations, as well as the rights and responsibilities of landowners or land users. Secondly, the vector of directing resources to the formation of land and resource potential is modified according to the basic economic rules: profitability of land, its value and price, supply and demand in the market, competitiveness of the territorial product, and so on. Third, land and resource potential are a specific economic field, where land relations are constantly implemented, which accelerate and integrate the distribution of rights to agricultural land and on the basis of financial feasibility, physical capacity, legal capacity ensure efficient use of land resources.

The main reason for the development of transparency in the use of land and resource potential is the investment attractiveness and competitiveness of the territorial product of agricultural enterprises. At the same time, for the organization of transparent use of land resources,

the objective necessity is the direction of transparency. This is the transparency of data on land with the permission of the landowner or land user; transparency of data on land with the permission of public authorities and local governments; transparency of data on landowners and land users with partial securitization of their land plots on the land market.

Systematic application of transparent, market and institutional approaches to the study of a new direction of land relations and assessment of land and resource potential allows creating a single methodological complex, which on the platform of methods and models of analysis involves building a common methodology for assessing land use in the economic system of agricultural enterprises within a certain region and formed rural areas. The methodology of this study highlights the following key points: development of methodological approaches to creating a transparent assessment of market turnover of agricultural land, identifying the relationship between land yield and decisions of the local village council to classify land in a particular category of land involved in business in the field of agriculture, the creation of a strong institutional base of land relations for different types of enterprises that own a certain category of agricultural land in compliance with economic, environmental, legal and social factors [17].

The latest methods in the methodology for assessing the effective use of land and resource potential of agricultural enterprises at different levels of sectoral distribution of land in rural areas, are the following [17]:

– method of coefficients and standardization of indicators (for the calculation of the difference between the indicators of profitability of land resources involved in different sectors of agriculture);

– application of the analysis for the purpose of definition of directions of institutional maintenance of land relations in the conditions of decentralization of the power;

– integrated method (development of land resources assessment according to a large number of characteristics, which reduces multidimensional statistical indicators of the object of assessment into a single integrated indicator);

– method of expert assessments for forecasting and assessment of future results from the use of land and resource potential.

The use of indicators to assess the land and resource potential of agricultural enterprises at the regional level contributes to the development of measures to improve the conditions of targeted use of agricultural land, and, consequently, improve land relations between land market participants (especially in agriculture) at the national level. It is proposed to use indicators that introduce effective practices of regulating land relations in rural areas and allow assessing the state of different categories of land while ensuring the profitability of agricultural sectors.

The indicators cover two aspects: monitoring the process of formation of land and resource potential of agricultural enterprises and land profitability in agricultural sectors, taking into account the parameters of their efficiency. Assessment of land and resource potential in rural areas involves determining its ability to form agricultural land resources for all types of land use to meet the production needs of economic entities in accordance with the planned income and expenses, taking into account economic, intellectual, social aspects of property rights (ownership, orders). At the same time, the analysis of alternative land use of agricultural enterprises for their most rational and efficient distribution among land market participants for the future is carried out (Table 1).

***Table 1**. Indicators for assessing land and resource potential, its development and transparent use*

Indicator	Evaluation mark
Price and volume in the markets of agricultural lands	Directions of coordination of the market of agricultural lands
Information on property rights	Rational distribution of land between branches of agriculture
Information on the activities of institutions operating in the market	The same attitude of the state to all citizens, citizens' trust in the government, the legal foundation of society
Corruption-unstable spheres of the agricultural sector of the economy	Identifying areas of the agricultural sector of the economy that are threatened by corruption
Procedures for changing the targeted purpose of agricultural land	Transition from "manual valuation regime" to forecast regime, according to land use incentives, carried out with the help of land tax rates
Public auctions	Granting lease rights on a transparent basis via the Internet and publishing the results on websites
Evaluation indicators	Rating, economic and monetary valuation of land plots for various agricultural purposes
Rent charge	Determining rent rates by conducting open electronic land auctions
Economic indicators of agricultural industries	Attractive and profitable agricultural sectors for investment
Taxation	The number and composition of taxpayers in terms of legal entities and individuals for agricultural land and their functional use shows the most effective market measures for land use and stimulates the development of agriculture

***Source**: developed by the authors*

The proposed indicators are an innovative lever for assessing the state of land resources at the local level, which can be used by local governments of united territorial communities, interested investors to identify conflicts in sectoral land use of agriculture and increase the investment attractiveness of agricultural enterprises in agricultural market.

RESULTS AND DISCUSSION

Peculiarities of the method of assessing the effectiveness of the use of land and resource potential

Institutional provision of natural resources to the land and resource potential of agricultural enterprises forms the status of their land use, one of the forms of expression of which is the targeted purpose. The purpose of agricultural land simultaneously forms the profitability of land in rural areas [18].

In agricultural production, the tools of economic analysis of credit, financial, investment direction of land are coefficients (indicators) that characterize land rent, income, profitability, land value, productivity of agricultural land groups, as well as identify differences between forms of labor organization, forms of ownership on land for various purposes and functional uses. The profitability ratio reflects changes in profitability, the level of economic efficiency of land use, comparison of economic efficiency of land use within the enterprise and industry. We propose to calculate the yield ratio in the classical way: the numerator is the yield obtained in the production of cereals, and the denominator is the normative monetary value of 1 ha of arable land, according to formula (1) [19]:

$$C_p = \frac{\Delta P}{NMV} \times 100 \quad (1)$$

where: C_p – profitability ratio, %; ΔP – profitability obtained in production activities (agriculture: in the production of cereals and legumes); NMV – normative monetary valuation of 1 ha of land resource, USD.

Under market conditions, to determine the fair value of land and value in use by comparison with analogues in order to reduce errors and greater objectivity in determining the value of land we use the rent multiplier, which is calculated as the inverse of the rate of return by formula (2) [19]:

$$M_p = \frac{1}{C_p} \quad (2)$$

where: M_p – profitability multiplier; C_p – rate of return, %.

Under ideal conditions in the stable development of agriculture, profitability has limits in the range from 20 to 80. A high level of profitability is shown by a lower value of the multiplier, and vice versa. We propose to introduce in the cadastral accounting the coefficient of profitability, which allows to track changes in the economic use of agricultural land, form of ownership, functional use of land and resource potential of agricultural enterprises and the quality of agricultural groups. The rate of return reflects land as capital involved in production activities. The relevance of the normative monetary valuation and its indexation is mediated by the inverse indicator of the rate of return – the profitability multiplier, which more characterizes the market value with the existing use of land and resource potential.

At the same time, in terms of free access to land and private ownership, there is a difference in the use of land and resource potential. The behavior of a typical private agricultural enterprise is determined by comparing its needs and costs. Therefore, the difference in the use of land in terms of free access and private property will be explained by the size of private needs. Private property will be determined by the value of the marginal product, and free access to land will be determined by the value of the average product. At the same time, the creation and protection of private property rights requires costs that should be reduced, provided that the rent from the use of land resources will exceed them, i.e. [19]:

$$NPV_p = \sum_{i=1}^{n} \frac{(R_t - C_t)}{(1+i)^t} - C_i \geq 0 \quad (3)$$

where: NPV_p – net present value of investments in the creation of exclusive property rights to a rare resource, %; C_t – current costs associated with the protection of property rights in time t; R_t – profits in the form of rent, received due to the specification and protection of property rights in time t; C_i – initial costs.

Land economy at the level of agriculture of the state analyzes the profitability and efficiency of the use of land and resource potential, at the level of industry – profitability and efficiency of land resources use, at the level of agricultural enterprises – profitability and efficiency of land use [7]. Accordingly, the economic efficiency of land use in agriculture is manifested in the level of production on it, which is determined by the number of products, taking into account the quality and cost per unit area. Economic efficiency of land use in agriculture is characterized by a system of natural and cost indicators [20] (Fig. 1).

Economic methods for assessing the effective use of land and resource potential of agriculture in the country are carried out in two directions:

– creation of an institutionalized economic environment (rent, quality and value of land (market, mortgage, regulatory), taxation system (tax, rent), promotion of rational land tenure and land use (system of benefits and subsidies));

– use of economic levers (investment, financing, lending, economic protection against withdrawal of agricultural land for non-agricultural purposes, penalties for mismanagement of land, reduction of soil fertility, losses, compensation for land conservation, etc.). The instruments of the economic mechanism of effective use of land and resource potential of agriculture are the institute of land valuation, the institute of taxation, the institute of the land market.

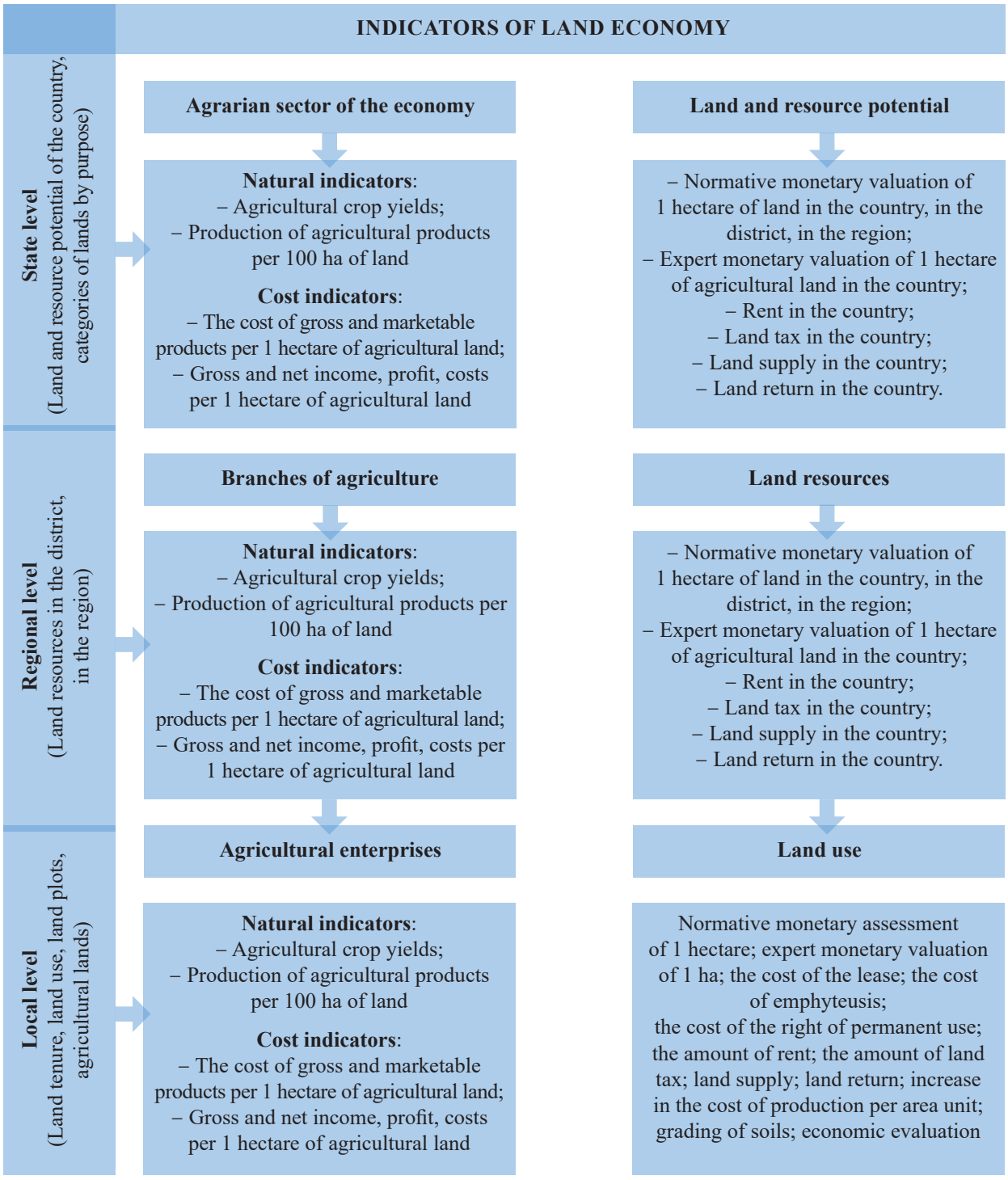

***Figure 1**. Indicators of land economy by levels of their use in agriculture*
***Source**: developed by the authors based on data [7; 20]*

In the process of evaluating the efficiency of the use of land and resource potential by agricultural enterprises, a comprehensive methodological approach is identified, which is determined by the variety of criteria (Fig. 2). An integrated methodological approach to land and resource potential assessment takes into account the relationship and interdependence of indicators and criteria used in the study of land use efficiency of agricultural enterprises, and allows a deeper and comprehensive assessment of the effectiveness of the overall impact.

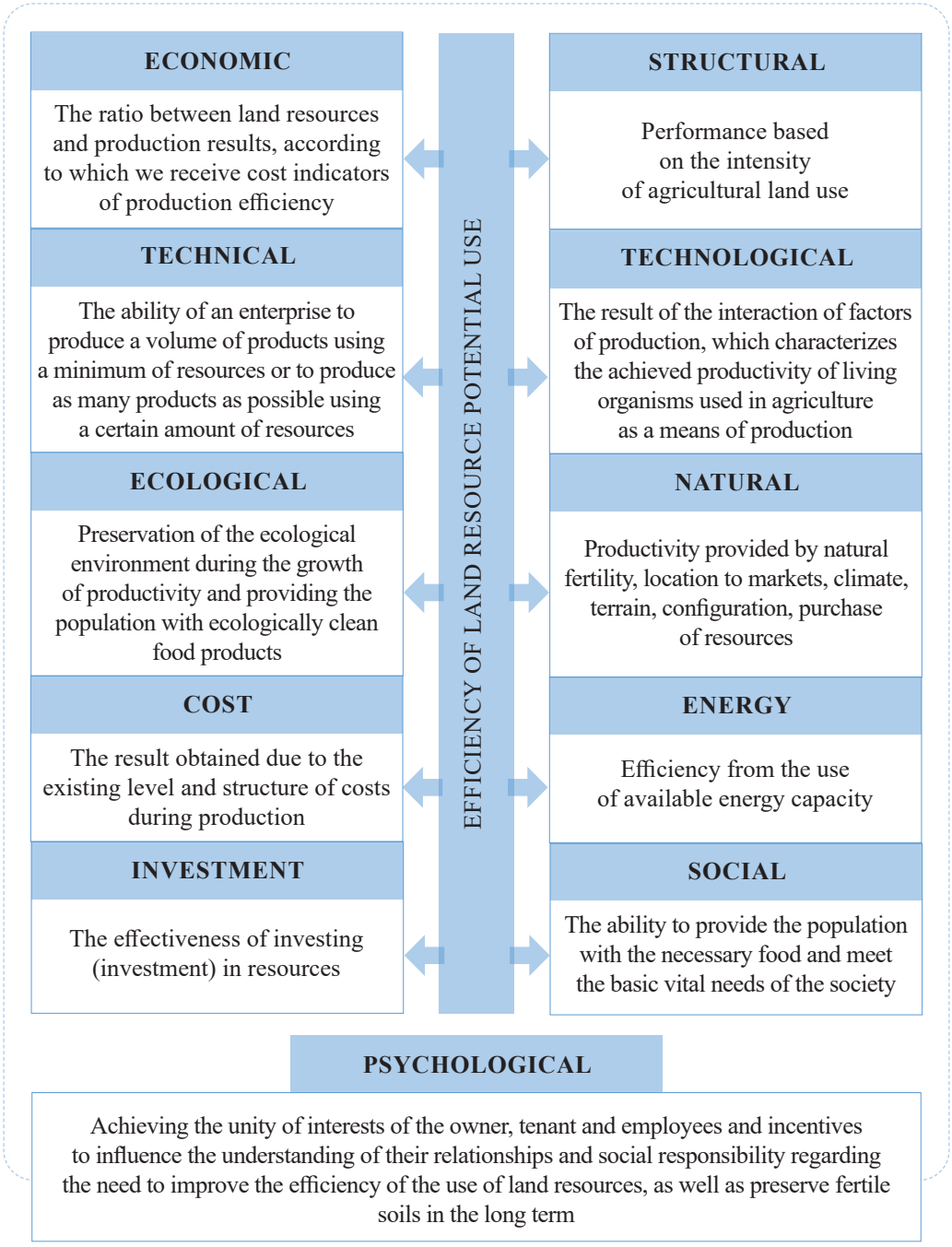

***Figure 2**. Components of the efficiency of the use of land and resource potential of agricultural enterprises*
***Source**: built by the authors according to data [6; 9; 14; 17-19]*

Thus, ecological and economic efficiency of agricultural land use reflects the level of impact of the economic complex on the environment, reveals the interactions between economic and environmental subsystems and key environmental issues and disparities in economic development. This is an integrated economic efficiency of land use in agriculture, which takes into account the reduction of economic results due to the eco-destructive impact of economic activity [21; 22]. Coordination of ecological and economic interests acquires special significance in the context of ensuring the environmental, resource-saving and reproductive nature of the exploitation of agricultural land.

