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# ЗМІСТ

<b>І. С. Данілова, Т. М. Данілова</b> Розробка методів оцінки якості м'яса равликів.....	9
<b>О. М. Чечет, С. В. Шуляк, В. Л. Коваленко, М. Є. Романько, О. С. Гайдей</b> Вплив комплексного застосування симбіотичних та біоцидних препаратів на метаболічний статус крові курчат-бройлерів.....	19
<b>Т. С. Буднік, С. В. Гуральська, О. В. Пінський, Г. П. Грищук, В. В. Гончаренко</b> Гістоархітектоніка гардерової залози курей в поствакцинальний період.....	32
<b>Н. В. Пузріна, О. В. Токарєва, Р. Д. Василюшин, А. І. Карпук, О. М. Мельник</b> Моніторингові дослідження оселищ рідкісних видів та деревоживучих комах в об'єктах Смарагдової мережі.....	41
<b>В. В. Москалець, Т. З. Москалець, М. М. Ключевич, Н. П. Пелехата, М. М. Світельський</b> Обліпиховий галовий кліщ ( <i>Aceria hippophaena</i> Nal.) в садах обліпихи крушиноподібної ( <i>Hippophae rhamnoides</i> L.) та елементи агротехнології його контролю.....	51
<b>В. Г. Дідора, Л. Д. Романчук, М. М. Ключевич, П. С. Вишнівський, Н. Г. Матвійчук</b> Сортові особливості елементів органічної технології вирощування сої.....	60
<b>П. М. Кузнєцов, А. Ю. Тихомиров, О. О. Бєдункова, С. В. Зайцев</b> Удосконалення методів контролю енергетичної оливи агрегатів оборотного водопостачання градирень Рівненської атомної електростанції.....	69
<b>Е. Тіястугі, Ш. Марванті, Р. У. Фаджарнінгсіх</b> Конкурентоспроможність та детермінанти експорту натурального каучуку Індонезії в основних країнах-партнерах.....	80
<b>Д. Рахмаваті, С. Х. Пурномо, Ш. Марванті</b> Показники експорту індонезійських товарів «Ластівчине гніздо» до основних країн призначення.....	90
<b>Н. Джафаров, Е. Ібрагімов, М. Гусейнов</b> Аналіз потужностей експортного потенціалу зернових культур України, можливих причин занепаду та напрямів розвитку.....	102
<b>К. Хушвахзода</b> Підвищення рівня конкурентоспроможності за допомогою управлінської звітності на підприємствах аграрного сектору.....	113
<b>ОГЛЯДОВА СТАТТЯ</b>	
<b>К. В. Сухецька, Л. П. Альошкіна, А. В. Мовчанюк, І. М. Новак, Н. Я. Пітель</b> Напрями та рекомендації підприємствам щодо подолання кризових ситуацій з використанням антисипативних команд.....	122

---

# CONTENTS

---

**I. Danilova, T. Danilova**

Development of methods for assessing the quality of snail meat.....9

**O. Chechet, S. Shulyak, V. Kovalenko, M. Romanko, O. Haidei**

The effect of complex application of symbiotic and biocidal preparations  
on the metabolic status of broiler chickens' blood .....19

**T. Budnik, S. Huralska, O. Pinsky, H. Hryshchuk, V. Honcharenko**

Histoarchitectonics of the Harderian gland of chickens in the post-vaccination period.....32

**N. Puzrina, O. Tokarieva, R. Vasylyshyn, A. Karpuk, O. Melnyk**

Monitoring studies of habitats of rare species and tree-dwelling insects in the Emerald Network sites.....41

**V. Moskalets, T. Moskalets, M. Kliuchevych, N. Pelekhata, M. Svitelskyi**

Sea buckthorn gall mite (*Aceria hippophaena* Nal.) in the orchards of sea buckthorn (*Hippophae rhamnoides* L.)  
and elements of its control agrotechnology.....51

**V. Didora, L. Romantschuk, M. Kliuchevych, P. Vyshnivskyi, N. Matviichuk**

Varietal features of elements of organic soybean cultivation technology.....60

**P. Kuznietsov, A. Tykhomyrov, O. Biedunkova, S. Zaitsev**

Improvement of methods for controlling power oil of cooling tower recycling water supply units  
at Rivne nuclear power plant.....69

**E. Tiyastuti, S. Marwanti, R. U. Fajarningsih**

Competitiveness and determinants of Indonesia's natural rubber exports in main partner countries .....80

**D. Rahmawati, S. H. Purnomo, S. Marwanti**

Export performance of Indonesian Swallow's Nest Commodities in main destination countries.....90

**N. Gafarov, E. Ibrahimov, M. Huseynov**

Analysis the capacity of grain export potential in Ukraine, possible reasons for the decrease and development trends.....102

**K. Khushvakhtzoda**

Increasing the competitiveness level with the help of management reporting at the agricultural sector enterprises..... 113

## REVIEW ARTICLE

**K. Sukhetska, L. Aleshkina, A. Movchaniuk, I. Novak, N. Pitel**

Directions and recommendations for enterprises to overcome crises using anticipatory teams ..... 122



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## Development of methods for assessing the quality of snail meat

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**Abstract.** The meat of edible snails is considered a delicacy and is part of Ukraine's food exports, but there are no regulations or legislation on its quality. The purpose of this work was to develop methods for determining the degree of freshness of snail meat by the content of ammonia and ammonium salts with Nessler's reagent, peroxidase in meat with copper sulfate solution, and processing a smear-print from meat with a fluorescent dye and to determine the quality of meat by the number of green pixels. During the research, first of all, it was determined the organoleptic characteristics of shellfish meat, which reflect their freshness. Next, research was performed to determine the enzymes and ammonia that are produced during meat storage. The following reagents were used: copper sulfate solution, Nessler's reagent, and fluorescent dye – acridine orange. The equipment used for these reactions was used, namely: a KFK-2-UHL 4.2 photometer and an SMT fluorescence microscope with a working current of 2.5 A. Thus, schemes for establishing reactions for determining the degree of freshness of snail meat were developed and tested: biochemical, photometric, and immunofluorescence methods. The stability of the indicators for determining the degree of freshness was established. It is analysed that the data presented relate only to the research on snail meat. Utility model patents have been granted for each method. The proposed methods for assessing the quality of snail meat are effective, technologically simple and fast, have high reliability of the results obtained and can be used in the work of research and experimental, production and regional laboratories of veterinary medicine

**Keywords:** gastropod, determination of freshness, biochemical method, photometric method, immunofluorescence reaction



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## INTRODUCTION

The quality of animal products is of great importance in Ukraine and globally. For the vast majority of Ukrainians, snails are an unusual delicacy, both due to the specifics of their consumption and their rather high price. The snail business in Ukraine is at the initial stage of development, thus, there is not enough scientific research on the consumer properties and safety of snails as a biologically valuable food product.

Babina *et al.* (2017), Down (2018) argue that meat quality control is one of the top priorities, as the quality of the products received by the consumer and their cost depends on the objectivity of freshness assessment. In addition, snail meat should be subjected to a freshness test (Kasianchuk & Bohatko, 2006). After analysing the publications of other foreign scientists Kehinde *et al.* (2020), та Kougiagka *et al.* (2022), it was established that there are no methods for determining the quality of snail meat. For rapid quality control of meat of different species of animals and poultry, there are conventional methods for determining the freshness of meat: pH, peroxidase reaction (benzidine test), copper sulfate reaction, hydrogen sulfide reaction, ammonia reaction, formalin reaction, ammonia and ammonium salts determination (Danilova & Hetmanets, 2018; Kasianchuk & Bohatko, 2003). These are standard methods for determining the freshness of animal meat. Notably, they are not designed and cannot be used specifically for snail meat.

Similar studies highlighted in the scientific publication by Ukrainian scientists Yatsenko *et al.* 2020 are significant but only concern the determination of the degree of freshness of snail meat by the content of ammonia and ammonium salts with the Nessler reagent but since the reaction is visual, it can be subject to error. In addition, there is a method for determining the degree of freshness of snail meat by reacting with copper sulfate, for which the authors later received a similar patent. The authors of this patent use a different concentration of meat and water extract for research and take snail meat at different periods after anabiosis (Zabarna & Bohatko, 2019).

It is difficult to give an unambiguous definition of the quality of fresh meat, as each consumer will describe it differently based on their preferences, which will vary depending on the perception of the product's appearance, odour, and flavour (Purslow, 2017; Karabasil *et al.*, 2019). In this case, it is necessary to use more precise research methods. The quality of fresh meat determines its usefulness for the consumer and its suitability for cooking (Przybylski & Hopkins, 2016). Since Ukrainian farmers export snails and their meat, it is essential to determine the degree of freshness on time.

Meat quality assessment is a kind of art, in which technological and methodological skills, instrumentation and laboratory equipment, professional experience

and aptitude for tasting play an important role (Raudienė *et al.*, 2018). According to the freshness indicators, meat is divided into fresh, questionable freshness and stale. The quality can be assessed by organoleptic methods (appearance, flavour, odour, colour, consistency, and in some cases juiciness), sensory highly instrumental methods (colour, odour), histological (microstructural) methods (Peshuk, 2018; Umer *et al.*, 2021). Determination of organoleptic indicators does not give a complete picture of the quality and safety of meat, it is necessary to conduct additional laboratory tests, such as physico-chemical, microbiological etc (Bohatko *et al.*, 2015; Liu *et al.*, 2018).

The issue of meat quality was explored by Kasianchuk & Bohatko (2006), who developed a way to improve the biochemical method for determining beef from diseased animals. In addition, these authors developed a method for determining the degree of freshness of beef and pork and received a utility model patent for it (Kasianchuk & Bohatko, 2003). There is a method for determining the degree of freshness of poultry meat using the photometric method, authored by Bohatko *et al.* (2015). But all these methods are not suitable for determining the quality of snail meat.

Shellfish meat is a product that is not resistant to long-term storage. According to Ng *et al.* (2013), it is explained by: the loose structure of muscle tissue, low amount of glycogen in the muscles, high water content, which serves as a favourable environment for the development of microorganisms, and the ability of snail microflora to develop at low positive temperatures (0... + 5°C). But its quality depends on storage conditions (Batyrbekov & Zhumabaev, 2017). Most snail meat is frozen. Therewith, unfavourable conditions are established for the development of microorganisms, and the rate of biochemical processes under the influence of enzymes is sharply reduced (Damez & Clerjon, 2008; Soren & Biswas, 2020). However, note that the meat can be frozen for a very long time, compliance with the requirements for freezing shellfish meat or during transportation, and there are no temperature requirements (Saryglar, 2020).

The purpose of this work is to identify the quality of snail meat by developing methods for determining the degree of freshness.

## MATERIALS AND METHODS

The work was performed during 2018-2019 at the Department of Chemistry and Biochemistry of the Kharkiv State Zooveterinary Academy. Three methods for determining the quality of snail meat were developed: a method for determining the degree of freshness of snail meat by the biochemical method; a method for determining the degree of freshness of snail meat by the photometric method; and a method for determining

the degree of freshness of edible snail meat by immunofluorescence. Utility model patents have been obtained for each of the methods: No. 134319 (Danilova, 2019), No. 128984 (Danilova & Hetmanets, 2018), and No. 136331 (Danilova & Hetmanets, 2019), respectively. These methods are individual both in their design and in the results obtained. Therefore, performers, or the laboratory in general, have the opportunity to choose the most convenient and affordable option for themselves. In a series of experiments, meat from 150 snails of the *Helix pomatia* species was used.

**Research on determining the degree of freshness of snail meat by the biochemical method.** More than 60 snails were selected and the meat was extracted (8 to 17 g per snail). The meat samples were divided into 2 groups of 30 samples each. In terms of shelf life, these groups corresponded to two categories: 1) fresh meat; 2) stale meat. Next, meat samples of different concentrations were prepared, with dilutions of 1:10, 1:15, 1:20, 1:25, and 1:30. In conical flasks, 20.0, 25.0, 30.0, 35.0, and 40.0 g of chopped snail meat were separately placed and 200.0, 300.0, 400.0, 500.0, and 600.0 cm<sup>3</sup> of distilled water were added, respectively. The contents of the flasks were stirred, closed with a watch glass, and placed in a boiling water bath for 10 minutes. The contents of the flasks were then filtered through a layer of cotton wool. If the resulting broth was cloudy and protein flakes remained in it after filtering, the broth was filtered through filter paper. The filtrate from each flask was poured into test tubes of 2.0 cm<sup>3</sup> each. A copper sulfate solution of different concentrations was prepared in parallel: 1.0%, 1.5%, 2.0%, 2.5%, and 3.0%. For this, 1.0, 1.5, 2.0, 2.5, and 3.0 g of copper sulfate were weighed, and 100.0 cm<sup>3</sup> of distilled water was added to each sample. Subsequently, 3 drops of copper solution at 1.0%, 1.5%, 2.0%, 2.5%, and 3.0% concentrations were added to the tubes of each dilution of the filtrate. Distilled water was used as a control. For this purpose, to 2.0 cm<sup>3</sup> of water, 3 drops of CuSO<sub>4</sub> of different concentrations were added. The tubes were shaken 3 times and placed on a rack. The reaction was recorded visually after 5 minutes by changing the colour and consistency of the broth (Danilova, 2019).

**Method for determining the degree of freshness of snail meat by the photometric method.** It was selected 45 snails of the species *Helix pomatia*, from which meat was removed (from 8 to 11 g each). The meat samples were divided into 3 groups of 15 samples each. In terms of shelf life, these groups corresponded to three categories: 1) fresh meat; 2) stale; 3) questionable. Next, the meat samples were chopped with scissors and 2.0 g of each was taken (15 samples for each group). To 5 weights of each group were added 10.0, 20.0, 30.0, 40.0, and 50.0 cm<sup>3</sup> of distilled water, respectively (3 series

of 5 weights in total) and infused for 15 minutes, filtered, and 0.5 cm<sup>3</sup> of Nessler's reagent was added to 3.0 cm<sup>3</sup> of filtrate. Then, the optical density of the colour intensity of the supernatant for each sample was immediately measured using a KFK-2-UHL 4.2 photoelectric photometer in a cuvette with an absorbing light thickness of 1.0 cm at wavelengths of 400, 440, 490, and 540 nm. Distilled water was used as a control (Danilova & Hetmanets, 2018).