A prerequisite for assessing the effectiveness of the use of land and resource potential of agricultural enterprises is to identify: 1) environmental results, which contributes to increasing the number and improving the quality of land suitable for use; 2) social result, which consists in improving the living standards of the population, health care, improving working and leisure conditions, maintaining ecological balance; 3) economic result, which provides a permanent economic effect from

the fuller and rational use and arrangement of land, increasing the efficiency of social production [17].

The importance of the issue of efficient use of land and resource potential of agricultural enterprises necessitates the definition of criteria and indicators for assessing the efficiency of land use. We should note that the criteria provide a broad description of the effectiveness, while the indicators are derived from the criteria and act as their specific expression (Table 2).

***Table 2**. Criteria for evaluating the efficiency of the use of land and resource potential of agricultural enterprises*

Kind of efficiency	Evaluation criteria
Economic	Agricultural products at actual prices; marketable products at current sales prices; net profit; gross net income per area unit; profit per hectare of agricultural land; profitability
Structural	Level of development of agricultural lands; the level of plowing of rural areas; proportion of intensive crops; land reuse rate; area of crops in the area of arable land; land supply; land armament; anthropogenic load factor; proportion of intensive crops; level of reclamation
Technical	Gross output per unit of land area; livestock productivity; agricultural crop yields
Technological	Cost of production; crop yield per unit of sown area; livestock and poultry productivity; increase in agricultural crop yields; reducing the energy intensity of agricultural production; increase in gross agricultural output at actual prices (per 1 ha of agricultural land, per worker)
Ecological	Soil fertility; humus balance; fertility of the soil; harvest area in the structure of agricultural crop areas; pollution; the level of erosion risk of crops; coefficient of ecological stability of rural area; anthropogenic load factor; reduction of environmental pollution; the level of land erosion; change of land area; the share of net profit of the enterprise aimed at environmental measures; share of environmentally friendly products; the scale of use of mineral fertilizers; availability of modern treatment facilities
Expensive	The general level of production costs; capital adequacy; depreciation level; cost price
Energy	Energy consumption; energy capacity per 1 hectare of agricultural land; energy capacity per 1 ha of arable land; energy cost; energy armament
Social	The share of income directed to social activities in the total mass of net income; the amount of profit directed to social activities, per one average employee of the enterprise; the level of remuneration of employees of agricultural enterprises; loading land (area of agricultural land per worker employed in agricultural production); structure of agricultural lands by forms of ownership; structure of agricultural lands by organizational and legal forms
Ecological and economic	Gross harvest and crop yields; area of agricultural land collection; the cost of gross output per area of land; product profitability; the amount of mineral and organic fertilizers; share of fertilized area with mineral and organic fertilizers; correlation of yield and condition of soils and means of stimulation of productivity; costs of reclamation and environmental measures; coefficient of variability of land productivity
Socio-economic	Rent for land shares; rent for property shares (units); increase in the value of a unit of land area and output per capita
Production and technical	Land return; return on assets; material efficiency; work capacity
Socio-ecological and economic	The amount of energy produced by biomass; the level of use of different energy sources; the ratio of biomass energy to energy consumption of natural fuel and man

***Source**: grouped by the authors according to data [6; 9; 14; 17-19; 21]*

We offer economic efficiency of the use of land and resource potential of agricultural enterprises by [7] calculation through profit of production, taking into account normative factors [23]:

$$Pr = \sum_{i=1}^{n\Sigma}\sum_{j=1}^{m\Sigma} C_{c_i} \times P_{p_j} \times Sq_{ij} - \sum_{i=1}^{n\Sigma}\sum_{j=1}^{m\Sigma}\sum_{l=1}^{h} Sq_{ijl} \times \left[\begin{array}{l} \frac{1}{f_1(G_{f;N_s;}C_{c;T_{op}}) \times K_1} \times (P_{n.ch} + \\ \frac{7Ctr_{ijl} \times (a_{tr_{ijl}} + r_{tr_{ijl}})}{t_{ijl}} + \frac{7Cm_{ijl} \times (a_{m_{ijl}} + r_{m_{ijl}})}{t_{ijl}}) + \\ +f_2(G_{f;P_{n.ch;}}C_{c;T_{op}}) \times K_1 \times Poth_{lub} \end{array}\right] \quad (4)$$

where: C_{ci} – agricultural crop yield, c/ha; P_{pj} – the price of production per unit, USD/c; Sq_{ij} – area of cultivated crop, ha; n – the number of plots in the crop rotation field (i=1,2,3,...,n); m – the number of agricultural crops

grown in crop rotation (i=1,2,3,…,m); $P_{n.ch}$ – price (cost) of norm change; G_f – field group; N_s – sowing rate of agricultural crops; T_{op} – type of operation; K – production rate, determined depending on the class of soils; h – the total number of technological operations in the cultivation of one agricultural crop (i=1,2,3,…,h); C_{tr},C_m – book value of tractor and agricultural machine; a_tr,a_m – the percentage of depreciation deductions (normative) from the book value of the tractor and agricultural machinery, respectively; t – time of work performance; r_{tr},r_m – deductions (deductions from the book value) for repair, inspection and storage of tractor and agricultural machinery, respectively, %; P_{lub} – unit price of fuels and lubricants; $Cost_{oth}$ – other expenses, USD.

As there are different types of efficient use of land and resource potential of agricultural enterprises, approaches to its evaluation are not universal. In addition, there are absolute and comparative economic efficiency of land management [24]. The calculation of absolute efficiency aims at selecting the most appropriate areas and scope of land management measures in agriculture, its industries and enterprises. When assessing the comparative effectiveness, the best option for implementing specific measures is selected. On the basis of the above, we propose a comprehensive comparative indicator of the efficiency of the use of land and resource potential of agricultural enterprises, which is calculated by formula (5) [24]:

$$I_{LRP} = a_1 \frac{S_{lu}}{S_{lu^0}} + a_2 \frac{M_{p_{100ha}}}{M_{p_{100ha}{}^0}} a_3 \frac{Pr_{100ha}}{Pr_{100ha^0}} a_4 \frac{P_{lev}}{P_{lev^0}} + a_5 \frac{Em}{Em^0} \quad (5)$$

where: I_{LRP} – a comprehensive indicator of the efficiency of land use; a_1, a_2, a_3, a_4, a_5 – weighting factors that determine the significance of indicators; S_{lu} – the amount of land use in the relevant year, ha; M_{p100ha} – received per 100 hectares of agricultural land of marketable products in the relevant year, USD; Pr_{100ha} – received per 100 hectares of agricultural land profit (loss) in the relevant year, USD; P_{lev} – the level of profitability in the relevant year, %; Em – per employee of agricultural land in the relevant year, ha; $S_{lu}{}^0$ – the amount of land use in the reporting year, ha; $M_{p100ha}{}^0$– received per 100 hectares of agricultural land of marketable products in the reporting year, USD; $Pr_{100ha}{}^0$– received per 100 hectares of agricultural land profit (loss) in the reporting year, USD; $P_{lev}{}^0$ – the level of profitability in the reporting year, %; Em^0 – per employee of agricultural land in the reporting year, ha.

Predicting the magnitude of land and resource potential, using intuitive and formalized (extrapolation, modeling) methods allows distinguishing the following criteria for its evaluation [25]: a combination of subjective value and objective significance of estimates; clear application of estimates, which does not allow different interpretations of the choice of methods; enabling the accumulation of statistical information and its use for forecasting. The application of these methods is of great value, because the identified forecast trends are the basis for the development of measures, levers of the economic mechanism of efficient use of land resources of agricultural enterprises.

To assess the effectiveness of the use of land and resource potential, it is proposed to apply the economic and mathematical model of the optimal structure of sown areas of agricultural enterprises. That is, the strategic direction of development and operation of each agricultural enterprise is the formation of a set of organizational, economic and agro-technological measures to improve the quality parameters of available land resources to increase the efficiency of production activities. In this case, the criterion of optimality is taken to be the maximum profit of activity [25]:

$$L = \sum_{j=1}^{l} C_j X_j + \sum_{k=l+1}^{n} C_k X_k \rightarrow max \quad (6)$$

where: C_j – the amount of profit received from 1 hectare of the y-th crop; X_j – sown area of the i-th crop; C_k – the amount of profit received from one structural head of the k-th type of cattle; X_k – the number of structural heads of the k-th type of cattle; i – types of resources (i=1,2,3,…,n); j – ordinal number of agricultural crops (j=1,2,3,…,n).

The obtained values of the variables are the optimized size of sown areas, according to which the farm is expected to increase the area of economically most profitable grain and industrial crops, as well as perennial grasses, which will contribute to the organization of the efficient land use. In conclusion, we should note that, in our opinion, the method of assessing the effectiveness of the use of land and resource potential should primarily include a study of the structure of the land fund by major landowners and land users and the development of the market for agricultural land lease. The role of land relations should be taken into account and strategic guidelines for the efficient use of agricultural land resources should be outlined. After all, a significant number of owners and users of land have no experience of rational land use. For example, the introduction of appropriate measures to preserve and restore soil fertility, rather than just trying to get the most out of property (rent). Therefore, it is necessary to take into account the interests of agricultural land use to improve the level of soil fertility and the possibility of increasing it through the implementation of land improvements.

Models of adjustment of normative monetary valuation of agricultural lands

The permanent process of land relations, especially in the field of agriculture, which is taking place in Ukraine, has changed the vector of existing land ownership and land use of agricultural enterprises in the context of the use of land and resource potential. During the period 2016-2020, the number of agricultural enterprises in the country decreased by 3.5%, due to the dominance

of extensive farming and the inefficiency of relations regarding the lease of agricultural land. In addition, the dynamics of land use of agricultural enterprises tends to decrease by 6% (Fig. 3).

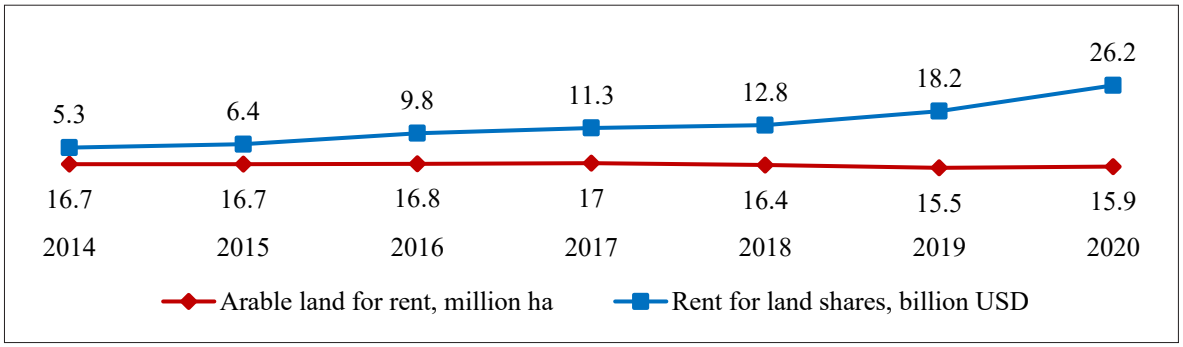

Figure 3. *The amount of rent of agricultural enterprises of Ukraine by land shares for 2014-2020*
Source: *developed by the authors according to data [26]*

During the period 2014-2020, the area of leased land decreased from 94.8% to 96.2%, the area of arable leased land decreased by 5%. The average rent per 1 ha of arable land in agricultural enterprises has increased almost 5.0 times.

World practice proves that only intensive use of soils with high fertility contributes to increasing the efficiency of production in agriculture, along with reducing investment in degraded and unproductive lands. Fertility is affected by the level of fertilizer application, as proper land use can improve its natural properties. During the period of 2016-2020, the area fertilized with mineral fertilizers increased six times, organic – decreased by 68.4%. The significant reduction in the application of organic fertilizers is due to the decline of the livestock industry and the reduction of livestock. In 2016, the number of cattle in agricultural enterprises of Ukraine amounted to 9423.7 thousand heads, in 2020 – only 39% from the base period [27]. Annually 0.5-0.7 tons of humus is applied to 1 ha of arable land, but to ensure its deficit-free balance according to the standards, it should be 11-12 t/ha per year [26; 28] (Fig. 4).

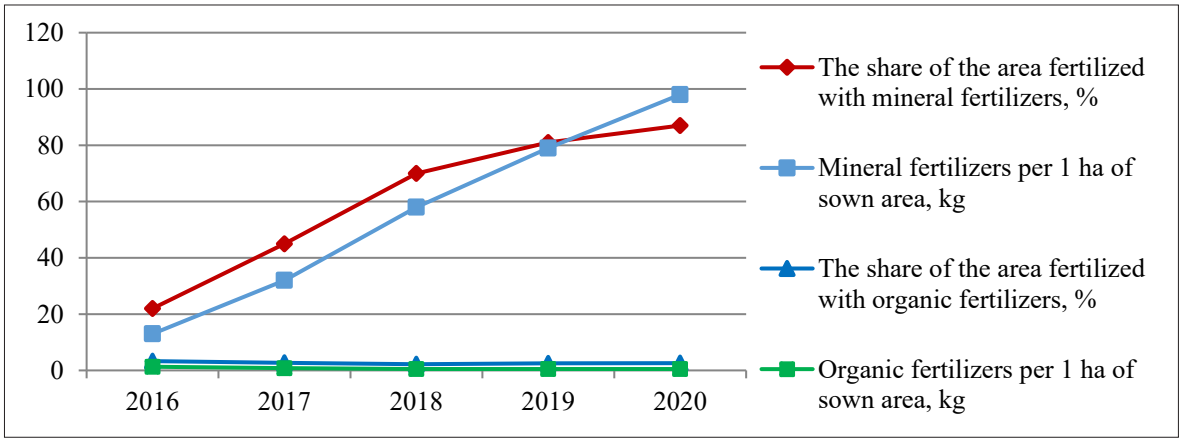

Figure 4. *The amount of fertilizer per 1 ha of sown area of agricultural enterprises of Ukraine for 2016-2020*
Source: *calculated by the authors according to data [26-28]*

The main tasks of the agricultural sector are to increase the volume of agricultural production, provide the population with food and agricultural products, achieve high economic performance and increase competitiveness in the world market. Among the main areas of functioning of the agricultural sector are: 1) positive results of the development of agricultural production; 2) increase in the production of basic crop products; 3) the general growth of indicators of the agricultural sector [27]. Thus, during the period of 2016-2020, the yield of grain crops in Ukraine increased on average by 2.7 times, sugar beets – by 2.9 times, sunflower – almost by 2 times, vegetables – by 4.3 times, fruit and berry crops – almost by 6.7 times (Fig. 5).

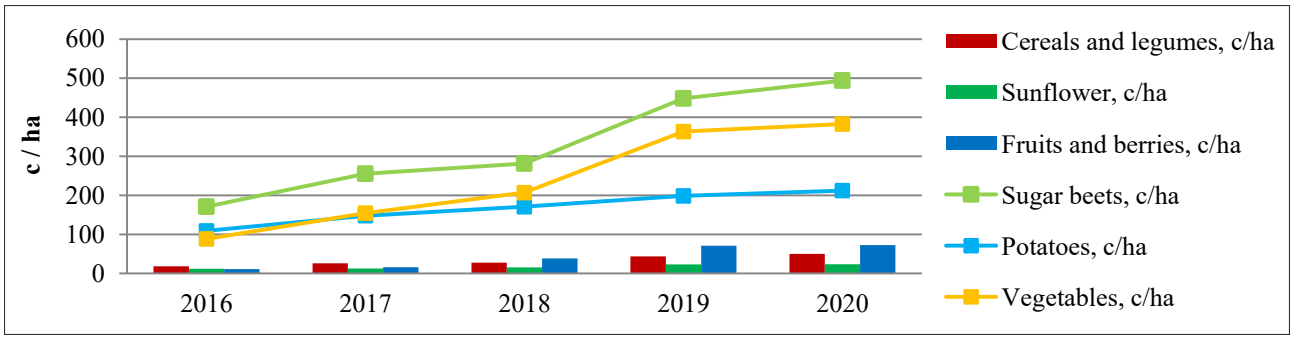

Figure 5. *Crop yields of agricultural enterprises of Ukraine in 2016-2020, c/ha*
Source: *calculated by the authors according to data [26-28]*

The reflection of interconnected and interacting results of agricultural enterprises in the plane of rational use of land and resource potential, through determining the overall economic effect of the production process per 1 hectare of agricultural land, allowed determining the impact of the cost component and its comparability with profitability to achieve this effect (Fig. 6).

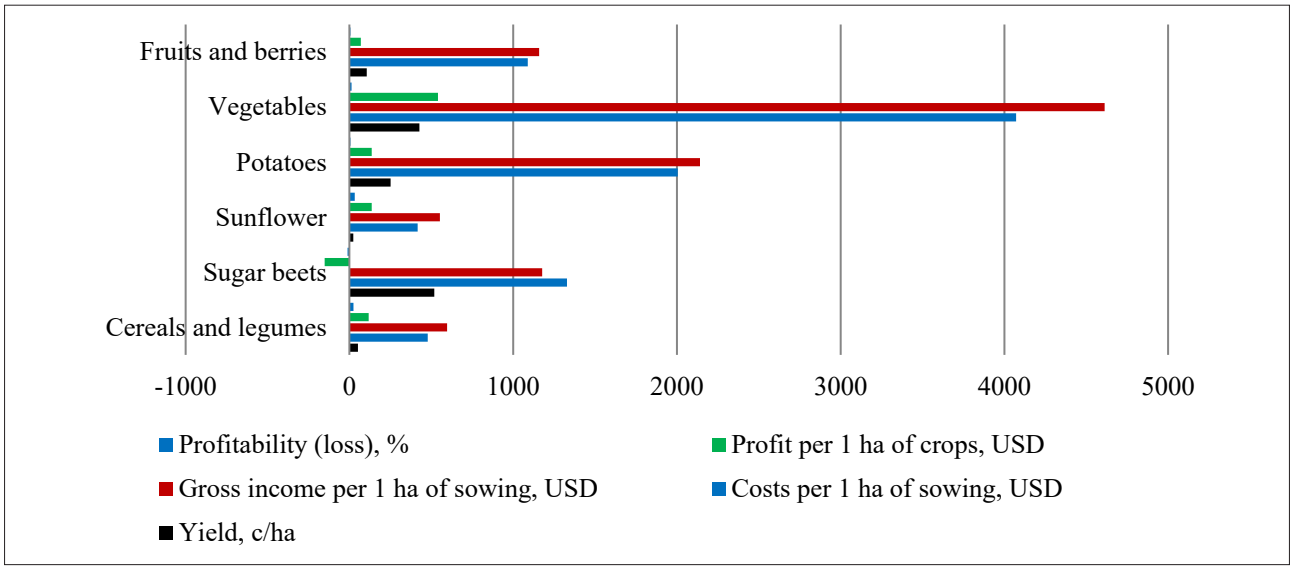

Figure 6. *Economic efficiency of crop production in Ukraine in 2020*
Source: *calculated by the authors according to data [26-28]*

Economic indicators of the results of economic activity of agricultural enterprises in the field of crop production are the basis for the normative monetary valuation of agricultural land according to the method [29], but it causes significant fluctuations in the monetary valuation of 1 ha of arable land. We believe that it is necessary to move the calculation of crop yields from its actual value to natural, i.e., without taking into account the cost of mineral and organic fertilizers [3; 7].

There are two options for calculating the normative monetary valuation of arable land, which is based on the actual yield of cereals and legumes (excluding corn for grain) and its growth through the introduction of mineral and organic fertilizers (option I) in Ukraine; option II – on the natural yield of cereals and legumes (excluding corn for grain) in rural areas on average per region of Ukraine; option III – on the natural yield of cereals and legumes (excluding corn for grain) on average per one region of Ukraine. According to the first option, based on the research results, the natural yield of grain and legumes on average in Ukraine in 2020 is 52.2 c/ha [28], the potential yield is higher by 20.9%, i.e. 63.1 c/ha (Fig. 7).

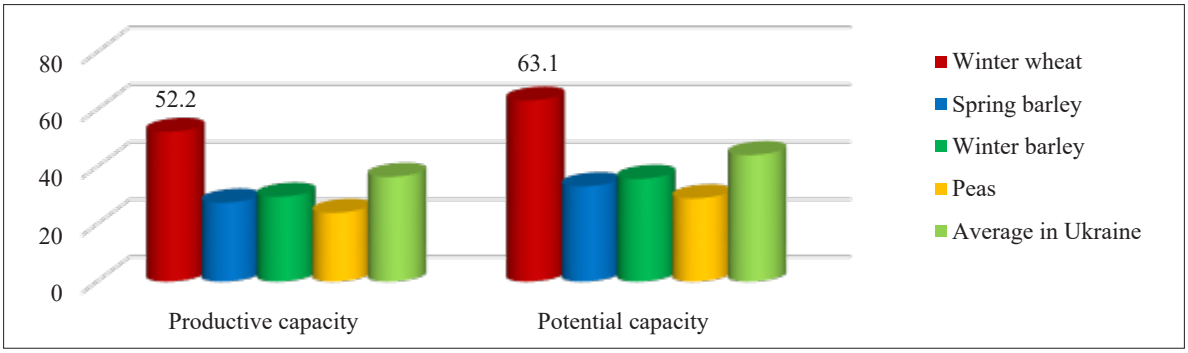

***Figure 7**. Productive capacity of natural and potential soil fertility by cereals and legumes (excluding corn for grain) in Ukraine*
***Source**: calculated by the authors according to data [26-28]*

The frequency of conducting and updating indicators of normative monetary valuation of agricultural lands is 5-7 years. The study period is five years (2016-2020), in which the actual yield of cereals and legumes without corn for grain fluctuated within 46.1-50.2 c/ha, and the average in Ukraine was 52.2 c/ha. The lowest yield was observed in 2017 – 42.5 c/ha, c/ha, and the highest in 2020 – 52.2 c/ha [28]. Based on the fact that due to the application of mineral and organic fertilizers, the potential yield is achieved, respectively, the natural yield by reducing the actual by 20.9% will be equal to 52.2×0.791=41.3 c/ha. Then the average natural yield for the study period will be (36.5+33.6+37.5+34.6+39.7+ +41.3)/5=44.6 c/ha (Fig. 8).

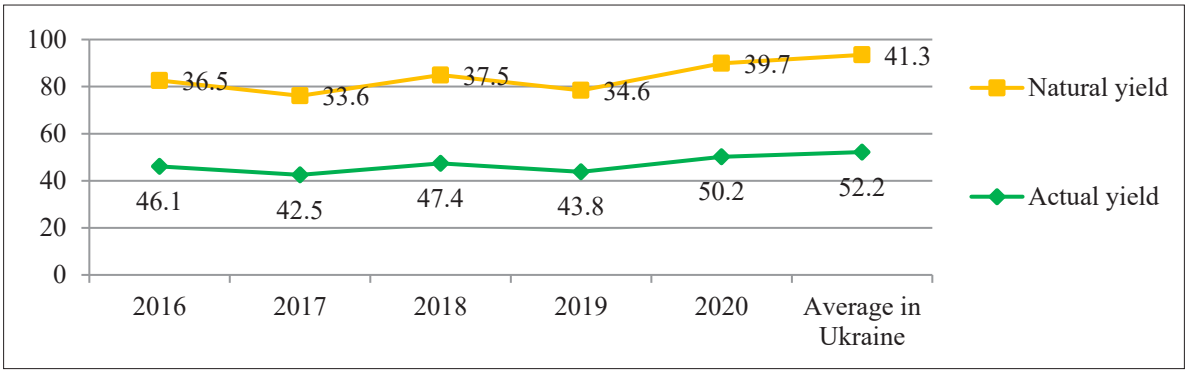

***Figure 8**. Natural and potential yields of cereals and legumes (excluding corn for grain) in Ukraine*
***Source**: calculated by the authors according to data [26-28]*

As part of the production costs of agricultural enterprises for the cultivation of cereals and legumes (excluding corn), the cost of mineral fertilizers for 2016-2020 fluctuated in the range 18-23%, in Ukraine they averaged 20% (Fig. 9).

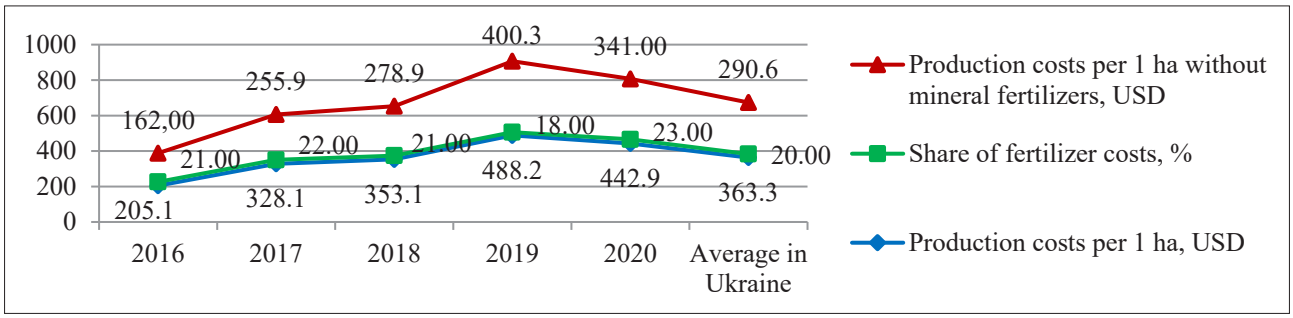

***Figure 9**. Production costs for growing cereals and legumes (excluding corn for grain) in Ukraine for 2016-2020*
***Source**: calculated by the authors according to data [26-28]*

We should note that there is a disproportion in the growth rate of costs in accordance with the rate of yield and price, which needs to be adjusted. Therefore, the growth rate of costs is greater than the growth rate of productivity by 21%, and the growth rate of sales price – by 5%. We should note that the average selling price of cereals and legumes (excluding corn for grain) in 2016 was – 10.30 USD/c, in 2017 – 11.86 USD/c, 2018 – 16.01 USD/c, 2019 – 21.23 USD/c, 2020 – 32.39 USD/c, the average in Ukraine – 20.4 USD/c (Fig. 10). That is, production costs when adjusting for natural yields will be for the study period within 161.9-381.5 USD/c, the selling price – within the limits 9.79-30.77 USD/c respectively.

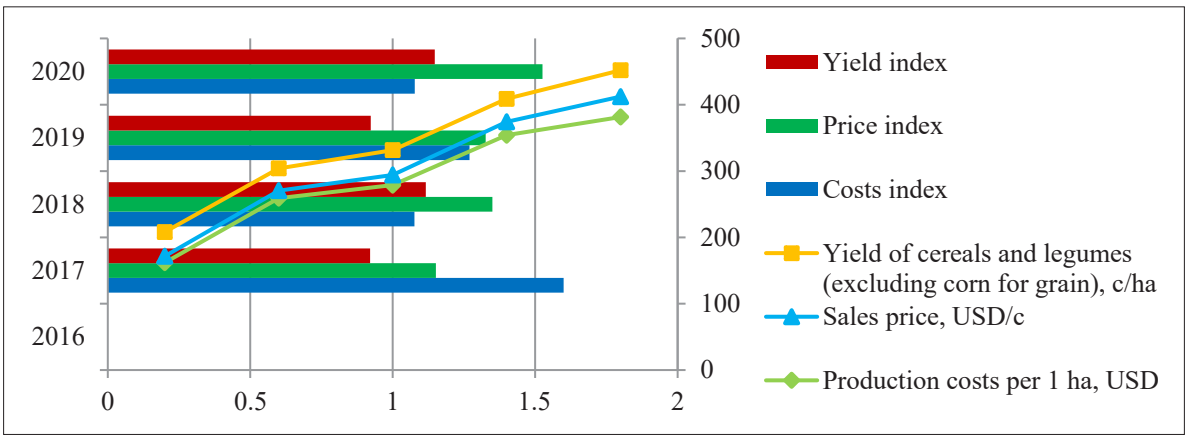

Figure 10. *Growth rates of grain and legumes (excluding corn for grain), sales prices and costs in Ukraine for 2016-2020*

Source: *calculated by the authors according to data [26-28]*

The normative monetary valuation of 1 ha of arable land according to the first option, which forms the potential of the land and resource potential of agricultural enterprises of Ukraine, is presented in (Table 3).

Table 3. *Regulatory monetary valuation of 1 ha of arable land when adjusting for natural yields of cereals and legumes (excluding corn for grain) in Ukraine in 2020 (option I)*

Indicators	Value
Yields of grains and legumes (without corn), c/ha	41.3
The average selling price of 1 centner of grain, USD USA	30.77
Gross output from 1 ha, USD	1270.8
Production costs per 1 ha, USD	381.5
Cost ratio (35%), USD	133.5
Costs with the standard, USD	515.0
Differential rental income, USD/ha	74.6
Differential rental income, c/ha	3.2
Absolute rental income, c/ha	1.6
Total rental income, c/ha	4.8
Normative monetary valuation, USD/ha	2472.0

Source: *calculated by the authors*

Differentiation of normative monetary valuation of 1 ha of arable land of agricultural enterprises depending on natural-climatic and qualitative-spatial indicators of location of rural territories on average per one region of Ukraine in 2020 is carried out (Fig. 11).