**Development of a method for determining the degree of freshness of edible snail meat by immunofluorescence.**

More than 45 snails were selected and the meat was extracted (8 to 11 g per snail). The meat samples were divided into 3 groups of 15 samples each. In terms of shelf life, these groups corresponded to three categories: 1) fresh meat; 2) stale meat; 3) meat of questionable freshness. From the surface of the cut of each meat sample, smears were placed on a slide. The smears were dried at room temperature. Then they were fixed in chilled chemically pure acetone for 30 minutes at -18°C by complete immersion. Next, the smears were removed, air-dried at room temperature, and transferred to a humid chamber, where they were stained with a working solution of acridine orange dye (dilution 1:10,000) in a dark place for 20 minutes at room temperature. The dye is a catalyst for the immunofluorescence reaction. Subsequently, the smears were washed with distilled water 3 times. They were air-dried and examined in an SMT fluorescence microscope with a working current of 2.5 A (40×10 magnification) (Danilova & Hetmanets, 2019). The image of each sample was displayed on a computer monitor and further analysed using "Adobe Photoshop 7.0" software. For this, the image size was set to a constant 1777×1333=2368741 pixels (according to the dimensions of the monitor screen). The "Histogram" command was used to check the presence and corresponding total size of green spots X (in pixels) in the image (Baranovsky *et al.*, 2017).

All experimental studies were conducted according to modern methodological approaches and in compliance with the relevant requirements and standards, in particular, they correspond to the requirements of DSTU ISO/IEC 17025:2005 (2006). The animals were kept and all manipulations were performed according to the provisions of the Procedure for conducting experiments and experiments on animals by scientific institutions (Law of Ukraine No. 249, 2012), the European Convention for the Protection of Vertebrate Animals Used for Experimental and Other Scientific Purposes (European convention..., 1986).

## RESULTS AND DISCUSSION

**Method for determining the degree of freshness of snail meat by biochemical method.** The results of this method are presented in Tables 1 and 2.

**Table 1.** Reaction of copper with sulfate of fresh snail meat

Diluting broth	CuSO <sub>4</sub> concentration, %				
	1.0	1.5	2.0	2.5	3.0
1:10	The broth is clear, brown in colour		The broth is blue-brown in colour, with brown flakes		
1:15	Transparent brown liquid		Transparent blue-brown liquid		
1:20	Transparent brown liquid		Transparent blue-brown liquid		
1:25	Transparent brown liquid		Transparent blue-brown liquid		
1:30	Transparent brown liquid		Transparent blue-brown liquid		
Distilled water	Transparent liquid with a subtle blue tint on a contrasting background				

**Source:** developed by authors

**Table 2.** Reaction of copper with sulfate of stale snail meat

Diluting broth	CuSO <sub>4</sub> concentration, %				
	1.0	1.5	2.0	2.5	3.0
1:10	The broth is clear, brown in colour		The broth is blue-brown in colour, with brown flakes		The broth is blue-brown in colour, significantly cloudy, with brown flakes
1:15	Transparent brown liquid	Transparent blue-brown liquid	Blue-brown broth, barely noticeable brown flakes, traces of jelly generation	Blue-brown broth, barely noticeable brown flakes, traces of jelly generation	
1:20	Transparent brown liquid	Transparent blue-brown liquid	Transparent liquid of blue-brown colour, with brown flakes, traces of jelly generation	Transparent liquid of blue-brown colour, with brown flakes with jelly generation	
1:25	Transparent liquid of blue-brown colour, with barely noticeable brown flakes				Transparent liquid of blue-brown colour, with barely noticeable brown flakes, traces of jelly generation
1:30	Transparent liquid of blue-brown colour, with barely noticeable brown flakes				Transparent liquid of blue-brown colour, with barely noticeable brown flakes, traces of jelly generation
Distilled water	Transparent liquid with a subtle blue tint on a contrasting background				

**Source:** developed by authors

Thus, analysing the data for determining the freshness of snail meat in the reaction of copper with sulfate, which is presented in Tables 1 and 2, it can be concluded that the authors' data are consistent with the study of a 1:15 meat-water extract and CuSO<sub>4</sub> concentrations of 2.5% or 3.0%. Thus, to determine the degree of freshness of snail meat in the reaction of copper with sulfate, it is necessary to use a meat-water extract at a dilution of 1:15 and a CuSO<sub>4</sub> concentration of 2.5% or 3.0%.

**Research results in the development of a method for determining the degree of freshness of snail meat by the photometric method.** The results obtained during the development of this method are presented in Table 3 in the form  $M \pm m$ , where  $M$  – the average optical density for the group,  $m$  – the error of the average.

For clarity, the average values are presented in Figure 1.

**Table 3.** Colour intensity optical density values of the supernatant by groups

Groups	Wave length, nm			
	400	440	490	540
1	2	3	4	5
Fresh meat				
1. (1:10 + 0.5 cm <sup>3</sup> Nessler's reagent)	1.28 ± 0.11	0.26 ± 0.03	0.30 ± 0.03	0.42 ± 0.05
2. (1:15 + 0.5 cm <sup>3</sup> Nessler's reagent)	0.65 ± 0.06	0.46 ± 0.03	0.42 ± 0.04	0.12 ± 0.02

Table 3, Continued

	1	2	3	4	5
3. (1:20 + 0.5 cm <sup>3</sup> Nessler's reagent)		0.52 ± 0.07	0.53 ± 0.06	0.54 ± 0.08	0.10 ± 0.02
4. (1:25 + 0.5 cm <sup>3</sup> Nessler's reagent)		0.52 ± 0.06	0.27 ± 0.03	0.15 ± 0.02	0.06 ± 0.01
5. (1:30 + 0.5 cm <sup>3</sup> Nessler's reagent)		0.45 ± 0.06	0.25 ± 0.03	0.12 ± 0.02	0.05 ± 0.01
Stale meat					
1. (1:10 + 0.5 cm <sup>3</sup> Nessler's reagent)		1.38 ± 0.06	1.24 ± 0.03	1.80 ± 0.05	1.46 ± 0.07
2. (1:15 + 0.5 cm <sup>3</sup> Nessler's reagent)		1.80 ± 0.07	1.37 ± 0.06	1.91 ± 0.05	1.40 ± 0.06
3. (1:20 + 0.5 cm <sup>3</sup> Nessler's reagent)		1.10 ± 0.03	1.46 ± 0.02	2.10 ± 0.04	0.95 ± 0.05
4. (1:25 + 0.5 cm <sup>3</sup> Nessler's reagent)		0.68 ± 0.07	0.36 ± 0.03	0.29 ± 0.03	0.10 ± 0.02
5. (1:30 + 0.5 cm <sup>3</sup> Nessler's reagent)		0.95 ± 0.08	0.56 ± 0.06	0.26 ± 0.03	0.55 ± 0.05
Questionable meat					
1. (1:10 + 0.5 cm <sup>3</sup> Nessler's reagent)		0.69 ± 0.08	0.80 ± 0.05	0.85 ± 0.05	0.84 ± 0.10
2. (1:15 + 0.5 cm <sup>3</sup> Nessler's reagent)		0.93 ± 0.07	0.83 ± 0.04	1.58 ± 0.04	0.97 ± 0.07
3. (1:20 + 0.5 cm <sup>3</sup> Nessler's reagent)		1.18 ± 0.08	1.17 ± 0.03	1.63 ± 0.05	1.35 ± 0.09
4. (1:25 + 0.5 cm <sup>3</sup> Nessler's reagent)		1.00 ± 0.07	0.99 ± 0.07	0.86 ± 0.06	0.69 ± 0.06
5. (1:30 + 0.5 cm <sup>3</sup> Nessler's reagent)		0.71 ± 0.07	0.78 ± 0.08	0.59 ± 0.06	0.93 ± 0.09

Source: developed by authors

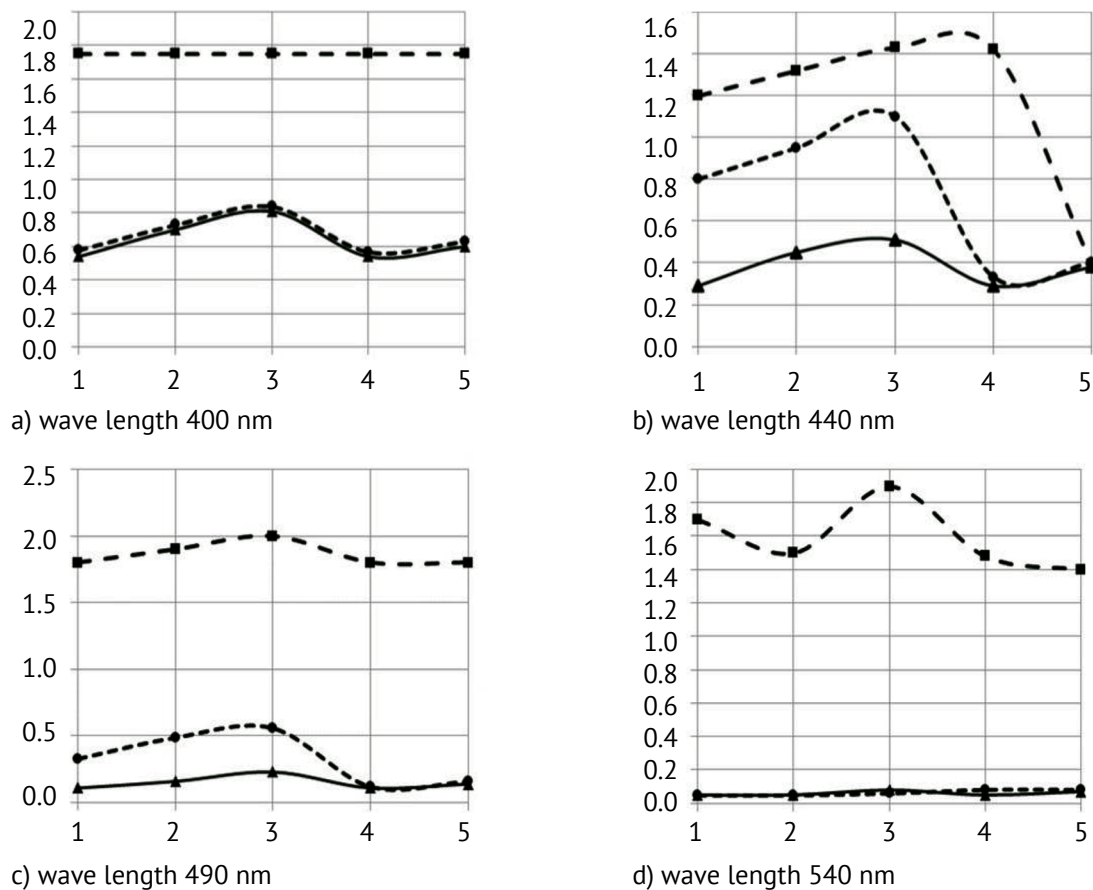


Figure 1. Dependence of the average values of the optical density of the colour intensity of the additive fluid on the group number

Note: 1 – 1 : 10 + 0.5 cm<sup>3</sup> of Nessler's reagent; 2 – 1 : 15 + 0.5 cm<sup>3</sup> of Nessler's reagent; 3 – 1 : 20 + 0.5 cm<sup>3</sup> of Nessler's reagent; 4 – 1 : 25 + 0.5 cm<sup>3</sup> of Nessler's reagent; 5 – 1 : 30 + 0.5 cm<sup>3</sup> of Nessler's reagent. Fresh meat – —▲—, questionable meat – —●—, stale meat – —■—

Source: developed by authors

The data in Table 3 and Figure 1 demonstrate that the highest reliability of the difference between fresh, stale and questionable snail meat is obtained by photometry at 440 and 490 nm and using a meat-water extract in ratios of 1 : 10, 1 : 15 or 1 : 20 with the addition of 0.5 cm<sup>3</sup> of Nessler's reagent. Low extract concentrations of 1 : 25 and 1 : 30 are generally uninformative in determining the degree of freshness of meat.

These conclusions can be summarised in Table 4, which presents the ranges of changes in the optical density

of colour intensity according to the degree of freshness of snail meat at 440 and 490 nm. The ranges were determined according to the "three sigmas" rule according to Table 3, i.e., about 99.9% of the experimental data fell into these ranges.

As can be seen from this Table, the ranges of optical density for different degrees of the freshness of meat do not overlap, thus, Table 4 can be specifically applied to the examination of snail meat to its degree of freshness.

**Table 4.** Indicators of optical density of colour intensity according to the degree of freshness of snail meat

Wave length, nm	The degree of freshness of meat		
	Fresh	Questionable freshness	Stale
	Dilution of meat and water extract 1 : 10		
440	0.10-0.42	0.54-1.06	1.08-1.40
490	0.12-0.48	0.53-1.07	1.44-1.98
Dilution of meat and water extract 1 : 15			
440	0.33-0.59	0.61-1.05	1.07-1.67
490	0.21-0.63	1.37-1.79	1.84-2.36
Dilution of meat and water extract 1 : 20			
440	0.24-0.82	0.95-1.31	1.35-1.57
490	0.15-0.93	1.41-1.85	1.91-2.29

**Source:** developed by authors

**Obtained data on the method of determining the degree of freshness of edible snail meat by immunofluorescence.** Conducted research to determine the

degree of freshness of edible snail meat by immunofluorescence. The results are presented in Table 5.

**Table 5.** Results of measuring the immunofluorescence of snail meat

No. of sample	Number of pixels, X	The ratio of the number of pixels X to the total number, %	Average value of M, pixels (percent)	Standard deviation $\sigma$ , pixels (percent)
1	2	3	4	5
Fresh meat				
1	0	0.000	285.7 (0.012%)	211.5 (0.009%)
2	82	0.003		
3	90	0.004		
4	102	0.004		
5	150	0.006		
6	161	0.007		
7	211	0.009		
8	252	0.011		
9	253	0.011		
10	303	0.013		
11	386	0.016		
12	435	0.018		
13	507	0.021		
14	645	0.027		
15	708	0.030		

Table 5, Continued

1	2	3	4	5
Meat of questionable freshness				
16	1091	0.040	1386.9 (0.058%)	165.6 (0.008%)
17	1133	0.048		
18	1178	0.050		
19	1221	0.052		
20	1301	0.055		
21	1378	0.058		
22	1402	0.059		
23	1414	0.060		
24	1457	0.062		
25	1492	0.063		
26	1502	0.063		
27	1511	0.064		
28	1545	0.065		
29	1567	0.066		
30	1611	0.068		
Stale meat				
31	4235	0.179	6270.8 (0.265%)	1272.2 (0.054%)
32	4649	0.196		
33	4917	0.208		
34	5132	0.217		
35	5572	0.235		
36	5821	0.246		
37	6008	0.254		
38	6140	0.259		
39	6307	0.266		
40	6614	0.279		
41	7031	0.297		
42	7391	0.312		
43	7756	0.327		
44	8124	0.343		
45	8365	0.353		

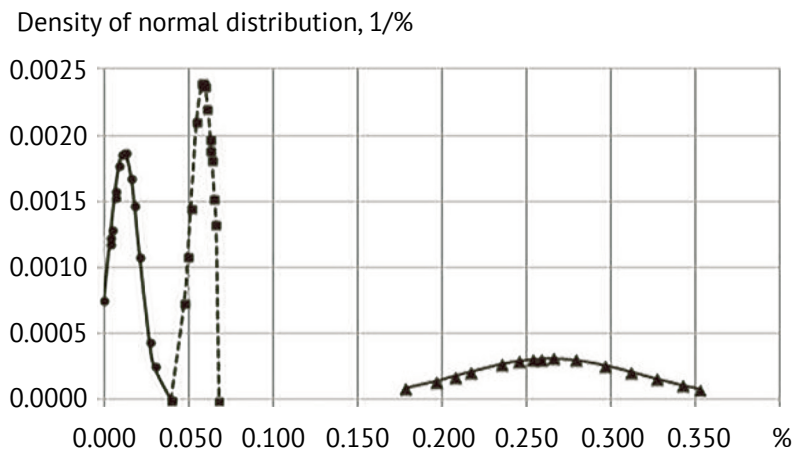
**Source:** developed by authors

In this Table, samples 1 through 15 deliberately corresponded to fresh meat; samples 16 through 30 to the meat of questionable freshness; and samples 31 through 45 to stale meat. Since the total number of pixels in each image was a large value of 2368741, Table 5 presents the absolute number of pixels for each sample, since the corresponding percentages to the total number are extremely small. Table 5 presents the mean values and standard deviations of the number of pixels

for each group of snails by the degree of freshness. The Figure 2 presents probability density plots of the normal distribution for each group of snails in Table 5 according to formula (1):

$$f(X) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{(X-M)^2}{2\sigma^2}} \quad (1)$$

which are compared with the results of observations (points on the graphs).



**Figure 2.** Graphs of the normal distribution of the percentage of green pixels from the total number of pixels in the image for each group of snails

**Note:** Fresh meat – —●—, questionable meat – —■—, stale meat – —▲—

Figure 2 demonstrates that the boundary between fresh meat and meat of questionable freshness is at the level of 1000 pixels (0.042%) of green colour, and if the number of pixels exceeds 2000 (0.084%), the meat is stale.

The authors have developed three methods for determining the quality of snail meat, which are simple and expressive, but believe that the photometric method is more acceptable. This method requires using inexpensive equipment that is available in almost all laboratories, while the researcher will get a reliable, fast result, and the Nessler reagent gives a clear colour intensity.

Ukrainian scientists have been exploring the degree of freshness of snail meat and have developed methods to the determination of the degree of freshness of snail meat by bacterioscopic method (Zabarna & Bohatko, 2019), photometric method (Zabarna & Bohatko, 2019), reaction with copper sulfate (Zabarna & Bohatko, 2019), and ammonia and ammonium salts (Zabarna & Bohatko, 2019). The similarity of these methods with the methods developed by the authors is that the studies were conducted on snails and used Nessler's reagent and copper sulfate solution. Differences include various concentrations of meat and water extracts and reagents and different reaction times. To ensure the accuracy of the results, the author offers to use special equipment, which will ultimately provide a smaller error.

In addition, these methods can be used to determine the degree of freshness, but each researcher should choose the simplest, accurate, and acceptable method for them. The authors Kasianchuk & Bohatko (2006) та Bohatko *et al.* (2015) determined the quality of meat but from other species. Researchers Onishchenko *et al.* (2006) have developed a method for the rapid diagnosis of blood-borne diseases of sheep using fluorescence microscopy, but it cannot be used to explore snail meat, as it involves fluorochromation of preparations, as a result of which the parasites themselves become a source of light and contrast against the dark background of the

preparation, and in this case, fluorochromation in preparations occurs due to meat spoilage. Thus, the less bright green colour in the microscope, the fresher the meat.

Similar studies are covered in scientific publications by foreign researchers – Sando *et al.* (2012), Kehinde *et al.* (2020), but they do not devote sufficient attention to the analysis of indicators responsible for the quality and safety of gastropod meat. Thus, considering the growth of snail consumption and exports in Ukraine, the issue of snail meat quality examination is very relevant, interesting and significant.

## CONCLUSIONS

Snail meat can be analysed by biochemical, photometric and immunofluorescence methods. The modes of performing each method have been developed. Thus, when using the biochemical method, it is necessary to obtain a meat and water extract at a dilution of 1 : 15 with a CuSO<sub>4</sub> concentration of 2.5% or 3.0%. When testing with this method, the extract from fresh meat is transparent blue-brown in colour, and from stale meat, the broth turns blue-green in colour with jelly generation. Determination of the degree of freshness of meat with the Nessler's reagent is possible by examining the meat-water extract in dilutions of 1 : 10, 1 : 15 and 1 : 20 on the KFK-2-UFL 4.2 at a wavelength of 440 nm or 490 nm. Thus, the author found that with a dilution of the meat-water extract of 1:15 and a wavelength of 440 nm, the degree of freshness can be determined. If the indicator is from 0.33 to 0.59 nm, the meat is considered fresh, with indicators of 0.61 to 1.05 nm – of questionable freshness, and from 1.07 to 1.67 nm – stale. It was established that it is possible to determine the quality of snail meat by immunofluorescence. If the indicator is 1000 pixels, the meat is considered fresh, and if it is more than 2000 pixels, it is stale. As a prospect for further research, it is considered advisable to determine what factors affect the freshness of snail meat.

## REFERENCES

- [1] Babina, M.P., Koshnerov, A.G., & Balega, A.A. (2017). *Determination of freshness and good quality of meat and fish*. Vitebsk: Vitebsk State Academy of Veterinary Medicine.
- [2] Baranovsky, D.I., Hetmanets, O.M., & Khokhlov, A.M. (2017). *Biometrics in the MS Excel software environment*. Kharkiv: SPD FO Brovin O.V.
- [3] Batyrbekov, A.N., & Zhumabaev, A.K. (2017). *Veterinary and sanitary examination of poultry products, fish farming, beekeeping and plant growing*. Kostanay: KSU.
- [4] Biswas, A.K., & Mandal, P. (2020). *Meat quality analysis advanced evaluation methods, techniques, and technologies*. London: Academic Press. doi: 10.1016/C2018-0-01364-X.
- [5] Bohatko, N.M., Bukalova, N.V., Prylipko, T.M., & Bohatko, D.L. (2015). Method for determining the degree of freshness of poultry meat by photometric method (Patent of Ukraine No. 97932). Ministry of Education and Science of Ukraine. Retrieved from <https://uapatents.com/5-97932-sposib-viznachennya-stupenya-svizhosti-myasa-ptici-fotometrichnim-metodom.html>.
- [6] Damez, J.-L., & Clerjon, S. (2008). Meat quality assessment using biophysical methods related to meat structure. *Meat Science*, 80, 132-149. doi: 10.1016/j.meatsci.2008.05.039.
- [7] Danilova, I.S. (2019). Method of determining the degree of freshness of snail meat by biochemical method (Patent of Ukraine No. 134319). Ministry of Economic Development and Trade of Ukraine. Retrieved from <https://sis.ukrpatent.org/uk/search/detail/1355148/>.
- [8] Danilova, I.S., & Hetmanets, O.M. (2018). Method of determining the degree of freshness of snail meat by the photometric method (Patent of Ukraine No. 128984). Ministry of Economic Development and Trade of Ukraine. Retrieved from <https://sis.ukrpatent.org/uk/search/detail/237538/>.
- [9] Danilova, I.S., & Hetmanets, O.M. (2019). Method of determining the degree of freshness of the meat of edible snails by the method immunofluorescences (Patent of Ukraine No. 136331). Ministry of Economic Development and Trade of Ukraine. Retrieved from <https://sis.ukrpatent.org/uk/search/detail/1373172/>.
- [10] Down, A. (2018). Slithering to a big market: Ukraine's snail trade. *Ukrainian Business Journal: Agriculture Opportunity Reports*, 2, 58-60.
- [11] European Convention for the Protection of Vertebrate Animals Used for Experimental and Other Scientific purposes. (1986). Retrieved from <https://rm.coe.int/168007a67b>.
- [12] ISO/IEC 17025:2005. (2006). Retrieved from [http://online.budstandart.com/ua/catalog/doc-page.html?id\\_doc=50873](http://online.budstandart.com/ua/catalog/doc-page.html?id_doc=50873).
- [13] Karabasil, N., Boskovic, T., Vicic, I., Cobanović, N., Dimitrijevic, M., & Teodorovic, V. (2019). Meat quality: Impact of various pre-slaughter conditions. *IOP Conference Series: Earth and Environmental Science*, 333, article number 012033. doi: 10.1088/1755-1315/333/1/012033.
- [14] Kasianchuk, V.V., & Bohatko, N.M. (2003). Method for determining degree of freshness of beef and pork meat (Patent of Ukraine No. 59032). Ministry of Education and Science of Ukraine. Retrieved from <https://uapatents.com/3-59032-sposib-viznachennya-stupenya-svizhosti-yalovichini-ta-svinini.html>.
- [15] Kasianchuk, V.V., & Bohatko, N.M. (2006). Method of improvement of biochemical method of determination of beef obtained from sick animals (Patent of Ukraine No. 12206). Ministry of Education and Science of Ukraine. Retrieved from <https://uapatents.com/2-12206-sposib-vdoskonalennya-biokhimichnogo-metodu-viznachennya-yalovichini-otrimano-vid-khvorikh-tvarin.html>.
- [16] Kehinde, A.S., Adelakun, K.M., Halidu, S.K., Babatunde, T.O., & Fadimu, B.O. (2020). Biochemical evaluation of meat and haemolymph of African land snail (archachatinamarginata, swainson) in south-west Nigeria. *Egyptian Journal of Animal Production*, 57(3), 121-126. doi: 10.21608/EJAP.2020.121422.
- [17] Kougiagka, E., Apostologamvrou, C., Giannouli, P., & Hatzioannou, M. (2022). Quality factors of commercial snail fillets as affected by species. *Food Technology and Biotechnology*, 60(3), 330-337. doi: 10.17113/ftb.60.03.22.7403.
- [18] Law of Ukraine No. 249 "On the Procedure for Carrying out Experiments and Experiments on Animals by Scientific Institutions". (2012, March). Retrieved from <https://zakon.rada.gov.ua/laws/show/z0416-12#Text>.
- [19] Liu, M., Wei, Y., Li, X., Quek, S.Y., Zhao, J., Zhong, H., Zhang, D., & Liu, Y. (2018). Quantitative phosphoproteomic analysis of caprine muscle with high and low meat quality. *Meat Science*, 141, 103-111. doi: 10.1016/j.meatsci.2018.01.001.
- [20] Ng, T.P., Saltin, S.H., Davies, M.S., Johannesson, K., Stafford, R., & Williams, G.A. (2013). Snails and their trails: The multiple functions of trail-following in gastropods. *Biological reviews of the Cambridge Philosophical Society*, 88(3), 683-700. doi: 10.1111/brv.12023.
- [21] Onishchenko, N.G., Volkolupova, V.A., Pasunkina, M.O., & Pinchuk, V.A. (2006). Method of express diagnostics of blood-parasitic diseases of sheets using luminent microscopy (Patent of Ukraine No. 15429). Ministry of Education and Science of Ukraine. Retrieved from <https://iprop-ua.com/inv/pdf/z7w6hc00-pub-description.pdf>.
- [22] Peshuk, L.V. (2018). *Fundamentals of animal husbandry and veterinary examination of meat and meat products*. Kyiv: Center for Educational Literature.
- [23] Przybylski, W., & Hopkins, D. (2016). *Meat quality genetic and environmental factors*. CRC Press Taylor & Francis Group.
- [24] Purslow, P.P. (2017). *New aspects of meat quality: From genes to ethics*. Argentina: Woodhead Publishing. doi: 10.1016/B978-0-08-100593-4.00001-1.