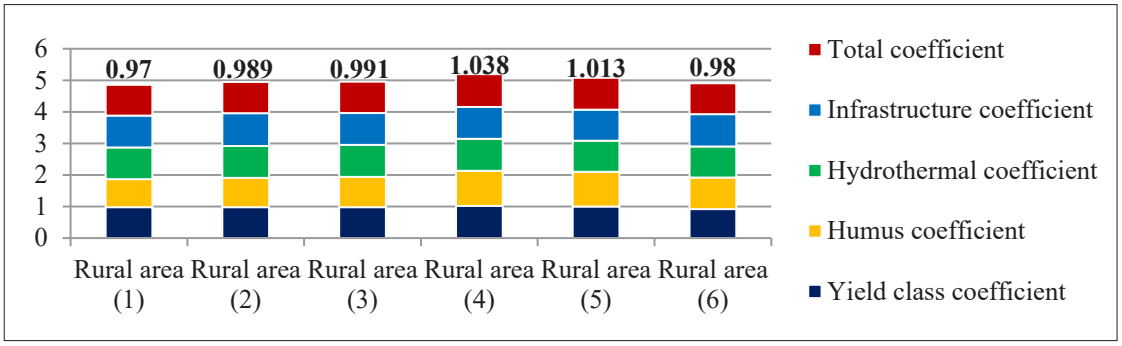

***Figure 11**. Determination of the total coefficient for arable land by natural characteristics of rural areas on average per region of Ukraine*

***Source**: calculated by the authors*

Thus, on average in one region of Ukraine the normative monetary valuation of 1 ha of arable land of agricultural enterprises, taking into account the total coefficient of differentiation is the largest in rural areas (4) equal to 10.6% more than the Methodology [29], the smallest – in rural areas (1) is 1246.9 USD/ha, which is 7.4% more than the current Methodology [29] (Fig. 12).

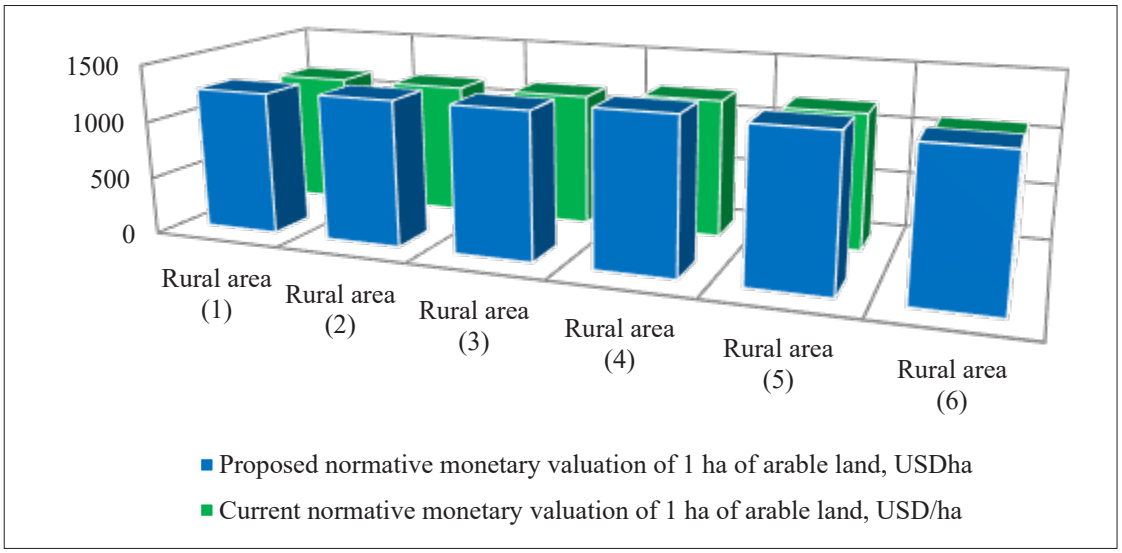

***Figure 12**. Comparison of the proposed and current normative monetary valuation of 1 ha of arable land in rural areas on average per one region of Ukraine, 2020 (option II)*

***Source**: calculated by the authors*

There are significant fluctuations in the normative monetary value of 1 ha of arable land, which is calculated on the basis of natural yields in each region of Ukraine separately. This will lead to a decrease in tax revenues to local budgets in some regions (Fig. 13).

The considered models of adjustment of normative monetary valuation of agricultural lands constitute a scientifically substantiated system of imperatives of efficient use of land and resource potential of agricultural enterprises, taking into account differences in rural development in the regions of crop production, taking into account their natural and economic features on agro-biological basis.

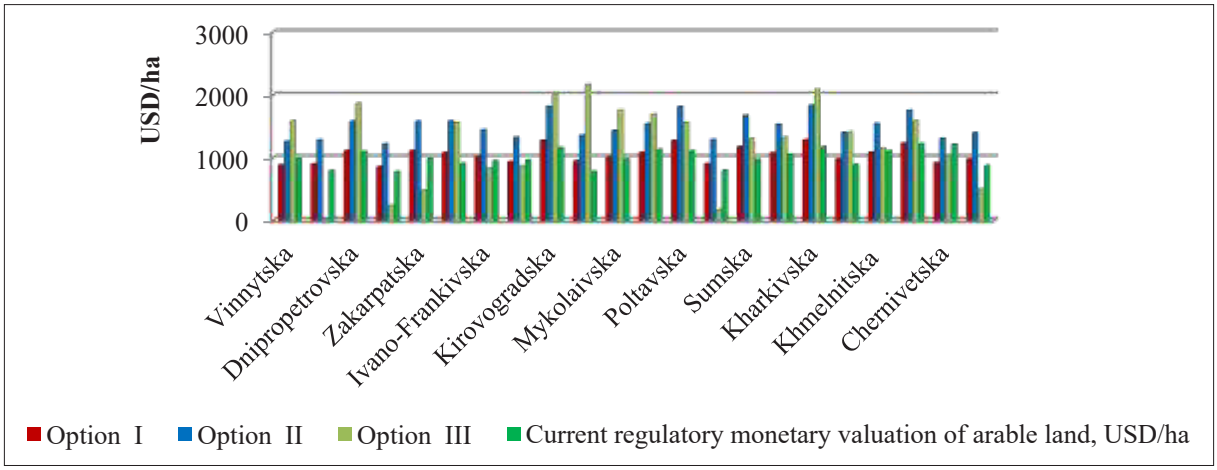

***Figure 13**. Normative monetary valuation of arable land by regions of Ukraine when adjusting for natural yields of cereals and legumes (excluding corn for grain) in 2020, USD/ha*

***Source**: calculated by the authors*

The selected options for such an assessment include: first, the development of appropriate methods, secondly, a nationwide assessment of all lands in the country, and thirdly, the creation of a portal of normative monetary assessment for free and transparent access of stakeholders to its results in online mode at any time.

Forecasting of the efficiency of the use of land and resource potential of agricultural enterprises in Ukraine

Based on the study of concentration and intensification of agricultural production, it is advisable to determine the forecast efficiency of the use of land and resource potential of agricultural enterprises in one rural area of Ukraine, on the three main components of efficiency – technological, social and economic (Table 4).

To predict the effectiveness of the use of land and resource potential of agricultural enterprises on a set of indicators, the latter must be reduced to a comparable form. To do this, each indicator determines the forecast direction of its positive development (i.e. the "best representative" of the studied group of indicators in terms of enterprises). Each value of the indicator is compared with the "best representative" of the studied group of indicators and transformed into appropriate coeffi-cients. The transformed matrix of indicators of efficiency of the use of land and resource potential of agricultural enterprises is presented in (Table 5).

***Table 4**. Initial indicators for forecasting the efficiency of the use of land and resource potential of agricultural enterprises by technological, social and economic components, 2020 (on average per region of Ukraine)*

Indicators	Agricultural enterprises					
	1	2	3	4	5	6
Technological efficiency indicators						
Commodity products on agricultural lands, thousand USD	0.4167	0.906	0.297	1.194	0.521	1.947
The amount of advanced capital per 1 hectare of agricultural land, thousand USD	0.662	0.778	0.298	1.073	0.346	37.59
Production costs per 1 hectare of agricultural land, thousand USD	0.295	0.560	0.356	0.887	0.422	1.589
Indicators of social efficiency						
The average salary of an employee, USD	165.8	213.5	273.1	237.8	253.9	246.5
Arable land area per 1 worker, ha	14	40	27	94	15	12
Labor costs per 1 ha of arable land, thousand USD	133.8	153.4	168.6	145.1	177.2	152.7
Indicators of economic efficiency						
Return on advanced capital ratio on net income from sales	0.6	1.2	1.0	1.1	1.5	0.1
Product profitability, %	85.4	59	51.6	27.2	15.1	22.4
Labor productivity, thousand USD	228.8	996.9	221.4	3078.6	374.2	530.1

***Source**: calculated by the authors*

***Table 5**. Transformed matrix of indicators of efficiency of the use of land and resource potential of agricultural enterprises of the region (on average per region of Ukraine), 2020*

Indicators	Agricultural enterprises					
	1	2	3	4	5	6
Technological efficiency indicators						
Commodity products on agricultural lands, thousand USD	0.21	0.47	0.15	0.61	0.27	1/00
The amount of advanced capital per 1 hectare of agricultural land, thousand USD	0.02	0/02	0/01	0.03	0.01	1.00
Production costs per 1 hectare of agricultural land, thousand USD	1.00	0.53	0.83	0.33	0.70	0.19
Indicators of social efficiency						
The average salary of an employee, USD	1.00	0.94	0.99	0.73	0.06	0.77
Arable land area per 1 worker, ha	0.15	0.43	0.29	1.01	0.16	0.11
Labor costs per 1 ha of arable land, thousand USD	0.45	0.68	0.72	1.00	0.34	0.06
Indicators of economic efficiency						
Return on advanced capital ratio on net income from sales	0.40	0.80	0.67	0.73	1.00	0.07
Product profitability, %	1.00	0.69	0.60	0.32	0.18	0.26
Labor productivity, thousand USD	0.07	0.32	0.07	1.00	0.12	0.17

***Source**: calculated by the authors*

An important factor in the used research method is taking into account the use of expert assessments of the significance of each indicator within their study groups in terms of technological, social and economic efficiency, respectively. The ranking of the weight of the value of each important of the proposed indicators is on a scale in the range from 0 to 1. The generalized weight of each evaluation indicator was determined with the help of arithmetic mean. The obtained weights within each group of indicators are a total of 1.0 [10]. According to the results of the evaluation, nine groups of significance weights were obtained, from which the final ones were derived. The final weights of significance of indicators of efficiency of the use of land and resource potential of agricultural enterprises are combined in Table 6. Based on the established transformed values of indicators and established weights of indicators and their groups, forecast values of indicators of technological, social and economic efficiency as generalizing characteristics of efficiency of the use of land and resource potential of agricultural enterprises in the region are determined (Table 7).

***Table 6**. Significance coefficients of the forecasted indicators of efficiency of the use of land and resource potential of agricultural enterprises of the region (on average per region of Ukraine)*

Indicators	Result
Commodity products on agricultural lands, thousand USD	0.26
The amount of advanced capital per 1 hectare of agricultural land, thousand USD	0.36
Production costs per 1 hectare of agricultural land, thousand USD	0.38
In general, according to indicators of technological efficiency	1
The average salary of an employee, USD	0.34
Arable land area per 1 worker, ha	0.28
Labor costs per 1 ha of arable land, thousand USD	0.38
In general, according to indicators of social efficiency	1
Return on advanced capital ratio on net income from sales	0.45
Product profitability, %	0.27
Labor productivity, thousand USD	0.28
In general, according to indicators of economic efficiency	1

***Source**: calculated by the authors*

***Table 7**. Matrix of forecast values of indicators of efficiency of the use of land and resource potential of the agricultural enterprises of the region for 2021 (on average per region of Ukraine)*

Indicators	Agricultural enterprises					
	1	2	3	4	5	6
Commodity products on agricultural lands, thousand USD	0.06	0.12	0.04	0.16	0.07	0.26
The amount of advanced capital per 1 hectare of agricultural land, thousand USD	0.01	0.01	0.003	0.01	0.003	0.36
Production costs per 1 hectare of agricultural land, thousand USD	0.38	0.20	0.31	0.13	0.27	0.07
Technological efficiency	**0.44**	**0.33**	**0.36**	**0.30**	**0.34**	**0.69**
The average salary of an employee, USD	0.34	0.32	0.34	0.25	0.02	0.26
Arable land area per 1 worker, ha	0.04	0.32	0.34	0.25	0.02	0.26
Labor costs per 1 ha of arable land, thousand USD	0.17	0.26	0.27	0.38	0.13	0.02
Social efficiency	**0.55**	**0.70**	**0.69**	**0.91**	**0.19**	**0.32**
Return on advanced capital ratio on net income from sales	0.18	0.36	0.30	0.33	0.45	0.03
Product profitability, %	0.27	0.19	0.016	0.09	0.05	0.07
Labor productivity, thousand USD	0.02	0.09	0.02	0.28	0.03	0.05
Economic efficiency	**0.47**	**0.64**	**0.48**	**0.78**	**0.53**	**0.15**

***Source**: calculated by the authors*

Forecast calculations of the effective use of land and resource potential of agricultural enterprises in the region by technological, social and economic component are presented in Figure 14.

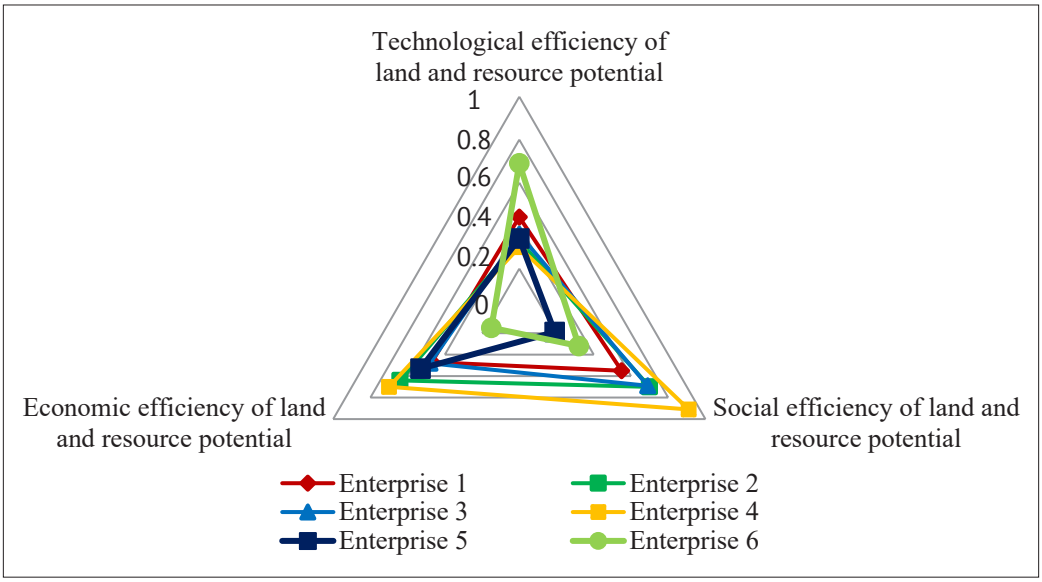

***Figure 14**. Three-dimensional model of coordinates of efficiency of the use of land and resource potential of agricultural enterprises of the region for 2021 (on average per region of Ukraine)*

***Source**: calculated by the authors*

Based on the essence of the studied indicators, it is determined that the higher the value of each generalization of the efficiency indicator, the better the position of the agricultural enterprise, the higher the efficiency of its land and resource potential. It is established that the best results are demonstrated by an agricultural enterprise No. 4, the second place in the hierarchy of efficient use of land and resource potential is occupied by enterprises No. 2, No. 3, No. 1, No. 5 and No. 6. However, it should be noted that the business entity No. 6 has the highest technological efficiency of the studied set of enterprises, which indicates the likelihood of increasing land use and the development of intensive production in the region.