- [25] Raudienė, E., Gailius, D., Vinauskienė, R., Eisinaitė, V., Balčiūnas, G., Dobilienė, J., & Tamkutė, L. (2018). Rapid evaluation of fresh chicken meat quality by electronic nose. *Czech Journal of Food Sciences*, 36(5), 420-426. doi: 10.17221/419/2017-CJFS.
- [26] Sando, D., Grujić, R., Meho, B., Lisickov, K., & Vujadinović, D. (2012). Quality indicators of snail meat grown in different conditions. *Quality of Life*, 3(3-4), 55-64. doi: 10.7251/QOL1203055S.
- [27] Saryglar, L.K. (2020). *Veterinary and sanitary examination of meat and meat products in infectious diseases*. Kyzyl: Tuva State University.
- [28] Soren, N.M., & Biswas, A.K. (2020). Methods for nutritional quality analysis of meat. In A.K. Biswas, P.K. Mandal (Eds.), *Meat quality analysis: Advanced evaluation methods, techniques, and technologies* (pp. 21-36). Cambridge: Academic Press. doi: 10.1016/B978-0-12-819233-7.00002-1.
- [29] Umer, S.G., Munera, A.U., Yesihak, Y.M., & Abdulmuen, M.I. (2021). Quality of cattle meat and its compositional constituents. *Veterinary Medicine International*, 2021, article number 7340495. doi: 10.1155/2021/7340495.
- [30] Xing, T., Gao, F., Tume, R.K., Zhou, G., & Xu, X. (2019). Stress effects on meat quality: A mechanistic perspective. *Comprehensive Reviews in Food Science and Food Safety*, 18(2), 380-401. doi: 10.1111/1541-4337.12417.
- [31] Yatsenko, I.V., Zabarna, I.V., Bohatko, N.M., Rodionova, K.O., & Palii, A.P. (2020). *Determining the degree of freshness of snail meat by the content of ammonia and ammonium salts with Nessler's reagent*. 4<sup>th</sup> International Scientific and Practical Conference – Modern Science: Problems and Innovations (pp. 32-41). SSPG Publish: Stockholm.
- [32] Zabarna, I.V., & Bohatko, N.M. (2019). Method for determining the degree of freshness of snail meat by the content of ammonia and ammonium salts (Patent of Ukraine No. 135107). Ministry of Economic Development and Trade of Ukraine. Retrieved from <https://sis.ukrpatent.org/uk/search/detail/1364703/>.
- [33] Zabarna, I.V., & Bohatko, N.M. (2019). Method of determining the degree of freshness of snail meat using the bacterioscopic method (Patent of Ukraine No. 135100). Ministry of Economic Development and Trade of Ukraine. Retrieved from <https://sis.ukrpatent.org/uk/search/detail/1364495/>.
- [34] Zabarna, I.V., & Bohatko, N.M. (2019). Method of determining the freshness of snail meat reacts with copper sulfate (Patent of Ukraine No. 135102). Ministry of Economic Development and Trade of Ukraine. Retrieved from <https://sis.ukrpatent.org/uk/search/detail/1364594/>.
- [35] Zabarna, I.V., & Bohatko, N.M. (2019). Method of determining the degree of freshness of snail meat using the photometric method (Patent of Ukraine No. 135106). Ministry of Economic Development and Trade of Ukraine. Retrieved from <https://sis.ukrpatent.org/uk/search/detail/1364702/>.

## Розробка методів оцінки якості м'яса равликів

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**Анотація.** М'ясо їстівних равликів вважається делікатесом і становить частину українського експорту харчових продуктів, але нормативні та законодавчі документи щодо його якості відсутні. Метою цієї роботи було розробити способи визначення ступеня свіжості м'яса равликів за вмістом аміаку та солей амонію з реактивом Неслера, пероксидази в м'ясі з розчином міді сульфату та обробки мазка-відбитка з м'яса флуоресцентним барвником і за кількістю пікселів зеленого кольору встановити якість м'яса. В ході досліджень, у першу чергу, визначали органолептичні показники м'яса молюсків, які відображають їх свіжість. Далі виконували дослідження щодо визначення ферментів та аміаку, які утворюються у процесі зберігання м'яса. При цьому були використані наступні реактиви: розчин міді сульфату, реактив Неслера та флуоресцентний барвник – акридиновий помаранчевий. При постановці даних реакцій також було використано і обладнання, а саме: фотометр фотоелектричний КФК-2-УХЛ 4,2 та люмінесцентний мікроскоп SMT з подачею робочого струму 2,5 А. Таким чином були розроблені та відпрацьовані схеми постановки реакцій щодо визначення ступеня свіжості м'яса равликів: біохімічний, фотометричний та метод імунофлюоресценції. Була визначена стабільність показників визначення ступеня свіжості. Проаналізовано, що наведені дані стосуються лише дослідження м'яса равликів. На кожен метод було отримано патенти на корисну модель. Запропоновані способи оцінки якості м'яса равликів є ефективними, технологічно нескладними та швидкими, мають високу достовірність отриманих результатів і можуть бути використані в роботі науково-експериментальних, виробничих та регіональних лабораторіях ветеринарної медицини

**Ключові слова:** брюхоногий молюск, визначення свіжості, біохімічний метод, фотометричний метод, реакція імунофлюоресценції



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## The effect of complex application of symbiotic and biocidal preparations on the metabolic status of broiler chickens' blood

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**Abstract.** Using probiotic preparations and their complexes in poultry farming is an important step towards increasing poultry resistance and productivity, and thus producing environmentally friendly products. The purpose of the study was to investigate the effect of the complex action of symbiotic drugs and biocidal agents by investigating the clinical and biochemical parameters of blood and mineral metabolism in the body of broiler chickens under the conditions of their use according to the developed scheme. Hematologic, biochemical and immunologic blood parameters were explored by conventional methods, micro- and macroelements by optical emission spectrometry with inductively coupled plasma. Using the proposed complex of symbiotic and biocidal agents in the technology of rearing broiler chickens activates the processes of erythropoiesis, haemoglobin production, restoration of protein metabolism and normalisation of mineral status within physiological limits, which indicates the strengthening of the body's defences, increased resistance to stress factors and adverse environmental conditions, and will further have a positive effect on the growth and productivity of the target bird. The pronounced effect of the complex combination of drugs on the body of broiler chickens of experimental B is a better assimilation of many inorganic elements (by increasing the content of Calcium, Phosphorus, Cuprum, Ferrum and Selenium, Magnesium, Manganum); and, accordingly, causes the sustainable development of metabolic processes due to the prevalence of anabolic over catabolic processes (by increasing the level of total proteins against the background of a physiological increase in the number of globulin fractions; including the induction of the endogenous detoxification system – by reducing the level of production of toxic metabolites of purine metabolism: uric acid and creatinine; reduction of Chromium content; normalisation of transamination processes and deceleration of alkaline phosphatase activity) and immunobiological reactions (by enhancing erythropoiesis and haemoglobin production; induction of lysozyme, bactericidal and phagocytic activity), respectively. The proposed system of rearing young poultry using a complex of symbiotic preparations in combination with biocidal agents promotes the synergistic effect of the latter and their effective action on the body of experimental broiler chickens, which increases nonspecific resistance and restores metabolic reactions

**Keywords:** haematological parameters, biochemical parameters, mineral metabolism, natural resistance, probiotics, disinfectants



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## INTRODUCTION

In veterinary practice, scientists propose a large number of approaches to the integrated use of drugs to increase poultry resistance and productivity, using various regimens, including antibiotics. Despite the legal ban on using antibiotics for prophylactic purposes and as growth stimulants, most researchers document their widespread use (Stoyanovskyi *et al.*, 2012; Osimani & Clementi, 2016; Romanyuk *et al.*, 2019), but the issue of their quality and safe use is still relevant.

Thus, several researchers H. El-Adawy *et al.* (2015), T.N. Nguyen *et al.* (2016) and A.A. Moawad *et al.* (2018) have proven that uncontrolled use of antibiotics, sulfonamides, coccidiostatics and numerous vaccinations results in the emergence of antibiotic resistance, immunodeficiency and poultry death. To prevent microorganisms from gaining resistance, probiotics with a different spectrum of lactobacilli and other beneficial microorganisms in their composition have recently been used to decelerate the effects of stress and increase weight gain, bringing the physiological state of the poultry body back to normal. In works (Byrd *et al.*, 2001; Babenko *et al.*, 2014; Arena *et al.*, 2017), the mechanisms of action of probiotics based on representatives of normal commensal microflora (lacto- and bifidobacteria), their antibacterial and immunomodulatory properties, and antagonistic effects against infectious agents were explored. Other researchers (Adil *et al.*, 2010; El Kady *et al.*, 2012; Babenko *et al.*, 2014) have demonstrated that the most cost-effective is using complexes of symbiotic preparations, which, due to the synergistic effect of all components, have immunomodulatory and antioxidant properties, contribute to the strengthening of nonspecific immunity, which together improves digestion, improves feed conversion, increases safety and weight gain and contributes to a better implementation of the productive potential of poultry.

Thomas, (2020), Stefańska *et al.*, (2021), Lytvynenko *et al.*, (2022) noted that effective drugs with universal properties and high-quality standards are required to protect animals from infectious diseases. Modern disinfectants should ensure the proper state of veterinary and sanitary welfare and reliable protection against infections, thus, they are one of the elements in the prevention of infectious diseases of productive animals and poultry in the technological process of their cultivation. Thus, previous studies by the authors (Chechet *et al.*, 2021; Chechet *et al.*, 2022; Kovalenko *et al.*, 2022) and several other scientists (Melnyk, 2017; Demchyshyn *et al.*, 2018) in *in vitro* and *in vivo* experiments have established the effectiveness and safety of biocides based on organic acids, peroxide compounds, chlorine dioxide, etc. As described by J. Bailly *et al.* (2017), "Biozapin", based on a mixture of cultures of probiotic bacteria *Bacillus subtilis* and *Bacillus amyloliquefaciens* and aluminosilicate for surface treatment, has a prolonged effect due to the gradual adsorption of ammonia and

urea in poultry housing. Studies by J. Bailly *et al.* (2017), O.M. Chechet *et al.* (2022) and V.L. Kovalenko *et al.* (2022) have demonstrated that the disinfectants "Diolaid" and "Biolaid" have an active antimicrobial effect against gram-positive and gram-negative bacteria, fungicidal properties, virulent effect and prevent resistance of microorganisms to the drug. V.L. Kovalenko *et al.* (2022) discusses using safe biocides in the presence of productive poultry and adding them to the water supply system, and proposes to combine the integrated use of symbiotic and disinfectants.

Thus, in the context of the intensification of the poultry industry, the health of productive poultry can be maintained by using complexes of safe probiotics, biocides and nutraceuticals, which will optimise metabolic processes in the body and increase natural resistance, effectively preventing the development of infectious diseases.

Thus, the purpose of the study was to explore the effect of a complex of symbiotic preparations in combination with biocidal agents on the dynamics of clinical and biochemical parameters and features of mineral metabolism in the body of broiler chickens in the technological scheme of rearing broiler poultry.

## MATERIALS AND METHODS

A system of rearing young broiler chickens with the oral use of the symbiotic preparation "Biomagn" with the probiotic "Biozapin" (by spraying in the air) in combination with the biocidal agents "Diolide" (with the addition of water supply) and "Biolide" (disinfection of the room in the presence of poultry) is proposed. "Biomagn" contains a mixture of probiotic bacteria *Bacillus subtilis*, *Bacillus licheniformis*, *Enterococcus faecium* and lyophilized fermentation products of microorganisms *Lactococcus Lactis*, *Bacillus subtilis* and *Bacillus licheniformis*. In addition, "Biomagn" contains aluminosilicates, which effectively absorb mycotoxins from fodder and bacterial toxins, and suppress mutagenic microflora; betaine, which has a hepatoprotective effect, helps to reduce fats in hepatocytes, neutralises toxic elements and their compounds; silymarin, which has antioxidant properties, stimulates the synthesis of proteins and phospholipids in the affected liver cells; mannan oligosaccharides – exhibit probiotic properties and contribute to the normalisation of intestinal microflora by binding mannose residues to the receptors of pathogenic bacteria, respectively.

The experiment was performed in the vivarium of the State Research Institute of Laboratory Diagnostics and Veterinary and Sanitary Expertise ("SRILDVSE", Kyiv). According to the principle of analogues, 2 experimental (A; B) and one control (n = 21) were established from broiler chickens of the COBB-500 cross in the amount of 63 heads, 5 days old. The birds were fed complete fodder "Starter" (first 14 days) and "Grover" until the end

of the experiment. Birds of experimental A and B were fed fodder with the addition of the symbiotic preparation "Biomagn" from the first to the 7<sup>th</sup> and from the 22<sup>nd</sup> to the 27<sup>th</sup> day of rearing at a rate of 0.5 mg per kg of fodder, respectively.

Therewith, chickens of experimental B were given a solution of the biocidal preparation "Diolaid" (based on chlorine dioxide) 1.0 mg/l (by chlorine dioxide) with water throughout the experiment, which

corresponds to a concentration of 0.0004% (Table 1). Disinfection in the experimental B poultry houses was performed with "Biolaid" biocidal preparation 0.2% (based on hydrogen peroxide, supralactic acid, and lactic acid) with an exposure time of 60 minutes. The technological rearing scheme included the probiotic preparation "Biozapin", which was used once every 2 weeks after disinfection and sprayed evenly in the poultry house at a rate of 10-30 g/m<sup>2</sup>.

**Table 1.** Scheme of application of symbiotic with probiotic and in combination with biocidal preparations in experiments on broiler chickens

Drugs/concentration	experimental A (probiotics) (n = 21)	experimental B (probiotics + + biocides) (n = 21)	Control (n = 21)
1	2	3	4
"Biomagn"	1-7 <sup>th</sup> , 22-27 <sup>th</sup> day	(1-7) <sup>th</sup> , (22-27) <sup>th</sup> day	Supplement was not provided
"Biozapin"	7 <sup>th</sup> ; 22 <sup>th</sup> day	7 <sup>th</sup> ; 22 <sup>th</sup> day	Supplement was not provided
"Diolaid"/0,0004%	Supplement was not provided	during the experiment	Supplement was not provided
"Biolaid"/0.2%	Supplement was not provided-	1time/week	Supplement was not provided
Antibiotics	Not provided-	-	(5-10) <sup>th</sup> day
Vitamins in mg per head	Not provided	-	(5-10) <sup>th</sup> day

**Source:** developed by authors

The control birds received a standard rearing scheme. Blood samples were collected from poultry on the 10<sup>th</sup>, 30<sup>th</sup> and 40<sup>th</sup> day of rearing in vivo, by puncture from the subcutaneous vein using a heparinized cannula-free needle, following the rules of asepsis and antisepsis. The collected whole blood samples were divided into two parts: one for the determination of micro- and macroelements, and the second was stabilised with an anticoagulant (1% heparin solution) at the rate of 2-3 drops per 10-12 ml of blood for further determination of biochemical parameters.

Hematologic, biochemical, and immunologic blood parameters were explored by conventional methods. The content of total haemoglobin in the blood was determined by the haemoglobin cyanide method by colourimetric analysis, the number of red blood cells and leukocytes by the test tube method, in a chamber with a Goryaev grid (Hunchak, 2013; Fersunin, 2014). To determine the bactericidal activity of blood serum (BAC), a daily broth culture of *E. coli*, serovar O26, grown on Hottinger broth according to the method of O.V. Smirnova and T.A. Kuzmina (Danchuk et al., 2013) was used. The determination of serum lysozyme activity ("SLA") was performed by the photonephelometric method of V.G. Dorofeichuk (Kotsiumbas et al., 2012; Hunchak, 2013). The test culture used for the study was *Micrococcus lysodeikticus*, strain 2665. The phagocytic activity (PA) of blood leukocytes was explored in heparin-stabilised blood using a daily broth culture of *E. coli* (strain VKM) according to the Gostev method (Danchuk et al., 2013).

Total proteins, albumin, uric acid, creatinine and the level of enzymatic activity [AST (K. F. 2.6.1.1); ALT (K. F. 2.6.1.2); AP (K. F. 3.1.3.1) activity] in plasma were determined using CORMAY (Poland, 2011) reagent kits as described in the manufacturer's manual (Vlizlo et al., 2014). Spectrophotometric measurements were performed using a SHIMADZU UV-1800 instrument (Japan, 2017).

The content of micro- and macronutrients was explored by inductively coupled plasma optical emission spectrometry using an optical emission spectrometer (ICP-OES) PlasmaQuant PQ 9000 (Germany, 2018). Ultrapure nitric acid (Merck, Germany), certified multi-element standard solutions for atomic emission spectrometry (Merck, Germany) with certified ion content were used to prepare samples and prepare background and calibration solutions (El Kady et al., 2012; Chechet et al., 2022). The solvent was ultra-pure deionised water according to ISO 11885:1996 (1996), prepared by the Atrium 631 UV purification system (Sartorius, Germany). For the mineralisation of blood samples, it was used the Milestone Ethnos Easy system with HPR-1000/10S high-pressure rotor autoclaves (Milestone, Italy, 2021).

The results are presented as mean  $\pm$  standard error ( $\bar{x} \pm SE$ ). To compare the difference in mean parameters between the control and experimental groups, the authors of the research used the Tukey test, where the differences were considered statistically significant at  $P < 0.05$  for all the data.

All experimental studies were conducted according to modern methodological approaches and in

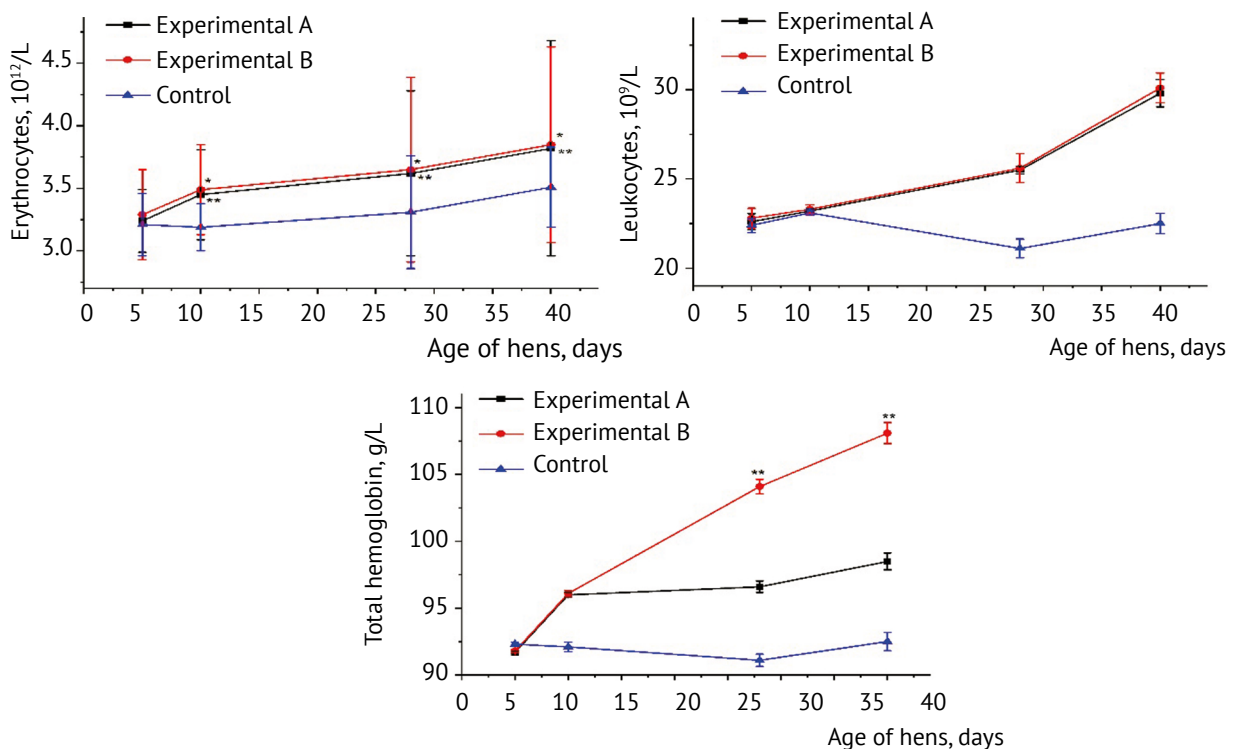
compliance with the relevant requirements and standards, in particular, they correspond to the requirements of DSTU ISO/IEC 17025:2005 (2006). The animals were kept and all manipulations were performed according to the provisions of the Procedure for conducting experiments and experiments on animals by scientific institutions (Law of Ukraine No. 249, 2012), the European Convention for the Protection of Vertebrate Animals Used for Experimental and Other Scientific Purposes (European convention..., 1986).

## RESULTS

Haematological parameters in experimental and control chickens were within their reference level and changed during the experiment within physiological limits. A gradual increase in the number of red blood cells in the blood of experimental poultry fed a probiotic agent and in combination with biocidal drugs was established. On the 10<sup>th</sup> day, the number of red blood cells in the blood of experimental A birds increased by 8.2%, and in experimental B – by 8.1%, respectively, compared to the control values of the indicator. By the end of the experiment, the tendency to increase the number of red

blood cells within physiological limits compared to the control was maintained, which on day 40 was 8.8% for experimental A and 9.6% ( $P < 0.05$ ) for experimental B birds, respectively.

It was established, within the physiological standard, a slight tendency to increase leukocytes in broilers of experimental A and B after disinfection on the 5<sup>th</sup> and 10<sup>th</sup> day by 0.89% and 1.70%, respectively, compared to the control. An increase in the content of total haemoglobin (Fig. 1) was established within the physiological standard, which is consistent with the dynamics of the number of red blood cells. Thus, on the 10<sup>th</sup> and 30<sup>th</sup> day of the experiment, the concentration of total haemoglobin in the blood of experimental A birds increased by 4.2 and 6.1% and experimental B – by 4.4 and 14.3% ( $P < 0.05$ ), respectively, compared to the control. This trend persisted until the end of the experiment: on day 40, the most significant increase in the level of the index in experimental B birds was recorded, which was 16.9% ( $P < 0.05$ ) compared to the control. Therewith, the increase in total haemoglobin in the blood of experimental A birds was determined to be only 6.1%, respectively.



**Figure 1.** Dynamics of haematological parameters in the blood of broiler chickens under the influence of symbiotic with probiotic and in combination with biocidal preparations:

**Notes:** Experimental A ("Biomagn"+"Biozapin"); Experimental B ("Biomagn"+"Biozapin" in the complex "Diolide"+"Biolide"); control (standard rearing diet); ( $\bar{x} \pm SE$ ;  $n=21$ ); \* – the mark indicates significant changes in the values of the indicator in the bird of the experimental group relative to that in the control group ( $P < 0.05$ ) according to the results of the ANOVA

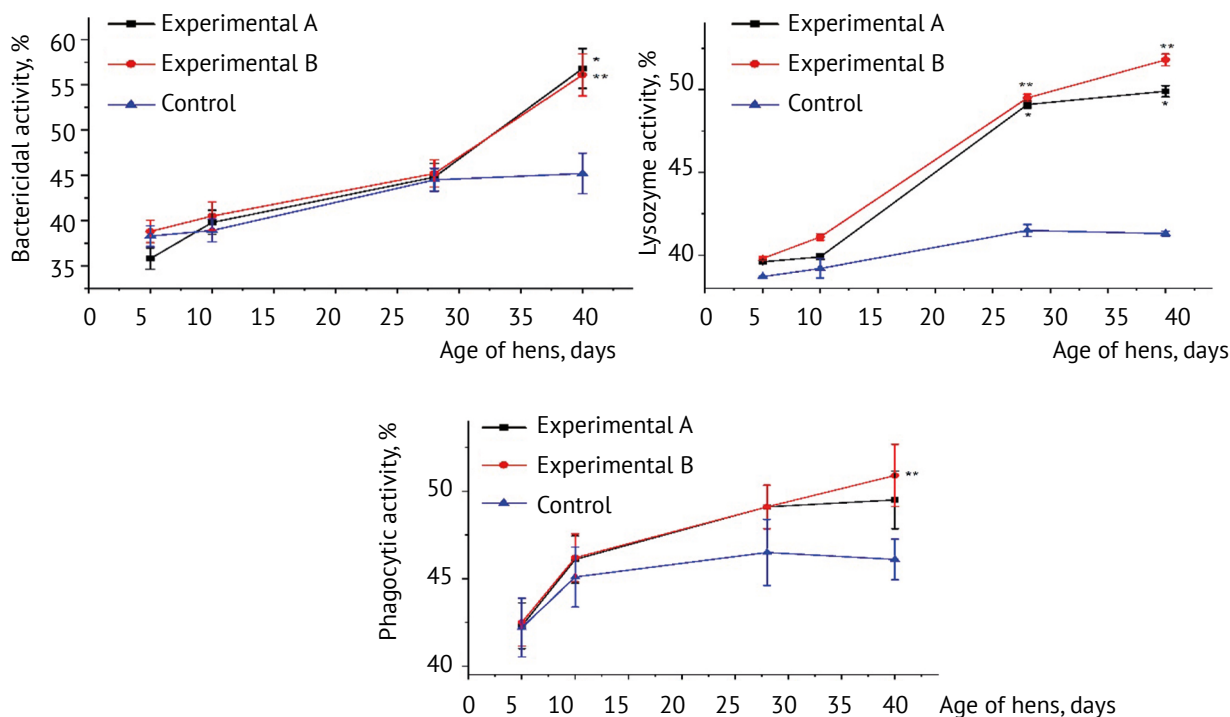
**Source:** developed by authors

As a result of the study of nonspecific resistance indicators, a significant increase in the level of serum

lysozyme activity and phagocytic activity (Fig. 2) in experimental B birds was established, which averaged

25.4% and 13.1% ( $P < 0.01$ ) relative to the control values of indicators. Therewith, the value of the bactericidal activity of blood serum (Fig. 2) increased in experimental A

and B birds from day 30 to day 40 inclusive, which at the end of the experiment averaged 26.1 and 24.1% ( $P < 0.01$ ) relative to the control.



**Figure 1.** Dynamics of bactericidal (BAC, %); lysozyme (SLA, %); serum activities and phagocytic activity (PA, %); in broiler chickens under the influence of symbiotic with probiotic and in combination with biocidal preparations  
**Notes:** experimental A (“Biomagn”+“Biozapin”); experimental B (“Biomagn”+“Biozapin”+in the complex “Diolide”+“Biolide”); control (standard rearing diet); ( $x \pm SE$ ;  $n = 21$ ); \* – the mark indicates significant changes in the values of the indicator in the bird of the experimental group relative to that in the control group ( $P < 0.01$ ) according to the results of the Tukey test  
**Source:** developed by authors

Table 2 presents the results of studies of the level of biochemical parameters in the blood serum of broiler chickens in the dynamics under the influence of symbiotic preparations and biocidal agents. It was established that the content of total proteins in the blood serum of experimental A and B birds increased on day 10 of the experiment and was higher than the control by 10.9% and 19.1% ( $P < 0.01$ ), respectively (Table 2). In addition, the same trend was observed at the end of the experiment, where the content of total proteins in the blood serum of experimental A and B birds on day 40 was higher than their control values by an average

of 7.6% and 2.9%, respectively. Notably, on the 10<sup>th</sup> and 40<sup>th</sup> day of the experiment, the values of the index in birds of experimental group B exceeded those in experimental A by an average of 8.1% and 3.1%, respectively. Thus, it is evident that the increase in the level of SLA and PA ( $P < 0.01$ ) in experimental B birds is caused by lysozyme secreted by phagocytes, which is a nonspecific factor of the immune system due to its pronounced hydrolytic, bactericidal effect, phagocytosis and antibody production. Therewith, the level of BAC increased in experimental A and B birds ( $P < 0.01$ ), starting from day 30 to day 40 inclusive.