CONCLUSIONS

Thus, the use of land and resource potential in Ukraine should be carried out within a clearly defined land policy, as the state is given the main role of regulator of land relations and dynamic development of the private sector. Institutionalization of land relations should ensure the viability of the principles of administrative, fiscal or complex nature, which, respectively, should provide decentralization and democratic development of rural areas for rational land use of agricultural lands of enterprises in the field of crop production based on intensive production. At the same time, their purposeful development should be aimed at improving the efficiency of the use of land and resource potential, through additional investments, the use of new technologies, modern forms of organization of production and labor. However, in the conditions of transformation of land reform there is a decline in economic efficiency of intensification of agricultural production. This indicates a number of shortcomings in ensuring measures to reduce the cost of production per 1 hectare of agricultural land.

In this context, an important role in both strategic and tactical terms is played by factors influencing the internal environment of agricultural enterprises, which are specific to agriculture. These are personnel, resources, technologies, economic mechanism, structure, business processes and products – as the results of management. The specificity of these factors for the efficient use of land and resource potential by agricultural enterprises is difficult to overestimate: soil fertility is the basis for harvesting; the number of sown areas rationally used is one of the sources of income. Effective use of agricultural land requires taking into account the impact of all factors and the degree of this impact on the technological, social and economic efficiency of the use of land and resource potential of agricultural enterprises of Ukraine demonstrate that the results of the three-dimensional coordinate model are rational because they represent not only the level of efficiency of the components, but also show a possible imbalance between them. This should be taken into account when developing imperatives to improve the efficiency of the use of land resources of agricultural enterprises in general.

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Імперативи ефективного використання земельного та ресурсного потенціалу сільськогосподарських підприємств України

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Анотація. У статті розглянуто інституціоналізацію земельних відносин та імперативи ефективного використання земельного та ресурсного потенціалу сільськогосподарських підприємств України. У межах інституціоналізації земельних відносин обґрунтовано методичний підхід до комплексної оцінки ефективного використання земельного та ресурсного потенціалу сільськогосподарських підприємств шляхом визначення інтегрального показника ефективності (кількісних та якісних характеристик залучених ресурсів, продуктивності та ефективності) основних видів діяльності суб'єктів господарювання на землях сільськогосподарського призначення. Запропоновано показники прозорості оцінки земельного та ресурсного потенціалу та показники земельної політики відповідно до рівня їх використання у сільському господарстві. Представлені комплексні критерії оцінки складових ефективності використання земельних ресурсів та ресурсного потенціалу сільськогосподарських підприємств. Проаналізовано розмір орендної плати за земельні паї та обсяг внесення добрив на 1 га посівної площі сільськогосподарських підприємств України. Визначено виробничі можливості природних і потенційних врожаїв зернових і зернобобових культур (крім кукурудзи на зерно) в Україні. Нормативна грошова вартість 1 га ріллі в сільській місцевості розраховується в середньому за одним регіоном України з поправкою на природну врожайність зернових та зернобобових культур без урахування внесення добрив. Представлено прогнозний рівень технічної, соціальної та економічної ефективності використання земельного й ресурсного потенціалу сільськогосподарських підприємств

Ключові слова: земельний та ресурсний потенціал, земельні відносини, рента, врожайність, витрати, собівартість, дохід, рентабельність

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Methodical Approach to Assessing Level of the State Energy Security and Its Influence on the National Security and Economy of the Country

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Abstract. This paper presents possible methodical approach to assessing level of the state energy security and its influence on the national security. In order to ensure proper level of the national security of the state, it is necessary to assess dangers in a great variety of areas, particularly, in the energy sector. Authors of this paper propose a version of solving the problem with the help of application of the state-of-the-art information technologies on the basis of the intellectual analysis of statistical data. The authors provide general description of the methodical approach in order to assess dangers for the existing level of the energy security. This approach is based on the comprehensive application of the grouped expert estimates, as well as on the theory of the experiment planning (the experimental design theory) and on the group method of data handling. The proposed approach is characterised by its relative simplicity and usability from the point of view of application of the already existing software products. The results, which would be obtained with the help of this method, can be easily interpreted and analysed. In addition, this paper proposes more adequate approach to understanding level of the energy security, as well the level of the national security of the state. The paper presents the specific example for assessing level of the energy security as well as procedure for finding explicit form of the computational functional with the help of the software GMDH Shell, which makes it possible to increase validity of the derived data as compared with the known approaches. Subsequent investigations will be carried out with the purpose of development of the scientifically substantiated approach to identification of the relevant criterial values of the danger indicators in order to ensure making adequate decisions in respect of responding to these dangers

Keywords: national security, economy of the country, GMDH Shell software, information technologies, energy

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INTRODUCTION

In these recent times, problems of the energy security of various countries grow worse and assume more importance. Manipulations with supplies of electric power and energy resources bring the state to the brink of catastrophe, because state of economy of various countries to a considerable degree depends on the state of assurance in energy resources. In these conditions, arrangement of conditions for neutralisation or elimination of hazards (both for the entire energy system, and for economy of the country) is the necessary condition of existence and development of the state. In other words, it is necessary to ensure energy security (hereinafter to be referred to as the "EnS") of the country. Energy security is one of the most important components of the national security; energy security is the condition, which is necessary in order to ensure sustainable development of the state. Energy security envisages achievement of the state of assurance (namely, state of the technically reliable, stable, economically efficient and ecologically safe assurance) of energy resources in the sphere of economy, as well as in the sphere of social protection of the state.

As for today, identification of the entire spectrum of hazards to the EnS, classification of these hazards, as well as identification of the approaches to assessing the energy security state of the country is the actual scientific task. Such assessing is of key importance for identification of the rational methods of the national security assurance (through increasing the national security). Analysis of the recent investigations and publications testifies that much attention is paid to investigation of issues of the EnS [1]. Unfortunately, lack of systematicity is inherent to the majority of papers. In other words, the EnS is only analysed in one of the aspects (resource, technological, and normative aspect). In these conditions, hazards of the economic nature are stated, for the most part, and considered as the main hazards. This fact significantly narrows down potentialities in respect of reliable and adequate assessing state of the EnS in the country. Hazards to the EnS are as follows: events of the short-time nature or long-run nature, which can destabilise operation of the entire energy sector, limit energy security or commit violation of energy security, as well as which can cause failures/emergencies and other negative consequences for the power industry, economy, and general public at large [2].

The analysis, which was carried out, has made it possible to perform conventional classification of various hazards to the EnS in accordance with several groups: economical hazards, social and political hazards, as well as external, technological, and natural hazards.

Group of economical hazards to the EnS includes the following hazards: lack of strategy of development of the fuel and energy complex; excessive energy consumption of economy, inefficiency of utilisation of fuel and energy resources, counterproductive structure of the fuel and energy complex of the state; shortage of funds available for investment (scarcity of investment resources); financial instability, which is to ensure performance of the entire energy sector; inefficient utilisation of fuel and material resources; lack of reserves of the fuel and energy resources; low innovation activity of energy enterprises; inefficiency of tariff and price policy; high prices of fuel and material resources; monopolistic behaviour of producers, suppliers, and distributors of electric power and fuel resources; imbalance of production and consumption of fuel and energy resources.

Social and political hazards. This group of hazards include the following hazards: instability in society; negative social and political events; unsound competition; unlawful actions of authorities and managers of enterprises; low qualifications of personnel; criminalisation of the "power supply business".

External hazards: excessive dependence of economy on the external monopolistic sources of supply of fuel and energy resources, power-generating equipment, materials, failures in performance of the contractual deliveries; absence of diversification of the sources and methods of the electrical power supply; discrimination measures from the part of other countries; critical dependence of export and import on the conditions of transportation through territories of other countries.

Technological hazards: high degree of wear-and-tear of the basic production assets at the enterprises of the fuel and energy complex; low technical level and quality of equipment and systems; non-observance of: the operating and maintenance rules, workplace safety and health regulations, and fire-prevention measures.

Natural hazards: natural disasters; natural anomalous phenomena [3-5].

The purpose of the study is to present description of possible approach to assessing hazards to energy security of the country within the framework of influence of these hazards on the national security and economy of the country.

MATERIALS AND METHODS

The main problem is connected with identification of influence of these hazards on the level of the energy security. In these conditions, classic approach in such situations envisages [6] procedure of making payments with the help of elements of the vector-matrix algebra. For example, level (the current state) of the EnS (E_{EnS}) is usually calculated taking into account the specific contribution of each indicator.

Level of the energy security state is calculated as the weighted product of the security levels of various components of the energy system (1, 2):

$$E_{EnS} = \sum_{i=1}^{n} \alpha_i E_i \quad (1)$$

$$\sum_{i=1}^{n} \alpha_i = 1 \quad (2)$$

where: E_{EnS} is actual current state of the EnS (as the efficiency of performance of the entire energy system of the state); α_i is the degree of influence of each i-th component of the energy system upon general security.

In other words, in order to implement this method, it is necessary to determine dependence E_i of the i-th group of factors and evaluate (with the help of the expert method or any other method) values of contributions α_i of each factor from a group of factors to general level of the energy security [7].

That is, the task comes down to the fact that with the help of the known functions $E_i(m_{ij})$ of the m_{ij} factors of each i-th group ($i=\overline{1,n}$) to assess general level of the EnS. From the point of view of the vector-matrix algebra, function of efficiency $E_i(m_{ij})$ of any one of the components of the entire system can be presented by the multidimensional ($j=\overline{1,m_{ij}}$) by vector ($\overline{E_i}$) in the coordinate form in such a manner (3):

$$\overline{E_i} = E_{i1}\bar{i} + E_{i2}\bar{j} + E_{i3}\bar{k} + \cdots + E_{ij}\bar{s} + \cdots + E_{im}\bar{l} \quad (3)$$

where: $E_{i1}, E_{i2}, E_{i3}, \ldots, E_{ij}, \ldots, E_{im}$ are coordinates of the vector $\overline{E_i}$ within the m-dimensional space with orthonormal basis, which is represented as the pairwise otrhogonal unit vectors $\bar{i}, \bar{j}, \bar{k}, \ldots, \bar{s}, \ldots, \bar{l}$; m_{ij} is quantity ($j=\overline{1,m_{ij}}$) of the factors, which are usually taken into account in the i-th component ($i=\overline{1,n}$) of the system. In these conditions, it is assumed that multitude of coordinates (of elements) E_{ij} ($i=\overline{1,n}, j=\overline{1,m_{ij}}$) creates matrix in the following form (4):

$$\|E_{ij}\| = \begin{Vmatrix} E_{11} & E_{12} & E_{13} \cdots E_{1j} & \cdots & E_{1m} \\ E_{21} & E_{22} & E_{23} \cdots E_{2j} & \cdots & E_{2m} \\ E_{31} & E_{32} & E_{33} \cdots E_{3j} & \cdots & E_{3m} \\ \cdots & \cdots & \cdots \cdots \cdots & \cdots & \cdots \\ E_{i1} & E_{i2} & E_{i3} \cdots E_{ij} & \cdots & E_{im} \\ \cdots & \cdots & \cdots \cdots \cdots & \cdots & \cdots \\ E_{n1} & E_{n2} & E_{n3} \cdots E_{nj} & \cdots & E_{nm} \end{Vmatrix} \quad (4)$$

Elements of rows of this matrix are coordinates of relevant vectors $\overline{E_i}$. These coordinates are initial / original data for calculation of values of modulus of the vector $\overline{E_i}$. Provided that this modulus is determined as the scalar product of this same vector with itself (it is equal to the sum of products of the coordinates having the same names) or as the squared elements of the i-th rows of the matrix $\|E_{ij}\|$ in such a manner (5):

$$\left|\overline{E_i}\right| = E_i = \sqrt{\left(\overline{E_i} \cdot \overline{E_i}\right)} = \sqrt{E_{i1}^2 + E_{i2}^2 + E_{i3}^2 + \cdots + E_{ij}^2 + \cdots + E_{im}^2} = \sqrt{\sum_{j=1}^{m} E_{ij}^2} \quad (5)$$

In principle, this expression determines value of efficiency E_i of one or another component of the entire system. Each coordinate of the $\overline{E_i}$-th of vector (of the i-th component), in its turn, is the function of the relevant (m_{ij}-th) of the factor, which assists in increasing this function.

RESULTS AND DISCUSSION

In accordance with such approach, the most complicated problems are the following ones: identification of weight of factors (α_i); identification of the actual form/view of the function $E_{EnS}=f(E_i)$ (1).

In order to solve these problems, it is proposed to use the following approach [8], which is based on the theory of the experiment planning (the experimental design theory) [9], as well as on the group method of data handling (GMDH) [10-14].

The following proposition is made for the selected experts in the EnS issues: to assess influence of the assembly of the identified hazards to energy security upon general level of the energy security. It is proposed the following for these experts: to fill in the table of plans of the experiment (Table 1), which was compiled in accordance with results of papers [12; 14].

Table 1. *Plan of the experiment for assessing level of the energy security ($E_{the\ EnS}$)*

Seq. Nos. of hazards	Value of the partial parameter					Value of the integral parameter E_{EnS}, in the opinion of the expert
	E_{ec}	E_{sp}	E_z	E_t	E_n	
1.						
2.						
...						

In other words, these experts will determine general form of the dependence $E_{EnS}=f(E_i)$ [11] with the help of their intuitive methods. In these conditions, this function will have the following form for the above-proposed list of hazards:

$$E_{the\ EnS} = f\left(E_{ec}, E_{sp}, E_{ext}, E_t, E_n\right) \quad (6)$$

where: E_{ec}, E_{sp}, E_{ext}, E_t, E_n are levels of economical, social and political, external, technological and natural hazards respectively.

At this stage, value E_{EnS} is determined at the discretion of the selected expert in accordance with the values of the input variables, while from this point on this value will be used in order to ensure formalisation

of this dependence. In the cases of selection of several experts, it is necessary to determine one of them, estimates of which are the most reasonable. With this aim in view, it is proposed to apply the "Kemeny median" [15]. Particularly, in order to derive the averaged outcome estimate of the agreed group of experts, it is necessary to minimise the total distance (metric) between binary relations [11; 16].

Distance (metric) between binary relations A and B, *which* are described as matrices $\|a_{ij}\|$ and $\|b_{ij}\|$, respectively, is the following number (7):

$$d(A,B) = \sum |a_{ij} - b_{ij}| \quad (7)$$

Summation is performed over all values *i, j,* that is, the Kemeny distance is equal to the sum of modules of differences of those elements, which stand at the same places in the relevant matrices [17]. In order to perform subsequent analysis, it will be necessary to select those results of the experts' work, which are the most averaged values in respect of other estimates. In these conditions, it is necessary to take into account that coefficient of concordance (which characterises degree of the opinion consistency of experts) must be not less than 0.75 [15]. In the case of non-performance of this condition, group of experts must be collected and formed once again.

In order to derive the dependence (2) in the explicit form (in the form of a functional), the experiment plan, which was completed by the selected expert, will be further processed with the help of the GMDH, which makes it possible to obtain the mathematically formalised connection between values of the partial indicators and value of the summarising indicator. In other words, it will be possible to obtain the formalised description of the expert's subjective opinion [13]. The statement of the problem in general terms will be presented as follows: let there be a sample of "A" observations of the input $X(i)$ and of output $Y(i)$ vectors. In accordance with the results of these observations, it will be necessary to determine $F(x)$ on the condition that structure of the $F(x)$ model is not known. The most comprehensive dependence between $X(i)$ inputs and $Y(i)$ outputs can be presented with the help of the Kolmogorov-Gabor polynomial (as generalized polynomial) [18].

Therefore, let there be the sample of $X=\{x_1, \ldots, x_N\}$, then such polynomial must have the form, which is presented in formula (8):

$$y = f(x) = a_0 + \sum_{j=1}^{k} a_j x_j + \sum_{j=1}^{k} a_{jj} x_j^2 + \sum_{j,\gamma=1}^{k} a_{j\gamma} x_j x_\gamma + \cdots + \sum_{j=1}^{k} a_{jjj} x_j^3 + \cdots \quad (8)$$

where: $j<\gamma<k$.

Immediate assessing the level of the energy security is performed due to substitution of actual values of the partial indicators (E_{ec}, E_{sp}, E_{z}, E_{t}, E_{n}), which were identified by experts, to the computational dependence, which was derived on the basis of GMDH.

With the purpose of simplification of perception of the derived results, it is proposed to perform normalisation of the calculated values within the range 0÷1 (or 0÷100%) provided that the following condition will be kept and valid: the higher value, the higher hazard. In accordance with the results of assessing a hazard (on the condition of application of the inverse analysis [10]), it is possible to ensure formation of the list of main hazards to energy security of the state, as well as to ensure development of propositions in respect of neutralisation of these hazards, as well as in respect of minimisation of possible negative consequences for the national economy of the state. In accordance with results of the known approaches ([10; 19; 20]), it is proposed (in the course of such analysis) to determine general level of the national or economical security depending on the current state of the energy security $Q(E_{EnS})$ (taking into account goal of the investigation, it is possible to ignore groups of the factors, which are not connected with the energy security, and consider these factors as constants) as dependence of such form:

$$Q(E_{the\ EnS}) = 1 + e^{-E_{EnS}} \quad (9)$$

Graph of the function $Q(E_{EnS})$ is presented in Figure 1.

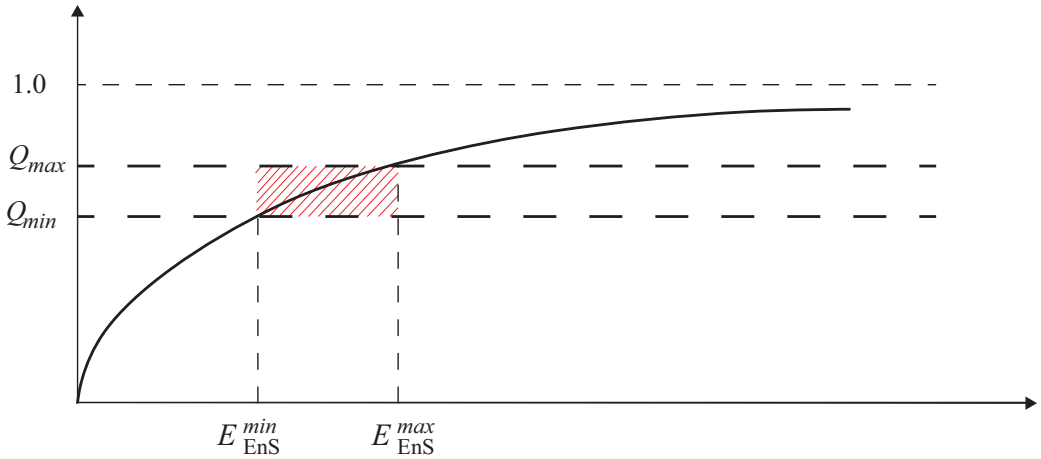

Figure 1. *Dependence of the national security of the state on the energy security*

In the case of application of such approach, expression (1) will be presented in the form of (10) however, this expression (as it was demonstrated by results of practical investigations [11]) does not correspond to actual processes.

$$E = \sum_{i=1}^{n} \alpha_i E_i = \sum_{i=1}^{n} \alpha_i \sqrt{(\overline{E_i}\,\overline{E_i})} = \sum_{i=1}^{n} \alpha_i \sqrt{\sum_{j=1}^{m} E_{ij}^2} = \sum_{i=1}^{n} \alpha_i \sqrt{\sum_{j=1}^{m} (1 - e^{-m_{ij}})^2} \quad (10)$$

In order to increase reliability of the results, it is proposed to apply the S-shaped curve (the Verhulst equation) (Fig. 2) (11):

$$Q(E_{EnS}) = \frac{1}{1 + e^{-E_{EnS}}} \quad (11)$$

In the case of application of such approach, range of the acceptable values of the EnS narrows down, however, rate of change in the relevant indicators is changed, and this fact is confirmed by practice. In these conditions, there will be no limitations in respect of consistency of forms of the functions $Q(E_{EnS})$ and $E_{EnS}=f(E_{ec}, E_{sp}, E_z, E_t, E_n)$.

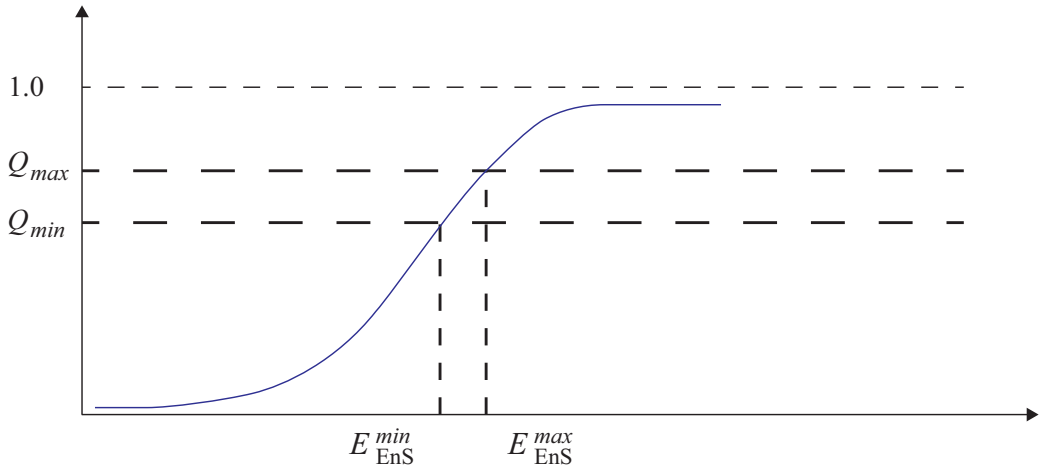

***Figure 2**. Dependence of the national security of the state on the energy security (the version, which is proposed to apply)*

Example of practical assessing the level of the energy security. In order to ensure immediate and direct assessing the level of the energy security, three experts were selected, who have completed relevant tables (Table 1) and assessed general level of the EnS depending on the values of partial hazards. These data were further processed with the help of the GMDH Shell software application, therefore, it was possible to derive relevant functional, which describes connection between the input and output parameters (this description was not included to this paper due to great volume of this description). The derived model is characterised by sufficiently high accuracy in respect of the initial/original data (Fig. 3), and this fact evidences working capacity of this model and possibility of its application in the course of practical activities. The derived values of the EnS and $Q(E_{EnS})$ levels are presented in Figure 4 and Figure 5 (these results are presented as the data of a hypothetical nature).

Error measure	Absolute ▼	Target: K	
Postprocessed results		Model fit	Predictions
Number of observations		16	4
Max. negative error		-1,22569E-13	-4,61853E-14
Max. positive error		7,81597E-14	1,30562E-13
Mean absolute error (MAE)		4,90719E-14	5,42899E-14
Root mean square error (RMSE)		5,87076E-14	7,07333E-14
Residual sum		-1,24345E-14	7,86038E-14
Standard deviation fo residuals		5,87025E-14	6,79488E-14
Coefficient of determination (R^2)		1	1
Correlation		1	1

It must be close to 0

It must be close to 1

***Figure 3**. Estimate of accuracy of the derived model*

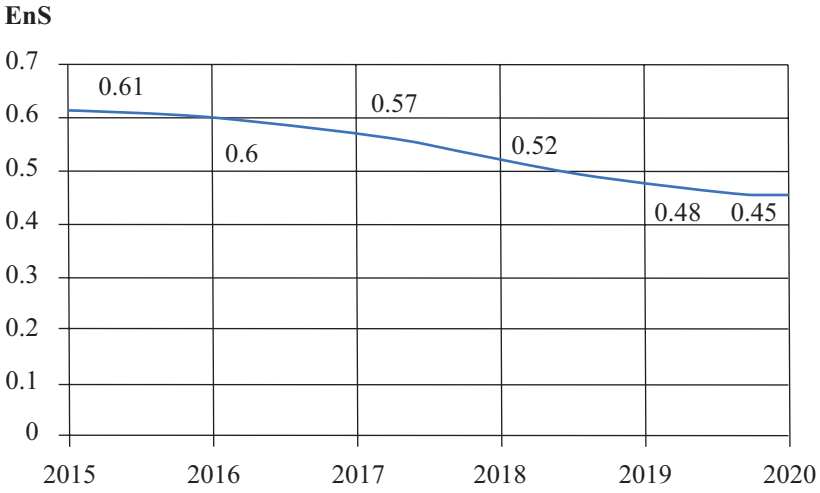

Figure 4. *Change in the level of EnS for Ukraine during 2015-2020*

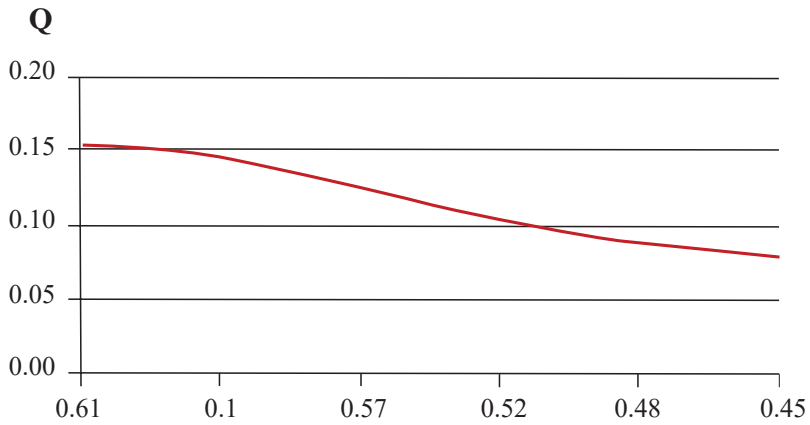

Figure 5. *Change in the level of the national security depending on the EnS value*

CONCLUSIONS

The proposed methodical approach is based on the application of the state-of-the-art information technologies in respect of the intellectual analysis of the data. It makes it possible to ensure adequate assessing the level of the state energy security and its influence on the national security. In future, this approach makes it possible to carry out more substantiated investigations of the energy security of the state, particularly, to determine degree of influence of hazards, their interconnection, as well as to develop the comprehensive system of relevant indicators for assessing efficiency of the measures with the purpose of further increasing level of the energy security.

The above-presented example of the procedure of calculations confirms working capacity of this approach and possibility of its application in the course of assessing general state in the energy sphere. Subsequent investigations will be carried out with the purpose of development of the scientifically substantiated approach to identification of the relevant criterial values of hazard indicators in order to ensure making adequate decisions in respect of making relevant decisions.

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Методичний підхід до оцінювання рівня енергетичної безпеки держави та її впливу на національну безпеку та економіку країни

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Анотація. У статті викладений можливий методичний підхід до оцінювання рівня енергетичної безпеки держави та її впливу на національну безпеку. Для забезпечення належного рівня національної безпеки держави потрібно оцінити загрози у широкому колі сфер, зокрема у енергетичній сфері. Автори пропонують варіант розв'язання цієї проблеми за допомогою застосування сучасних інформаційних технологій на основі інтелектуального аналізу статистичних даних. У науковій статті автори надають загальний опис методичного підходу оцінювання загроз рівня енергетичної безпеки. Підхід ґрунтується на комплексному використанні групових експертних оцінок, теорії планування експерименту та методу групового врахування аргументів. Запропонований підхід характеризується відносною простотою та зручністю з точки зору використання вже існуючих програмних продуктів. Отримані за його допомогою результати легко інтерпретуються та піддаються аналізу. Крім цього у статті пропонується більш адекватний підхід до визначення зв'язку рівня енергетичної безпеки та національної безпеки держави. У статті пропонується приклад оцінювання рівня енергетичної безпеки з визначенням явного виду розрахункового функціоналу за допомогою програми GMDH Shell, що дозволяє підвищити достовірність отриманих даних порівняно з відомими підходами. Подальші дослідження будуть проводитися в напрямі розроблення науково обґрунтованого підходу до визначення відповідних критеріальних значень показників загроз для забезпечення прийняття адекватних рішень щодо реагування на ці загрози

Ключові слова: національна безпека, економіка країни, програмне забезпечення GMDH Shell, інформаційні технології, енергетика

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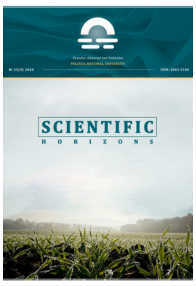

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Methodological Approaches to Forecasting Bread Prices in Ukraine

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Abstract. The article examines the current state of the bread and bakery market in Ukraine on the basis of the exponential smoothing method. An important aspect of the analysis of the bakery industry state is the issue of pricing for the number one product in Ukraine – bread and bakery products. The purpose of this study was to analyze the level of bread prices in the regional context, to identify trends and factors influencing them and to propose models on the basis of which it is advisable to make operational forecasts of bread prices. The study was performed on the basis of monitoring data of average consumer prices for wheat bread from first grade flour by months of 2017 and 2018 in the selected regions, Kyiv and Ukraine as a whole. The choice of areas is done due to their territorial location, and the choice of bread type – due to steady popularity among consumers. The dynamics of product prices, in particular in the regional aspect, was analyzed. The example of wheat bread made from first grade flour shows significant differences in the price level for these products by regions. Trends in price changes and their dependence on such factors as the price of flour, the price of gasoline A-95, wages have been identified. The expediency of using for the estimation of bread prices of models based on series of dynamics by exponential smoothing is shown. High accuracy of the received models is confirmed. The proposed approach in this study can be used by industry to construct models of product price forecasting as a benchmark for making management decisions about the real price. Performing these calculations online on a computer will provide businesses with particular advantages over their competitors, as well as the ability to plan their economic performance at the desired level

Keywords: modeling of pricing processes, exponential smoothing method, food industry, product competitiveness

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INTRODUCTION

According to Food and Agriculture Organization, in December 2019, the food price index reached a maximum of 181.7 in the last 5 years. The increase is observed in many countries around the world, as evidenced by studies in Africa, Asia and other regions [1-3]. Most often, price increases are associated with changes in oil prices [1; 3; 4-7]. Different models are being explored to identify the relationship between these metrics, including Autoregressive Distributed Lag (ARDL), A Nonlinear Autoregressive Distributed Lag (NARDL) [2; 5; 8]. For some types of products, here are recent articles on coffee price forecasts [9], soybean oil, fish and vegetables, on red chili peppers [10], using the ARIMA Models.