**Table 2.** Dynamics of biochemical parameters in the blood serum of broiler chickens under the conditions of exposure to symbiotic with probiotic and in combination with biocidal preparations ( $x \pm SE$ ;  $n = 21$ )

Indicator	Poultry group (n = 21)	Reference level	10 <sup>th</sup> day Of the Experiment	40 <sup>th</sup> day of the experiment
1	3	2	4	5
Total proteins, g/L	Experimental A	25-40	28.53 ± 1.36 <sup>ab</sup>	28.37 ± 1.30 <sup>a</sup>
	Experimental B		30.61 ± 1.41 <sup>b</sup>	29.21 ± 1.39 <sup>a</sup>
	Control		25.72 ± 1.05 <sup>a</sup>	26.23 ± 1.07 <sup>a</sup>

Table 2, Continued

Indicator	Poultry group (n = 21)	Reference level	10 <sup>th</sup> day Of the Experiment	40 <sup>th</sup> day of the experiment
1	3	2	4	5
Albumins, g/L	Experimental A	15-22	10.21 ± 0.45	10.12 ± 0.41
	Experimental B		10.98 ± 0.38 <sup>a</sup>	10.07 ± 0.40
	Control		13.45 ± 0.64	10.25 ± 0.42
Uric acid, mkmol/L	Experimental A	230-360	279.02 ± 11.52 <sup>a</sup>	206.08 ± 14.51 <sup>a</sup>
	Experimental B		271.41 ± 13.12 <sup>a</sup>	205.10 ± 15.12 <sup>a</sup>
	Control		314.71 ± 14.15	278.12 ± 11.88
Creatinine, mkmol/L	Experimental A	8.8-35.4	23.02 ± 3.25	20.04 ± 1.17 <sup>a</sup>
	Experimental B		22.25 ± 2.04 <sup>a</sup>	21.02 ± 1.19 <sup>a</sup>
	Control		24.12 ± 1.07	23.48 ± 1.25
AST activity, U/L	Experimental A	2-8	4.02 ± 0.21 <sup>a</sup>	3.02 ± 0.01 <sup>a</sup>
	Experimental B		3.25 ± 0.32 <sup>a</sup>	3.13 ± 0.03 <sup>a</sup>
	Control		5.17 ± 0.02	5.25 ± 0.02
ALT activity, U/L	Experimental A	200-300	254.25 ± 9.12	294.32 ± 15.43
	Experimental B		253.12 ± 9.05	289.11 ± 16.05
	Control		255.52 ± 10.29	295.63 ± 18.41
AP activity, U/L	Experimental A	1900-19000	14139.45 ± 113.29	2570.48 ± 62.27 <sup>a</sup>
	Experimental B		14320.12 ± 97.56	2620.25 ± 43.71 <sup>a</sup>
	Control		13471.22 ± 123.14	4170.36 ± 71.18

**Note:** experimental A (Biomagn + Biosapin); experimental B (Biomagn + Biosapin in the complex "Diolide" + "Biolide"); control (standard rearing diet); ( $x \pm SE$ ;  $n = 21$ ); \* – letters indicate significant differences between the groups in each period within column at ( $P < 0.05$ ) according to the results of the Tukey test

**Source:** developed by authors

A temporary tendency to increase the content of albumin in the blood serum of poultry of the control group was recorded. It was established that on day 10 of the study, the amount of albumin in the blood of experimental A and B birds was lower than in the control by an average of 19.6% ( $P < 0.01$ ) and 5.1%, respectively. However, the determined values of the index on the 40<sup>th</sup> day of the experiment did not vary statistically in experimental and control chickens and were almost at the same level. It was established that using symbiotic and biocidal preparations in the experimental chicken-rearing system significantly affected the dynamics of the end products of protein degradation in the poultry body – uric acid and creatinine, respectively (Table 2). It is known that urea synthesis in hepatocytes is the main way to neutralise nitrogen-containing compounds produced in the process of amino acid deamidation, and its concentration in the blood characterises the functional state of the liver and kidneys. The content of uric acid in the blood serum of chickens of experimental A and B on the 10<sup>th</sup> and 40<sup>th</sup> day of the experiment gradually decreased relative to the control values, which at the end of the experiment averaged 25.9% and 26.2% ( $P < 0.01$ ), respectively. In addition, the creatinine content in the blood serum of poultry decreased relative to the control, and its values were significantly lower on day 40 of the experiment than the control level in chickens of both experimental groups by an average of 14.6% and 10.6% ( $P < 0.01$ ), respectively.

An important indicator of the functional state of the liver is the activity of the cellular enzymes alanine aminotransferase (ALT activity) and aspartate aminotransferase (AST activity), which catalyse metabolic processes and participate in the biochemical transformations of carbohydrates, lipids, nucleic acids and amino acids (Hilal *et al.*, 2016). In birds of experimental A and B, during the experiment, the values of enzymatic AST activity gradually decreased within the physiological standard, and on day 40 of the experiment were lower than the control level of the enzyme by an average of 42.5 and 40.4% ( $P < 0.01$ ), respectively (Table 2).

However, the values of ALT activity in the blood serum of broiler chickens of the experimental groups in the dynamics of the experiment did not statistically vary from the control level and were within the physiological limits of the indicator.

The activity of alkaline phosphatase (AP activity) in the blood serum of experimental poultry was characterised by an upward trend at the beginning and its probable inhibition at the end of the experiment (Table 2). It was established that a moderate increase in AP activity within physiological limits relative to the control at the initial period of the study (day 10), in the future (day 40 of the experiment) the enzyme values significantly decreased relative to the previous ones, which for chickens of experimental A and B and control was 81.8% and 81.7% and 69.0% ( $P < 0.01$ ), respectively.

Therewith, a significant decrease in the level of activity of this enzyme relative to the control values was recorded in chickens of experimental A and B on day 40 of the experiment, which averaged 38.4 and 37.2% ( $P < 0.01$ ), respectively.

As a result of the analysis of the data obtained on the trace element composition of the blood of control and experimental poultry during the experiment, some changes in the indicators were established (Table 3).

It was established that the concentration of Calcium, Phosphorus, Kalium, Magnesium, Manganum, Natrium, Zinc, Ferrum and Selenium in the blood of control chickens physiologically increased during the experiment, and its values were within the reference level of indicators. The values of such elements as Cobaltum, Chromium and Cuprum in the blood of control chickens at all study periods did not vary statistically and were within the reference level of these indicators.

**Table 3.** Dynamics of biochemical parameters in the blood serum of broiler chickens under the conditions of exposure to symbiotic with probiotic and in combination with biocidal preparations ( $x \pm SE$ ;  $n = 21$ )

Element	Duration of the experiment, day	experimental A (n = 21)	experimental B (n = 21)	control (n = 21)
1	2	3	4	5
Magnesium, mg/kg	10 <sup>th</sup>	0.57 ± 0.01	0.59 ± 0.01 <sup>a</sup>	0.46 ± 0.06
	30 <sup>th</sup>	1.79 ± 0.01	1.83 ± 0.01 <sup>a</sup>	1.67 ± 0.03
	40 <sup>th</sup>	1.79 ± 0.02	1.84 ± 0.02 <sup>a</sup>	1.66 ± 0.11
Natrium, mg/kg	10 <sup>th</sup>	41.06 ± 2,48	42.85 ± 2.55	44.13 ± 2.62
	30 <sup>th</sup>	71.15 ± 5.68 <sup>a</sup>	88.74 ± 6.71	88.40 ± 6.58
	40 <sup>th</sup>	78.60 ± 3.12 <sup>a</sup>	109.00 ± 7.58	107.70 ± 6.98
Kalium, mg/kg	10 <sup>th</sup>	24.18 ± 1.68	25.00 ± 1.59	25.93 ± 1.58
	30 <sup>th</sup>	37.23 ± 1.75	38.36 ± 1.75	38.77 ± 1.80
	40 <sup>th</sup>	34.73 ± 1.70 <sup>a</sup>	37.20 ± 1.71	39.15 ± 1.68
Calcium, mg/kg	10 <sup>th</sup>	0.43 ± 0.05 <sup>a</sup>	0.45 ± 0.06 <sup>a</sup>	0.38 ± 0.043
	30 <sup>th</sup>	1.15 ± 0.06 <sup>a</sup>	1.12 ± 0.05 <sup>a</sup>	0.95 ± 0.051
	40 <sup>th</sup>	1.58 ± 0.08	1.57 ± 0.08 <sup>a</sup>	1.42 ± 0.060
Chromium, mg/kg	10 <sup>th</sup>	0.68 ± 0.06	0.60 ± 0.05 <sup>a</sup>	0.72 ± 0.07
	30 <sup>th</sup>	0.60 ± 0.06 <sup>a</sup>	0.62 ± 0.06 <sup>a</sup>	0.69 ± 0.063
	40 <sup>th</sup>	0.64 ± 0,06 <sup>a</sup>	0.64 ± 0.06 <sup>a</sup>	0.71 ± 0.069
Manganum, mg/kg	10 <sup>th</sup>	0.11 ± 0.04	0.20 ± 0.01 <sup>a</sup>	0.12 ± 0.004
	30 <sup>th</sup>	0.20 ± 0,05 <sup>a</sup>	0.66 ± 0.01 <sup>a</sup>	0.60 ± 0.006
	40 <sup>th</sup>	0.17 ± 0.01 <sup>a</sup>	0.68 ± 0.02 <sup>a</sup>	0,57 ± 0.009
Ferrum, mg/kg	10 <sup>th</sup>	4.25 ± 0.035	4,94 ± 0.03	4.63 ± 0.04
	30 <sup>th</sup>	19.73 ± 0.81 <sup>a</sup>	19.58 ± 1.62 <sup>a</sup>	15.22 ± 0.61
	40 <sup>th</sup>	22.01 ± 1.15 <sup>a</sup>	22.22 ± 1.01 <sup>a</sup>	15.45 ± 0.81
Cobaltum, mg/kg	10 <sup>th</sup>	0.03 ± 0.01	0.03 ± 0.02	0.03 ± 0.01
	30 <sup>th</sup>	0.036 ± 0.020	0.04 ± 0.01	0.04 ± 0.03
	40 <sup>th</sup>	0.021 ± 0.001 <sup>a</sup>	0.025 ± 0.002	0.025 ± 0.002
Cuprum, mg/kg	10 <sup>th</sup>	82.69 ± 1.68 <sup>a</sup>	70.21 ± 1.78	71.83 ± 1.88
	30 <sup>th</sup>	89.18 ± 1.85 <sup>a</sup>	73.38 ± 2.32	72.28 ± 2.68
	40 <sup>th</sup>	77.92 ± 1.28	76.08 ± 1.15	75.67 ± 1.08
Zinc, mg/kg	10 <sup>th</sup>	71.61 ± 5.69	74.30 ± 5.77	71.99 ± 5.56
	30 <sup>th</sup>	148.80 ± 11.18	152.30 ± 9.98	150.80 ± 9.78
	40 <sup>th</sup>	173.50 ± 12.55	174.80 ± 12.68	173.90 ± 11.80
Selenium, mg/kg	10 <sup>th</sup>	11.15 ± 0.035	13.64 ± 0.04 <sup>a</sup>	9.63 ± 0.07
	30 <sup>th</sup>	15.73 ± 1.81 <sup>a</sup>	16.98 ± 0.12 <sup>a</sup>	13.22 ± 1.11
	40 <sup>th</sup>	21.01 ± 1.12 <sup>a</sup>	23.22 ± 2.01 <sup>a</sup>	16.45 ± 0.81

Table 3, Continued

Element	Duration of the experiment, day	experimental A (n = 21)	experimental B (n = 21)	control (n = 21)
1	2	3	4	5
Phosphorus, mg/kg	10 <sup>th</sup>	15.59 ± 1.10 <sup>a</sup>	17.86 ± 1.20 <sup>a</sup>	13.55 ± 0.98
	30 <sup>th</sup>	46.57 ± 3.23 <sup>a</sup>	46.87 ± 3.72 <sup>a</sup>	30.19 ± 2.16
	40 <sup>th</sup>	46.39 ± 1.85 <sup>a</sup>	47.01 ± 1.97 <sup>a</sup>	34.42 ± 1.07
	30 <sup>th</sup>	71.15 ± 5.68 <sup>a</sup>	88.74 ± 6.71	88.40 ± 6.58
	40 <sup>th</sup>	78.60 ± 3.12 <sup>a</sup>	109.00 ± 7.58	107.70 ± 6.98

**Note:** experimental A (Biomagn + Biosapin); experimental B (Biomagn + Biosapin in the complex "Diolide" + "Biolide"); control (standard rearing diet); ( $\bar{x} \pm SE$ ; n = 21); \* - letters indicate significant differences between the groups in each period within column at ( $P < 0.05$ ) according to the results of the Tukey test

**Source:** developed by authors

The results obtained indicate that at all periods of research, the level of such elements as Calcium and Phosphorus in the blood of experimental chickens gradually increased relative to their control values: on the 10<sup>th</sup>, 30<sup>th</sup> and 40<sup>th</sup> day of the experiment in experimental A birds it was 13.2%, 21.1% and 11.3% ( $P < 0.01$ ) and 15.1%, 54.3% and 34.8% ( $P < 0.01$ ), respectively, and experimental B – 18.4%, 17.9% and 10.6% and 31.8%, 55.3% and 36.6%, respectively (Table 3). The data obtained, in general, indicate an intensification of the accumulation of Calcium and Phosphorus in the body of the experimental poultry.

In addition, a steady increase in the content of Ferrum and Selenium in the blood of experimental chickens was recorded, but for experimental A birds, it was recorded from day 20 to day 40 inclusive, which averaged 36.1% and 23.8% ( $P < 0.01$ ), respectively, compared to the control (Table 3). In contrast to the chickens of experimental A, in the blood of experimental B birds, a positive trend in the increase in the content of Ferrum and Selenium began to be established from day 10 until the end of the experiment, which averaged 36.3% and 37.0% ( $P < 0.01$ ), respectively, relative to the control level of indicators.