A. Volkov, M. Morkūnas, and V. Skvarciany [11], based on monthly data on retail prices of foodstuffs of the Lithuanian market for 2016-2018, substantiated the high efficiency of multiple regression models for forecasting prices for butter, eggs and rye bread. In particular, in the bread model, the retail price of rye bread is influenced by the volumes of bread produced, the volume of exports, the purchasing power (monthly average salary in the country) and the yield of rye. This paper examines the processes of changing the price of bread and bakery products (HBB) on the basis of the exponential smoothing method. An important aspect of the analysis of the bakery industry state is the issue of pricing for the number one product in Ukraine – bread and bakery products (BBP).

A lot of publications in the field of engineering, technology and economics are devoted to forecasting as an important function of management. It is economy where forecasting models have achieved special development and widespread use. Forecasting models and methods have been actively researched since the mid-twentieth century by both foreign and domestic specialists. Among the founders should be noted R.G. Brown [12], V.G. Kendall [13], H. Wold [14], G.E.P. Box, G.M. Jenkins [15], T. Anderson [16] and other works.

Among the Ukrainian authors, first of all, works of experts from Forecasting Institute of the NAS of Ukraine, in particular V.M. Heyets [17], should be noted. Among the publications of recent years devoted to the analysis of the bread and BBP market, the works of N.I. Kostetska [18], N.V. Navolska [19] should be noted.

In recent years, there has been a steady decline in the production of bread and HBV in Ukraine. According to the State Statistics of Ukraine, if in 2000 the output was 2646 thousand tons, in 2018 it was only 949 thousand tons (2.16 times less). Most researchers ([18; 19] etc.) associate this fact with population decline. What's more, they note the change in the structure of the population's nutrition towards consumption of other types of products. In addition, small enterprises, mini-bakeries and enterprises operating in the "shadow", whose data on production output is not recorded by the State statistics authorities, compete with the manufacturers of large and medium-sized enterprises.

The purpose of this study is to analyze the level of bread prices in the regional context, to identify trends and factors influencing them and to propose models on the basis of which it is advisable to make operational forecasts of bread prices.

MATERIALS AND METHODS

In contrast to the work discussed above, this paper focuses on the short-term forecast of bread prices using the exponential smoothing method. The study was performed on the basis of monitoring data of average consumer prices for wheat bread from first grade flour by months of 2017 and 2018 in the selected regions, Kyiv and Ukraine as a whole [1]. The choice of areas is done due to their territorial location, and the choice of bread type – due to steady popularity among consumers. The first stage examined the impact on bread prices of factors such as the price of flour of the first grade, the price of gasoline A-95 and average wages. In the second stage, forecast models were constructed on the basis of exponential smoothing method and bread price samples were presented as time series.

It is believed that through the time parameter, the time series is implicitly associated with many factors, taking into account the influence of which individually is not always possible. However, in time series most often there is autocorrelation in a series of "residues" and a certain inertia of economic processes takes place. Therefore, it is advisable to use adaptive forecasting methods for forecasting, in particular, the exponential smoothing method based on R. Brown's [12] model.

According to the classification of exponential smoothing models [20], the NN model is used in this paper, which does not take into account seasonal variations and the damping component (due to their absence). The method involves the representation of the time series y_t, $t = 1, 2, \ldots, T$, in the form of n-degree polynomial:

$$y_t = a_0 + a_1 \cdot t + \frac{a_2}{2!} \cdot t^2 + \cdots + \frac{a_n}{n!} \cdot t^n + \varepsilon_t \quad (1)$$

where ε_t – random variable; $a_0, a_1, \ldots, a_n$ – coefficients to be estimated on a sample basis.

Most often, representations of the series in the form of a linear or parabolic function are used.

Analysis of the dynamics of bread prices by months in 2017-2018 in the studied regions showed that it can best be described by a parabolic function:

$$\hat{y}_t = \hat{a}_0 + \hat{a}_1 \cdot t + \hat{a}_2 \cdot \frac{1}{2} \cdot t^2 \quad (2)$$

To test the feasibility of applying the method of exponential smoothing, the output time series for the

study objects were divided into two parts. The models were based on the first 20 observations (T=20), and the last 4 (l=1, 2, 3, 4) were used to estimate the accuracy of the forecasts.

Estimates $\hat{a}_0$, $\hat{a}_1$,$\hat{a}_2$ of the coefficients a_0, a_1,a_2 of the equation (1) for the parabolic model were determined according to the formulas [12; 21]:

$$\hat{a}_0 = 3(S_t^1 - S_t^2) + S_t^3 \quad (3)$$

$$\hat{a}_1 = \frac{\alpha}{2(1-\alpha)^2} \cdot [(6 - 5 \cdot \alpha) \cdot S_t^1 - (5 - 4\alpha)S_t^2 + (4 - 3\alpha)S_t^3] \quad (4)$$

$$\hat{a}_2 = \frac{\alpha^2}{(1-\alpha)^2} \cdot (S_t^1 - 2S_t^2 + S_t^3) \quad (5)$$

$$S_t^1 = \alpha y_t + (1-\alpha)S_{t-1}^1 \quad (6)$$

$$S_t^2 = \alpha S_t^1 + (1-\alpha)S_{t-1}^2 \quad (7)$$

$$S_t^3 = \alpha S_t^2 + (1-\alpha)S_{t-1}^3 \quad (8)$$

where S_t^1, S_t^2, S_t^3 – exponential means of the first, second and third order; α – smoothing parameter.

The initial conditions were determined according to the formulas:

$$S_0^1 = \hat{a}_{00} - \frac{1-\alpha}{\alpha} \cdot \hat{a}_{10} + \frac{(1-\alpha)(2-\alpha)}{2\alpha^2}\hat{a}_{20} \quad (9)$$

$$S_0^2 = \hat{a}_{00} - \frac{2(1-\alpha)}{\alpha} \cdot \hat{a}_{10} + \frac{(1-\alpha)(3-2\alpha)}{\alpha^2}\hat{a}_{20} \quad (10)$$

$$S_0^3 = \hat{a}_{00} - \frac{3(1-\alpha)}{\alpha} \cdot \hat{a}_{10} + \frac{3(1-\alpha)(4-3\alpha)}{2\alpha^2}\hat{a}_{20} \quad (11)$$

where $\hat{a}_{00}, \hat{a}_{10}, \hat{a}_{20}$ – estimates in the trend model obtained using the least squares (LS) method.

Predicted values $\hat{y}_{t+l}$ were determined according to the formula:

$$\hat{y}_{t+l} = \hat{a}_0 + l \cdot \hat{a}_1 + \frac{\hat{a}_2}{2!}l^2 \quad (12)$$

where l – prediction period.

An important point in forecasting $\hat{y}_{t+l}$ for l periods ahead is to determine the confidence interval within which the true value $\hat{y}_{t+l}$ should be expected. The confidence interval was determined according to the formula:

$$\hat{y}_{t+l} \pm \sigma_{t+l} \quad (13)$$

where:

$$\sigma_{t+l} = \Delta \approx S_{respr} \cdot (2\alpha + 3\alpha^2 + 3\alpha^3 \cdot l^2)^{\frac{1}{2}} \quad (14)$$

where S_{respr} is the standard deviation for absolute errors of the forecast periods.

Value α is usually selected within (0, 1). The closer α to 1, the greater the weight of the last actual values of the time series. This provides a low forecast error for the next period, but at the same time the confidence interval increases. Therefore, they are trying to determine the compromise value α at which a sufficiently high forecast accuracy for the coming periods and an acceptable confidence interval are achieved. The selection of the parameter α was performed by calculating the indicators of the model when α is changing with a certain step.

RESULTS AND DISCUSSION

Studies [22] have shown, that in recent years the level of bread products consumption per person in territorial aspect is not the same: the highest level of consumption is in Dnipro region, the lowest – in Lviv region. Amid the decline in production, bread prices are growing rapidly as evidenced by data in Table 1: for the period 2012-2018 bread had risen in price in Ukraine by more than 4 times. Prices grew at a particularly high rate in Kyiv region and in the city of Kyiv, below the national average they were in Mykolaiv region.

It could be assumed that the decrease in the level of bread consumption is due to the increase in prices for it, but this product for ordinal Ukrainian is a basic necessity, the elasticity coefficient of which is almost equal to one. Therefore, the bread price is influenced by other factors: the cost of grain and flour, and, in recent years, tariffs on energy, water, wages.

Table 1. *Consumer prices for wheat bread from first grade flour by regions and in Ukraine as a whole at the end of 2012-2018*

Consumer prices, UAH/kg, and indexes of prices by regions	Date						
	28.12.12	20.09.13	30.12.14	30.12.15	29.12.16	30.12.17	30.12.18
Dnipro region	**4.75**	**4.72**	**7.43**	**11.48**	**11.42**	**13.48**	**15.81**
Indexes to the previous year, %	100.0	99.4	157.4	154.5	99.5	118.0	117.3
Indexes to 2012, %	100.0	99.4	156.4	241.7	240.4	283.8	332.8
Kyiv region	**3.99**	**5.07**	**7.51**	**9.9**	**10.4**	**16.17**	**19.85**
Indexes to the previous year, %	100.0	127.1	148.1	131.8	105.1	155.5	122.7
Indexes to 2012, %	100.0	127.1	188.2	248.1	260.6	405.3	497.5
Lviv region	**4.62**	**4.88**	**6.67**	**10.67**	**11.21**	**13.96**	**17.71**
Indexes to the previous year, %	100.0	105.6	136.7	159.9	105.1	124.5	126.9
Indexes to 2012, %	100.0	105.6	144.4	230.9	242.6	302.2	383.3

Table 1, Continued

Consumer prices, UAH/kg, and indexes of prices by regions	Date						
	28.12.12	20.09.13	30.12.14	30.12.15	29.12.16	30.12.17	30.12.18
Mykolaiv region	**3.8**	**4.18**	**5.48**	**8.91**	**9.61**	**12.38**	**15.43**
Indexes to the previous year, %	100.0	110.0	131.1	162.6	107.8	128.8	124.6
Indexes to 2012, %	100.0	110.0	144.2	234.5	252.9	325.8	406.1
Kyiv city	**5.38**	**5.38**	**7.72**	**10.68**	**12.1**	**16.78**	**21.26**
Indexes to the previous year, %	100.0	100.0	143.5	138.3	113.3	138.7	126.7
Indexes to 2012, %	100.0	100.0	143.5	198.5	224.9	311.9	395.2
Ukraine	**4.29**	**4.78**	**6.61**	**10.36**	**10.87**	**14.19**	**17.48**
Indexes to the previous year, %	100.0	111.4	138.3	156.7	104.9	130.5	123.2
Indexes to 2012, %	100.0	111.4	154.1	241.5	253.4	330.8	407.5

If until 2012 the cost of bread was more than 75...80% dependent on the cost of flour, in 2018 the proportion of the cost of flour was already to 50 (Fig. 1, 2). A sharp increase in bread prices in 2017-2018 was also caused by the fact that the Cabinet of Ministers of Ukraine on the 1st of October 2016 canceled Resolutions No. 1548 [23] and No. 373 [24]. Those Resolutions provided for restrictions on the level of profitability of bread production weighing more than 500 grams from wheat flour of the highest, first and second grade and their mixtures, rye flour and a mixture of wheat and rye flour of simple recipes (flour, yeast, salt, water) without adding sugar, fat, other excipients, as well as bread and bakery products for diabetics. The abolition of restrictions on the level of profitability of bread production allowed enterprises to set economically reasonable prices according to expenses and with an average level of profitability [25].

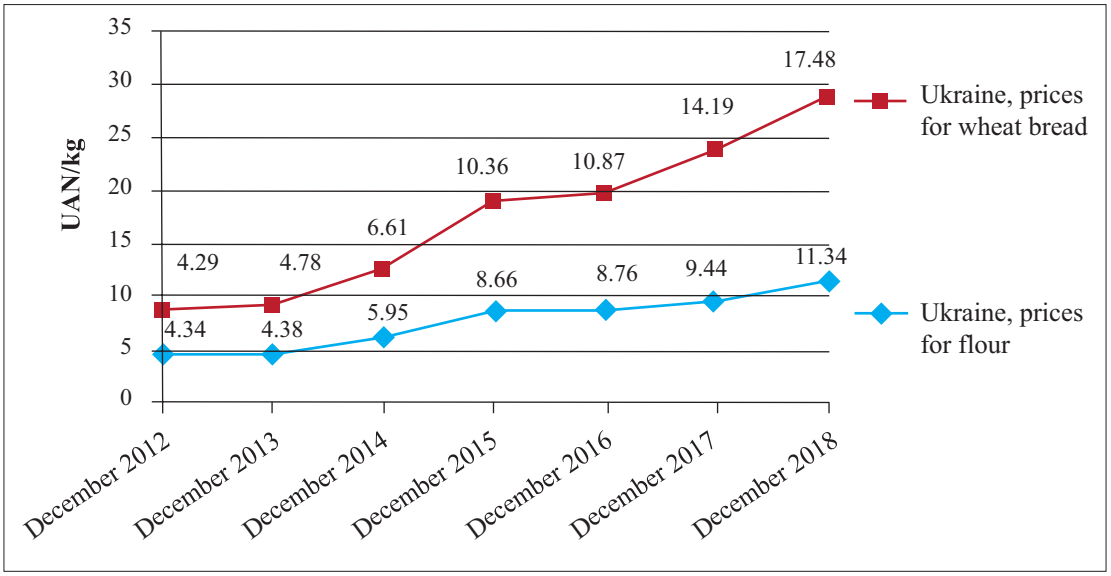

Figure 1. *Dynamics of prices for wheat bread and flour of the 1st grade in Ukraine in 2012-2018, UAH/kg*

In recent years, factors such as fuel tariffs and wages have also had a significant impact on bread prices. This is evidenced by the data of correlation analysis between the values of these indicators by months of 2017-2018 in the studied regions (Table 2).

The initial sample for these two years was formed on the basis of data from the State Statistics Committee of Ukraine precisely because during this period bread prices were more influenced by market factors, without regulatory influence from the Government.

The following notation is accepted in the Table 2: Y – the price of wheat bread, UAH/kg – function; X_1 – the price of 1st grade wheat flour, UAH/kg; X_2 – price of gasoline A-95, UAH/l; X_3 – average wage, UAH/month – factors affecting function.

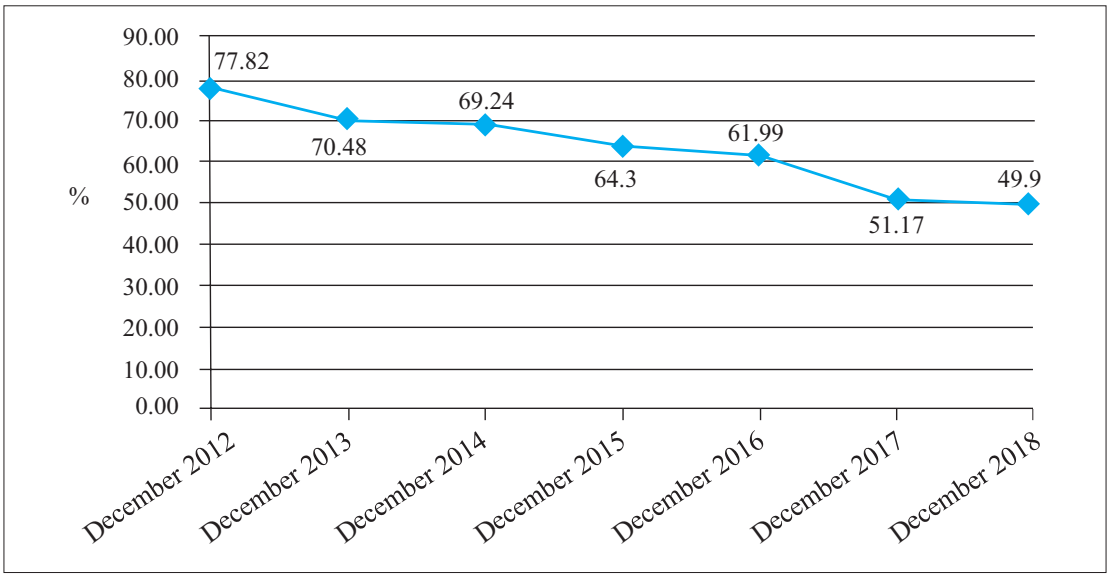

***Figure 2**. Share of the cost of the 1st grade flour in the cost of wheat bread in Ukraine, %*

***Table 2**. Matrix of coefficients of paired correlation between indicators*

	Y	X_1	X_2	X_3
		Dnipro region		
Y	1			
X_1	0.930	1		
X_2	0.927	0.796	1	
X_3	0.976	0.931	0.892	1
		Kyiv region		
Y	1			
X_1	0.955	1		
X_2	0.837	0.856	1	
X_3	0.917	0.927	0.874	1
		Lviv region		
Y	1			
X_1	0.957	1		
X_2	0.950	0.864	1	
X_3	0.937	0.910	0.834	1
		Mykolaiv region		
Y	1			
X_1	0.939	1		
X_2	0.937	0.833	1	
X_3	0.859	0.813	0.809	1
		Kyiv city		
Y	1			
X_1	0.738	1		
X_2	0.906	0.626	1	
X_3	0.901	0.791	0.832	1
		Ukraine		
Y	1			
X_1	0.979	1		
X_2	0.944	0.899	1	
X_3	0.949	0.948	0.859	1

Data of Table 2 indicates a high level of statistical relationship between function and factors. The factors themselves have a high level of communication. Therefore, it is not advisable to make price forecasts based on multiply regression models: the factors are expected to be collinear (which is confirmed by calculations) and their simultaneous use in the models will be incorrect. That is why, a sample of bread prices was presented as a time series [26-28]. It is believed that through the time parameter, the time series is implicitly associated with many factors, taking into account the influence of which individually is not always possible. However, in time series most often there is autocorrelation in a series of "residues" and certain inertia of economic processes takes place. Therefore, it is advisable to use adaptive forecasting methods for forecasting, in particular, the exponential smoothing method based on R. Brown's model.

To obtain the initial values S_t^1, S_t^2, S_t^3, trend models were constructed in Table 3. Model coefficients are estimated according to LS method.

***Table 3**. Trend models for changes in the price of wheat bread by region in 2017-2018*

Region	Type of model	Model accuracy indicators		
		S_{res}^2	R^2	E, %
Dnipro region	$\hat{y} = 12.046 + 0.106 \cdot t + 0.0018 \cdot t^2$	0.006	0.991	0.45
Kyiv region	$\hat{y} = 12.413 + 0.426 \cdot t + 0.0174 \cdot t^2$	0.118	0.953	1.60
Lviv region	$\hat{y} = 11.392 + 0.141 \cdot t + 0.0091 \cdot t^2$	0.037	0.984	1.06
Mykolaiv region	$\hat{y} = 10.445 + 0.140 \cdot t + 0.0033 \cdot t^2$	0.047	0.963	1.33
Kyiv city	$\hat{y} = 13.455 + 0.282 \cdot t + 0.0036 \cdot t^2$	0.235	0.944	2.14
Ukraine	$\hat{y} = 11.951 + 0.178 \cdot t + 0.0013 \cdot t^2$	0.012	0.991	0.65

Trend models' accuracy indicators were calculated according to the formulas:

$$S_{res}^2 = \frac{\sum_{t=1}^{T}(y_t - \hat{y}_t)^2}{T - K} = \frac{\sum_{t=1}^{T}\hat{u}_t^2}{T - K} \quad (15)$$

$$R^2 = 1 - \frac{\sum^{T}(y_t - \hat{y}_t)^2}{\sum_{t=1}^{T}(y_t - \bar{y})^2} \quad (16)$$

$$E\% = \frac{1}{T}\sum_{t=1}^{T}\left|\frac{y_t - \hat{y}_t}{y_t}\right| \cdot 100 \quad (17)$$

where – S_{res}^2 residual dispersion; T – number of observations; K – number of coefficients in the regression equation; $\bar{y}$ – arithmetic mean of y; R^2 – coefficient of determination; $E\%$ – average relative error of approximation. The closer S_{res}^2, $E\%$ to 0 and R^2 to 1, the more accurate the model is.

Fisher's F-test confirmed the statistical reliability of the models ($F_p > F_{tabl}$). As can be seen from the Table 3, the models are fairly accurate. Tables 4 and 5 show the results of calculations done according to the formulas (2-14) at the optimal value α from the position of forecast accuracy for the coming prediction periods and an acceptable level of the confidence interval.

From Tables 4 and 5 it follows that the forecast values of the price for *l*=1.2 are quite accurate. For further periods accuracy decreased. But the advantage of the method is its ability to adapt the model parameters by including new actual data in the sample and recalculating it. Predicted price values often come close to the actual from the "bottom". However, the confidence interval at the upper limit practically coincides with the real price [29]. Therefore, the final decision on pricing should be made by management, taking into account other factors as well. The Tables also show that for each region the best result was obtained at different values α. This indicates the need to carefully study the features of the original dynamic series, its structure and the selection of the best model, depending on the purpose of modeling. Considering the peculiarity of the exponential smoothing method, the aim should be to achieve high accuracy of short-term forecast for the coming prediction periods.

***Table 4**. Results of price forecasting in Ukraine as a whole, α=0.85*

$S^1{}_0$	11.920								
$S^2{}_0$	11.888								
$S^3{}_0$	11.857								
y_t	$S^1{}_t$	$S^2{}_t$	$S^3{}_t$	$\hat{a}_0$	$\hat{a}_1$	$\hat{a}_2$	$\hat{y}_t$	y_t-$\hat{y}_t$	$\left\|\frac{y_t - \hat{y}_t}{y_t}\right\| * 100$
11.99	11.979	11.966	11.949	11.990	0.005	-0.085			
12.41	12.345	12.288	12.238	12.408	0.490	0.196	11.953	0.457	3.68

Table 4, Continued

12.67	12.621	12.571	12.521	12.671	0.279	-0.004	12.996	-0.326	2.57
12.78	12.756	12.728	12.697	12.781	0.065	-0.108	12.948	-0.168	1.31
12.87	12.853	12.834	12.814	12.870	0.055	-0.060	12.792	0.078	0.60
13.00	12.978	12.956	12.935	13.000	0.126	0.005	12.895	0.105	0.81
13.11	13.090	13.070	13.050	13.110	0.108	-0.006	13.128	-0.018	0.14
13.28	13.251	13.224	13.198	13.280	0.183	0.033	13.215	0.065	0.49
13.50	13.463	13.427	13.393	13.500	0.242	0.046	13.479	0.021	0.15
13.72	13.681	13.643	13.606	13.720	0.232	0.018	13.765	-0.045	0.33
13.98	13.935	13.891	13.849	13.980	0.274	0.030	13.962	0.018	0.13
14.19	14.152	14.113	14.073	14.190	0.206	-0.018	14.269	-0.079	0.55
14.41	14.371	14.332	14.294	14.410	0.216	-0.004	14.387	0.023	0.16
14.68	14.634	14.588	14.544	14.680	0.282	0.030	14.624	0.056	0.38
14.90	14.860	14.819	14.778	14.900	0.216	-0.017	14.977	-0.077	0.51
15.14	15.098	15.056	15.014	15.140	0.239	0.003	15.108	0.032	0.21
15.27	15.244	15.216	15.186	15.270	0.104	-0.065	15.380	-0.110	0.72
15.35	15.334	15.316	15.297	15.35	0.049	-0.060	15.342	0.008	0.05
15.49	15.467	15.444	15.422	15.490	0.140	0.014	15.369	0.121	0.78
15.68	15.648	15.617	15.588	15.680	0.208	0.041	15.636	0.044	0.28
l	y_{t+l}	$\hat{a}_0$	$\hat{a}_1$	$\hat{a}_2$	y_{t+l}	y_{t+l}-$\hat{y}_{t+l}$	%	E% =	0.73
1	16.14	15.680	0.208	0.041	15.91	0.23	1.42		
2	16.54				16.18	0.36	2.18		
3	17.22				16.49	0.73	4.24		
4	17.48				16.84	0.64	3.66		
					S_{respr} =	0.23		E% =	2.88
		l	y_{t+l}	$\hat{y}_{t+l}$	Δ	Lower limit	Upper limit		
		1	16.14	15.91	0.56	15.35	16.47		
		2	16.54	16.18	0.79	15.39	16.97		
		3	17.22	16.49	1.06	15.43	17.55		
		4	17.48	16.84	1.35	15.49	18.19		

***Table 5**. Results of price forecasting by regions of Ukraine*

Region	l	y_{t+l}	$\hat{y}_{t+l}$	y_{t+l}-$\hat{y}_{t+l}$	$\left\|\frac{y_t-\hat{y}_t}{y_t}\right\|$, %	Δ	Lower limit	Upper limit	E%
Dnipro region α=0.60	1	14.87	14.84	0.03	0.20	0.25	14.62	15.12	
	2	15.24	15.07	0.17	1.12	0.33	14.91	15.57	
	3	15.68	15.30	0.38	2.42	0.42	15.26	16.10	
	4	15.81	15.55	0.26	1.64	0.53	15.28	16.34	
		S_{respr}=	0.15						1.35
Kyiv region α=0.60	1	17.71	17.87	-0.16	0.90	1.43	16.44	19.30	
	2	18.05	18.05	0.00	0.00	1.84	16.21	19.89	
	3	19.48	18.22	1.26	6.47	2.38	15.84	20.60	
	4	19.85	18.40	1.45	7.30	2.97	15.43	21.37	
		S_{respr}=	0.84					3.67	

Table 5, Continued

Region	l	y_{t+l}	$\hat{y}_{t+l}$	y_{t+l}-$\hat{y}_{t+l}$	$\left\|\frac{y_t-\hat{y}_t}{y_t}\right\|$, %	Δ	Lower limit	Upper limit	E%
Lviv region α=0.15	1	16.26	16.27	-0.01	0.06	0.15	16.12	16.42	
	2	16.63	16.59	0.04	0.24	0.16	16.43	16.75	
	3	17.32	16.91	0.41	2.37	0.17	16.74	17.08	
	4	17.71	17.24	0.47	2.65	0.18	17.06	17.42	
			S_{respr}=	0.25					1.33
Mykolaiv region α=0.45	1	14.53	14.38	0.15	1.03	0.16	14.22	14.54	
	2	14.78	14.73	0.05	0.34	0.19	14.54	14.92	
	3	15.01	15.11	-0.10	0.67	0.23	14.88	15.34	
	4	15.43	15.51	-0.08	0.52	0.28	15.23	15.79	
			S_{respr}=	0.12					0.64
Kyiv city α=0.30	1	19.06	19.82	-0.76	3.99	0.85	18.97	20.67	
	2	19.10	20.07	-0.97	5.08	0.95	19.12	21.02	
	3	20.90	20.32	0.58	2.78	1.10	19.22	21.42	
	4	21.26	20.57	0.69	3.25	1.28	19.29	21.85	
			S_{respr}=	0.87					3.78

To predict prices based on time series with an upward trend, the method of exponential smoothing based on the R. Brown model can be recommend. As noted in Yu.P. Lukashin [30], the positive characteristics of the model include the fact that the model requires the determination of the optimal value of only one parameter. And, what's more, the coefficients of the model are estimated according to the method of exponential smoothing in such a way as to reduce the autocorrelation in the "residues". Therefore, the model can be used in calculations on a computer, even in Excel.

CONCLUSIONS

An analysis of the dynamics of prices shows that they have been steadily increasing over the last 7 years, that is, the situation in the country is no different from world trends. The price level for these products has a significant impact on the prices of many other food products. So, research of the dynamics of changes in the prices of bread and BBP, identifying the factors of influence, construction and application of econometric models for the analysis, forecasting and management of the pricing process is a relevant task.

The proposed approach can be used by industry to construct models of product price forecasting as a benchmark for making management decisions about the real price. Performing these calculations online on a computer will provide businesses with particular advantages over their competitors, as well as the ability to plan their economic performance at the desired level.

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Методологічні підходи до прогнозування цін на хліб в Україні

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Анотація. У статті досліджується сучасний стан ринку хліба та хлібобулочних виробів в Україні на основі методу експоненціального згладжування. Важливим аспектом аналізу стану хлібопекарської промисловості є питання ціноутворення на продукт номер один в Україні – хліб і хлібобулочні вироби. Метою даного дослідження було проаналізувати рівень цін на хліб у регіональному розрізі, виявити тенденції та фактори, що впливають на них, а також запропонувати моделі, на основі яких доцільно робити оперативні прогнози цін на хліб. Дослідження виконано на основі даних моніторингу середніх споживчих цін на хліб пшеничний із борошна першого ґатунку за місяцями 2017 та 2018 років у виділених регіонах, Києві та Україні в цілому. Вибір районів обумовлений їх територіальним розташуванням, а вибір виду хліба зумовлений стабільною популярностю серед споживачів. Проаналізовано динаміку цін на продукцію, зокрема в регіональному аспекті. На прикладі пшеничного хліба, виготовленого з борошна першого сорту, видно значні відмінності в рівні цін на цю продукцію за регіонами. Виявлено тенденції зміни цін та їх залежність від таких факторів, як ціна на борошно, ціна на бензин А-95, заробітна плата. Показано доцільність використання для оцінки цін на хліб моделей на основі рядів динаміки методом експоненційного згладжування. Підтверджується висока точність отриманих моделей. Запропонований у статті підхід може бути використаний промисловістю для побудови моделей прогнозування ціни на продукцію як орієнтира для прийняття управлінських рішень щодо реальної ціни. Виконання цих розрахунків онлайн на комп'ютері дасть підприємствам певні переваги перед конкурентами, а також можливість планувати свої економічні показники на бажаному рівні

Ключові слова: моделювання процесів ціноутворення, метод експоненційного згладжування, харчова промисловість, конкурентоспроможність продукції

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