However, the values of such elements as Zinc in the blood of experimental broiler chickens in the dynamics of the experiment did not statistically vary from the control level, respectively, but increased during the experiment, which is physiological and within the reference range of the indicator. However, the bioavailability of Zinc is related to the action of phytic acid and the concentration of Cuprum. Consequently, the content of Cuprum in the blood of the experimental birds increased in value with their age. Thus, the highest concentration of the element was recorded on the 10<sup>th</sup> and 30<sup>th</sup> day of the experiment in chickens of experimental A, on average by 15.1% and 23.4% ( $P < 0.01$ ), respectively, compared to the control, which is obviously due to its active participation in the processes of hematopoiesis. After that, there was a significant decrease in the concentration of Cuprum in the blood of birds of this experimental group.

When determining the content of Magnesium and Manganum, a positive gradual dynamics was established in increasing the values of these elements only in

the blood of experimental B birds, starting from day 10 and up to day 40 of the experiment inclusive (Table 3). Thus, the increase in the concentration of Magnesium and Manganum in the blood of chickens of experimental B relative to the control during the experiment was on average 12.7% and 18.6% ( $P < 0.01$ ), respectively.

Notably, under the influence of Biomagn and Biosapin alone, the blood of experimental A chickens, on the contrary, decreased the content of such elements as Kalium, Manganum, Natrium and Cobaltum, which averaged 11.3%, 67.8%, 23.7% and 16.0% ( $P < 0.01$ ), respectively, relative to the control values of these elements (Table 3). Notably, this was recorded in most cases at the last stages of the study (day 30 and/or 40 of the experiment). The content of Chromium in the blood of experimental A and B birds decreased on the 30<sup>th</sup> and 40<sup>th</sup> and on the 10<sup>th</sup>, 30<sup>th</sup> and 40<sup>th</sup> day of the experiment compared to the control values by an average of 11.4% and 12.7% ( $P < 0.01$ ), respectively (Table 3).

## DISCUSSION

Based on the results obtained, notably, the increase in natural resistance in the body of experimental B chickens is more pronounced and is characterised by a gradual increase in total haemoglobin, SLA, BAC, PA and total proteins ( $P < 0.01$ ) under the influence of a complex of symbiotic preparations in combination with biocidal agents, and confirms the ability of the latter to inhibit and neutralise microbial agents. In addition, Kotsiumbas *et al.* (2012) and Boguśławska-Tryk *et al.* (2016) noted that the addition of probiotics to fodder in combination with biocide spraying stimulates the lymphatic system, the establishment of immunoglobulins, increases the amount of complement, macrophage and lysozyme activity, and the resistance of vascular and tissue barriers to toxins. Thus, due to the induction of oxidative processes, metabolism in the body of young poultry during intensive growth is intensified. The nature of the changes is consistent with the state of biochemical parameters in the blood of chickens of the experimental groups.

It should be emphasised that feeding the symbiotic "Biomagn" with the probiotic "Biozapin" and in combination with biocides in experimental B chickens,

through the restoration of proteinogram indicators (with an increase in the content of total proteins and albumin; ( $P < 0.01$ )), has a positive effect on erythropoiesis and haemoglobin development, indicating an improvement in the nutritional, respiratory and enzymatic functions of the blood and contributes to an increase in the body's defences. Stimulation of protein-synthetic processes in the poultry body is a sign of the prevalence of anabolic (synthetic) processes over catabolic ones, and a sign of increased metabolic intensity is a decrease in the establishment of purine metabolism products ( $P < 0.01$ ). Thus, the concentration of creatinine in the blood depends on the intensity of protein proteolysis in muscle tissue, which, along with a decrease in uric acid levels, indicates an activation of the functionality of endogenous detoxification systems in the body of chickens. It is consistent with the decrease in AST ( $P < 0.01$ ) in experimental A and B birds. In control poultry, the rearing scheme which included the addition of an antibiotic to the diet, hyperenzymemia of AST was recorded, which is a sign of impaired liver reamination and detoxification functions, and it is argued that the dynamics of aminotransferases is an indicative and informative test of hepatocyte cell membrane permeability during liver damage by exogenous or endogenous toxins (Romanovich *et al.*, 2017; Chechet, 2021).

AP activity in the blood of experimental poultry is characterised by an increase at the beginning of the experiment and a decrease at the end ( $P < 0.01$ ). Evidently, the probiotic "Biomagn" has a significant effect on the neuro-humoral regulation of the activity of this enzyme, and according to Denbow (2000; 2013) and Bailly *et al.* (2017), by improving the digestion and absorption of vitamins, trace elements and other biologically active substances in the gastrointestinal tract, it potentially enhances its activity. Therewith, the decrease in AP activity relative to the control in chickens of experimental A and B can be explained by the intensification of Calcium and Phosphorus metabolism between bone tissue and macroorganism and the increased functioning of osteoclasts, which occurs during physiological growth and development of poultry, as described by Danchuk *et al.* (2013). Notably, the dynamics of changes in Calcium and Phosphorus in the body of experimental poultry are more pronounced in experimental B chickens, indicating a more intensive absorption of these elements from fodder under the combined effect of probiotic preparations with biocidal ones. Boikiv *et al.* (2001) and Bhattacharya *et al.* (2016) associate the active accumulation of Calcium and Phosphorus in the blood with the intensification of absorption from the gastrointestinal tract as a result of the improvement of the poultry digestive system and biocenosis in it.

On the other hand, the positive effect of the drug complex on the immunobiological reactivity of experimental poultry can be explained by the biological role of inorganic elements. The authors of the research established an increase in the level of Magnesium and

Manganum in the blood of experimental B birds during the experiment. Thus, according to Devrim *et al.* (2010), El Kady *et al.* (2012) and Laur *et al.* (2020), the positive effect of the complex of drugs may be to improve redox processes, tissue respiration, bone development, hematopoiesis, biosynthesis of nucleic acids, proteins, antibodies, and affect the growth and development of young broilers. Thus, the content of Zinc was higher in the blood of experimental B birds compared to experimental A and control, which Hofmann & Hagey (2008) attributed to the dynamics of protein metabolism. As proved by Jegede *et al.* (2011) and Hajjarmanesh *et al.* (2022), the bioavailability of Zinc depends on the levels of phytic acid and Cuprum. Thus, the content of Cuprum in the blood of experimental poultry increases ( $P < 0.01$ ), which is associated with the active participation of this element in the processes of hematopoiesis and is consistent with the dynamics of haematological parameters in chickens. According to Kalinichenko (2013), Cuprum is a hematopoietic bioelement, participating actively in the synthesis of haemoglobin and the establishment of other iron porphyrins, plays an important role in the conversion of Ferrum into an organically bound form, stimulates the maturation of reticulocytes and their transformation into red blood cells (Wang & Pantopoulos, 2011; El Sabry *et al.*, 2021). Thus, a positive trend in the increase in the content of Ferrum and Selenium ( $P < 0.01$ ) in the blood of experimental B chickens during the experiment was established. It has been proved (Tsynovyi, 2013; Zapata, 2016) that Ferrum is a part of cytochrome C heme and is regulated in the body primarily by modulating its intestinal absorption and depends on the state of the intestinal microbiocenosis. Other researchers (Zwolak & Zaporowska, 2012) have demonstrated that increased absorption of Ferrum and Selenium in the body indicates a lack of their content in the poultry diet during intensive rearing. In the works of WHO. The European Health Report (2002), Li & Yang (2018), Dalia *et al.* (2020) and Sobolev *et al.* (2022) describe Selenium's ability to stimulate the production of antibodies, its role in liver function, protein synthesis and protection of the body from toxic minerals, participation in prostaglandin metabolism, and antioxidant and immunomodulatory properties. Researchers Klaenhammer *et al.* (2012) and Jaishankar *et al.* (2014) proved the possibility of influencing the biotransformation of such a heavy metal as Chromium and its significant reduction during critical physiological periods through the optimisation of poultry rearing technology by using probiotics. It is consistent with the determined decrease during the experiment in the content of Chromium ( $P < 0.01$ ) in the blood of poultry of both experimental groups compared to the control.

But, under the influence of drugs in the blood of chickens of experimental A, on the contrary, at the end of the experiment, there is a decrease in Kalium, Manganum, Natrium and Cobaltum ( $P < 0.01$ ) compared to the control.

According to Klaenhammer *et al.* (2012) and Kivit (2014), the biological role of Cobaltum is associated with its participation in the enzymatic function of vitamin B12, thus, evidently, the decrease in its content in the blood of experimental poultry is a consequence of the physiological maturity of its body and, accordingly, its lower need.

Based on the results obtained and according to (Kovalenko, 2008; Kalinichenko, 2013; Romanovich *et al.*, 2017), it can be emphasised that using a complex of probiotic and biocidal agents in the presence of birds will allow for an active action on pathogenic pathogens by reducing the microbial load in the environment, and will contribute to the stimulation of hematopoiesis, immune and metabolic reactions in the target bird.

### CONCLUSIONS

Using the symbiotic "Biomagn" with fodder in combination with the probiotic "Biozapin" and in combination with the biocidal agents "Diolaid" and "Biolaid" promotes the synergistic effect of these drugs and their effective action, which activates the processes of haemoglobin development and protein metabolism. In particular, a gradual increase in the number of red blood cells and total haemoglobin in the blood of poultry of both experimental groups within physiological limits was found by 8.8% and 5.2% for experimental A and 9.6% and 9.4% ( $P < 0.05$ ) for experimental B, respectively, compared to the control. It was established that the content of total proteins in the blood serum of experimental A and B

birds increased by an average of 7.6 % and 2.9 % ( $P < 0.01$ ), respectively, compared to the control, which, along with an increase in the level of BAC ( $P < 0.01$ ), and SLA and PA ( $P < 0.01$ ) – only in experimental B birds, characterises a significantly pronounced induction of immunobiological reactivity in the body of chickens of this group.

A decrease in the establishment of protein degradation products in the poultry body – uric acid and creatinine ( $P < 0.01$ ) in the blood of experimental chickens of both experimental groups indicates an increase in the intensity of metabolism in the poultry body under the influence of a complex of preparations of symbiotic/probiotic and biocidal action. The content of uric acid and creatinine in the blood serum of chickens of experimental A and B decreased by an average of 25.9% and 26.2% ( $P < 0.01$ ) and 14.6% and 10.6% ( $P < 0.01$ ), respectively, compared to the control values.

Analysis of the results of blood trace element composition indicates normalisation of mineral status, enhancement of endogenous detoxification activity and body defences, which increases resistance to stress factors and adverse environmental conditions, and in combination with an increase in total protein content in experimental chickens is a sign of the prevalence of anabolic (synthetic) processes over catabolic ones, which will further positively affect the growth and productivity of broilers. Considering the results obtained, it is advisable to further explore the quality and safety of poultry products obtained as a result of using this rearing scheme.

### REFERENCES

- [1] Adil, S., Banday, T., Ahmad, B.G., Saleem, M.M., & Rehman, M. (2010). Effect of dietary supplementation of organic acids on performance, intestinal histomorphology, and serum biochemistry of broiler chicken. *Veterinary Medicine International*, 47, article number 9485. doi: 10.4061/2010/479485.
- [2] Arena, M.P., Capozzi, V., Spano, G., & Fiocco, D. (2017). The potential of lactic acid bacteria to colonize biotic and abiotic surfaces and the investigation of their interactions and mechanisms. *Applied Microbiology and Biotechnology*, 101(7), 2641-2657. doi: 10.1007/s00253-017-8182-z.
- [3] Babenko, L.P., Mokrozub, V.V., Sokolvyak, O.Yu., Lazarenko, L.M., & Spivak, M.Ya. (2014). Antibacterial and immunomodulatory properties of lactic acid bacteria in normal and intravaginal staphylococci. *Journal EPMA*, 5, article number A137. doi: 10.1186/1878-5085-5-S1-A137.
- [4] Bailly, J., Faivre, B., Bernard, N., Sage, M., Crini, N., Driget, V., Garnier, S., & Rieffel, D. (2017). Multi-element analysis of blood samples in a passerine species: Excesses and deficiencies of trace elements in an urbanization. *Study Frontiers Ecology and Evolution. Urban Ecology*, 5, article number 6. doi: 10.3389/fevo.2017.00006.
- [5] Bhattacharya, P.T., Misra, S.R., & Hussain, M. (2016). Nutritional aspects of essential trace elements in oral health and disease: An extensive review. *Scientifica (Cairo)*, 2016, article number 5464373. doi: 10.1155/2016/5464373.
- [6] Bogusławska-Tryk, M., Piotrowska, A., Szymeczko, R., Burlikowska, K., & Głowińska, B. (2016). Lipid metabolism indices and fatty acids profile in the blood serum of broiler chickens fed a diet with lignocellulose. *Brazilian Journal of Poultry Science*, 18(3), 451-456. doi: 10.1590/1806-9061-2015-0157.
- [7] Boikiv, D.P., Svystun, Yu.D., & Fartushok, N.V. (2001). Trace elements: Achievements and prospects. *Experimental and Clinical Physiology and Biochemistry*, 2(14), 124-127.
- [8] Byrd, J.A., Hargis, B.M., Caldwell, D.J., Bailey, R.H., Herron, K.L., McReynolds, J.L., Brewer, R.L., Anderson, R.C., Bischoff, K.M., Callaway, T.R., & Kubena, L.F. (2001). Effect of lactic acid administration in the drinking water during pre-slaughter feed withdrawal on *Salmonella* and *Campylobacter* contamination of broilers. *Poultry Science*, 80, 278-283. doi: 10.1093/ps/80.3.278.
- [9] Chechet, O.M., Kovalenko, V.L., & Haidei, O.S. (2021). Preclinical tests of the drug "Biomagn" on laboratory animals and with the use of *Tetrahymena pyriformis* ciliate culture. *Medical and Clinical Chemistry*, 23(3), 48-56. doi: 10.11603/mch.2410-681X.2021.i3.12581.

- [10] Chechet, O.M., Kovalenko, V.L., Vishchur, O.I., Haidei, O.S., Liniichuk, N.V., Gutyj, B.V., & Krushelnytska, O.V. (2022). The activity of T- and B-cell links of specific protection of chicken-broilers under the influence of synbiotic preparation "Biomagn" and "Diolide" disinfectant. *Ukrainian Journal of Veterinary and Agricultural Sciences*, 5(1), 46-52. doi: 10.32718/ujvas5-1.08.
- [11] Chen, G., Wu, J., & Li, C. (2014). Effect of different selenium sources on production performance and biochemical parameters of broilers. *Journal of Animal Physiology and Animal Nutrition*, 98(4), 747-754. doi: 10.1111/jpn.12136.
- [12] Dalia, A.M., Loh, T.C., & Sazili, A.Q. (2020). Influence of bacterial organic selenium on blood parameters, immune response, selenium retention and intestinal morphology of broiler chickens. *BMC Veterinary Research*, 16, article number 365. doi: 10.1186/s12917-020-02587-x.
- [13] Danchuk, V.V., Nishchemenko, M.P., Peleno, R.A., Romanko, M.Ye., Ushkalov, V.O., & Karpovskiy, V.I. (2013). *Handbook of general and special methods of blood research of farm poultry*. Lviv: SPOLOM.
- [14] Demchyshyn, O.V., Kukhtyn, M.D., & Perkiy, Yu.B. (2018). Toxicity and biological value of meat of broiler chickens after drinking Akvasan acidifier. *Science Release Lviv National University of Veterinary of Medicine and Biotechnology Named After S. Z. Gzhitskyi*, 20(92), 94-97. doi: 10.32718/nvlvet9218.
- [15] Denbow, D.M. (2000). *Gastrointestinal anatomy and physiology*. In G.C. Whittow (Ed.), *Sturkie's avian physiology* (pp. 299-325). New York: Academic Press.
- [16] Devrim, S., Taylan, A., & Bülent, Ö. (2010). The effects of lower supplementation levels of organically complexed minerals (zinc, copper and manganese) versus inorganic forms on hematological and biochemical parameters in broilers. *Kafkas University. Veterinary Faculty Research*, 16(4), 553-559.
- [17] El Kady, M.F., Hassan, E.R., Radwan, I.A.E., Rabie, N.S., & Rad, M.M. (2012). Effect of probiotic on necrotic enteritis in chickens with the presence of immunosuppressive factors. *Global Veterinaria*, 9, 345-351. doi: 10.5829/idosi.gv.2012.9.3.63228.
- [18] El Sabry, M.I., Stino, F.K., & El-Ghany, W.A.A. (2021). Copper: Benefits and risks for poultry, livestock, and fish production. *Tropical Animal Health and Production*, 53, article number 487. doi: 10.1007/s11250-021-02915-9.
- [19] El-Adawy, H., Ahmed, M.F.E., Hotzel, H., Tomaso, H., Tenhagen, B.-A., Hartung, J., Neubauer, H., & Hafez, H.M. (2015). Antimicrobial susceptibilities of *Campylobacter jejuni* and *Campylobacter coli* recovered from organic turkey farms in Germany. *Poultry Science*, 94(11), 2831-2837. doi: 10.3382/ps/pev259.
- [20] European Convention for the Protection of Vertebrate Animals Used for Experimental and Other Scientific Purposes. (1986). Retrieved from <https://rm.coe.int/168007a67b>.
- [21] Fersunin, A.V., Semenenko, M.P., & Kuzminova, E.V. (2014). Complex use of mineral and vegetable raw materials for the production of drugs in veterinary medicine. *Scientific Journal of KubSAU*, 51, 97-99.
- [22] Hajjarmanesh, M., Zaghari, M., Hajati, H., & Ahmad, A. (2022). Effects of Zinc, Manganese, and Taurine on egg shell microstructure in commercial laying hens after peak production springer. *Biological Trace Element Research Follow Journal*, 102(1), article number 102283. doi: 10.1007/s12011-022-03388-z.
- [23] Hilal, E.Y., Elkhairey, M.A., & Osman, A.O. (2016). The role of zinc, manganese and copper in rumen metabolism and immune function: A review article. *Open Journal of Animal Sciences*, 6, 304-324. doi: 10.4236/ojas.2016.64035.
- [24] Hofmann, A.F., & Hagey, L.R. (2008). Bile acids: Chemistry, pathochemistry, biology, pathobiology and therapeutics. *Cellular and Molecular Life Sciences*, 65, 2461-2483. doi: 10.1007/s00018-008-7568-6.
- [25] ISO/IEC 17025:2005. (2006). Retrieved from [http://online.budstandart.com/ua/catalog/doc-page.html?id\\_doc=50873](http://online.budstandart.com/ua/catalog/doc-page.html?id_doc=50873).
- [26] Jaishankar, M., Tenzin, T.T., Anbalagan, N., Mathew, B.B., & Beeregowda, K.N. (2014). Toxicity, mechanism and health effects of some heavy metals. *Interdisciplinary Toxicology*, 7(2), 60-72. doi: 10.2478/intox-2014-0009.
- [27] Jegede, A.V., Oduguwa, O.O., Bamgbose, A.M., Fanimu, A.O., & Nollet, L. (2011). Growth response, blood characteristics and copper accumulation in organs of broilers fed on diets supplemented with organic and inorganic dietary copper sources. *British Poultry Science*, 52, 133-139. doi: 10.1080/00071668.2010.544714.
- [28] Kalinichenko, S.V. (2013). Current state of development and use of probiotic, prebiotic and synbiotic drugs. *Annals of the Mechnikov Institute*, 3, 5-2.
- [29] Kivit, S., Tobin, M.C., & Forsyth, C.B. (2014). Regulation of intestinal immune responses through TLR activation: Implications for pro- and prebiotics. *Frontiers in Immunology*, 5, 61-67. doi: 10.3389/fimmu.2014.00060.
- [30] Klaenhammer, T.R., Kleerebezem, M., Kopp, M.V., & Rescigno, M. (2012). The impact of probiotics and prebiotics on the immune system. *Nature Reviews Immunology*, 12, 728-734. doi: 10.1038/nri3312.
- [31] Kotsiumbas, I.Ya., Malyk, O.H., Zhyla, M.I., & Kosenko, Yu.M. (2012). Regarding the issue of conducting clinical trials of veterinary medicinal products. *The Animal Biology*, 14(1-2), 34-41.
- [32] Kovalenko, V., Kucheruk, M., & Chechet, O. (2022). Effect of the Biosapin probiotic and the Biolide disinfectant on the microclimate of poultry houses. *Ukrainian Journal of Veterinary Sciences: Scientific Journal*, 13(1), 44-51. doi: 10.31548/ujvs.13(1).2022.44-51.
- [33] Kovalenko, V.L. (2008). Current problems in the use of disinfectants. *Bulletin "Veterinary Biotechnology"*, (12), 78-91.
- [34] Laur, N., Kinscherf, R., Pomytkin, K., Kaiser, L., Knes, O., & Deigner, H-P. (2020). ICP-MS trace element analysis in serum and whole blood. *PLoS ONE*, 15(5), article number 0233357. doi: 10.1371/journal.pone.0233357.

- [35] Law of Ukraine No. 249 "On the Procedure for Carrying out Experiments and Experiments on Animals by Scientific Institutions". (2012, March). Retrieved from <https://zakon.rada.gov.ua/laws/show/z0416-12#Text>.
- [36] Li, L., & Yang, X. (2018). The essential element manganese, oxidative stress, and metabolic diseases: Links and interactions. *Oxidative Medicine and Cellular Longevity*, 2018, article number 7580707. doi: 10.1155/2018/7580707.
- [37] Lytvynenko, V., Ushkalov, V., Romanko, M., Melnyk, V., & Orobchenko, O. (2022). Clinical and biochemical assessment of a probiotic feed supplement application on calves. *Bulgarian Journal of Veterinary Medicine (BJVM)*, 2022. doi: 10.15547/bjvm.2444.
- [38] Melnyk, A.Yu. (2017). Some indicators of protein-lipid metabolism and the functional state of the liver in broiler chickens using the drug "Abetka for animals". *Scientific Bulletin of Veterinary Medicine*, 2, 69-78.
- [39] Moawad, A., Hotzel, H., Neubauer, H., Ehrlich, R., Monecke, S., Tomaso, H., Hafez, H.M., Roesler, U., & El-Adawy, H. (2018). Antimicrobial resistance in *Enterobacteriaceae* from healthy broilers in Egypt: Emergence of colistin-resistant and extended-spectrum  $\beta$ -lactamase-producing *Escherichia coli*. *Gut Pathogens*, 10, article number 39. doi: 10.1186/s13099-018-0266-5.
- [40] Nguyen, T.N.M., Hotzel, H., Njeru, J., Mwituria, J., El-Adawy, H., Tomaso, H., Neubauer, H., & Hafez, H.M. (2016). Antimicrobial resistance of *Campylobacter* isolates from small scale and backyard chicken in Kenya. *Gut pathogens*, 8(1), article number 39. doi: 10.1186/s13099-016-0121-5.
- [41] Osimani, A., & Clementi, F. (2016). The catering industry as a source of campylobacteriosis in Europe: A review. *International Journal Hospital. Management*, 54, 68-74. doi: 10.1016/j.ijhm.2016.01.006.
- [42] Romanovich, M., Vishchur, O., Kurtyak, B., & Smolyaninov, K. (2017). *Immunological reactivity and lipid peroxidation in broiler under the influence of BPS-44 drug and yeast Saccharomyces cerevisiae*. Lviv: National Academy of Agrarian Sciences of Ukraine Institute of Animal Biology.
- [43] Romanyuk, L.I., Kravets, N.Ya., Klymnyuk, S.I., Kopcha, V.S., & Dronova, O.Y. (2019). Antibiotic resistance of opportunistic microorganisms: Relevance, conditions of occurrence, ways of overcoming. *Infectious Diseases*, 4(98), 63-71. doi: 10.11603/1681-2727.2019.4.10965.
- [44] Sobolev, O.I., Gutyj, B.V., Kuzmenko, P.I., Riznychuk, I.F., & Kyshlaly, O.K. (2022). Selenium and its modeling effect on the body of young geese. *Scientific Messenger LNUVMB. Series: Agricultural Sciences*, 24(96), 462-468. doi: 10.32718/nvlvet-a9608.
- [45] Stefańska, I., Kwiecień, E., Piasecka-Jóźwiak, K., Garbowska, M., Binek, M., & Rzewuska, M. (2021). Antimicrobial susceptibility of lactic acid bacteria strains of potential use as feed additives – The basic safety and usefulness criterion. *Frontiers Veterinary Science*, 8, article number 687071. doi: 10.3389/fvets.2021.687071.
- [46] Stoyanovskiy, V.G., Kolomiets, I.A., Kamratzka, O.I., & Kolotnytskyi, V.A. (2012). Physiological state of the body of broiler chickens in critical age periods when using immunocorrective drugs against the background of vaccination. *Science release Lviv National University of Vet. of Medicine and Biotechnology named after S. Z. Gzhitskyi*, 14(3), 236-239.
- [47] The European Health Report. (2002). Retrieved from [https://www.euro.who.int/\\_data/assets/pdf\\_file/0007/98296/E76907.pdf](https://www.euro.who.int/_data/assets/pdf_file/0007/98296/E76907.pdf).
- [48] Thomas, C. (2020). Effect of peracetic acid solutions and lactic acid on microorganisms in on-line reprocessing systems for chicken slaughter plants. *Journal of Food Protection*, 83(4), 615-620. doi: 10.4315/0362-028XJFP-19-350.
- [49] Vlizlo, V.V., Slivinska, L.H., Maksymovych, I.A., Leno, M.I., & Halias, V.L. (2014). *Laboratory diagnostics in veterinary medicine: A guide*. Lviv: Afisha.
- [50] Wang, J., & Pantopoulos, K. (2011). Regulation of cellular iron metabolism. *Biochemical Journal*, 434, 365-381. doi: 10.1042/BJ20101825.
- [51] Zapata, R. (2016). *Effect of increasing levels of dietary zinc (Zn), manganese (Mn), and copper (Cu) from organic and inorganic sources on egg quality and egg Zn, Mn, and Cu content in laying hens* (Master's theses, Louisiana State University and Agricultural and Mechanical College, Louisiana, USA).
- [52] Zwolak, I., & Zaporowska, H. (2012). Selenium interactions and toxicity: A review. *Cell Biology and Toxicology*, 28(1), 31-46. doi: 10.1007/s10565-011-9203-9.

## Вплив комплексного застосування симбіотичних та біоцидних препаратів на метаболічний статус крові курчат-бройлерів

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**Анотація.** Використання у птахівництві пробіотичних препаратів, а також їх комплексів, є важливим кроком до підвищення резистентності, продуктивності птиці, а отже, і отримання екологічно чистої продукції. Метою роботи було вивчення впливу комплексної дії симбіотичних препаратів та біоцидних засобів шляхом дослідження клініко-біохімічних показників крові та мінерального обміну в організмі курчат-бройлерів за умов їх застосування відповідно розробленої схеми. Гематологічні, біохімічні та імунологічні показники крові досліджували загально-прийнятими методами, мікро- макроелементи – методом оптико-емісійної спектрометрії з індуктивно зв'язаною плазмою. Застосування запропонованого комплексу симбіотичних та біоцидних засобів у технології вирощування курчат-бройлерів сприяє активізації процесів еритропоезу, гемоглобіноутворення, відновленню показників білкового обміну та нормалізації мінерального статусу в фізіологічних межах, що свідчить про підсилення захисних сил організму, підвищення стійкості до стресових факторів і негативних умов зовнішнього середовища, та у подальшому буде позитивно впливати на ріст та продуктивність цільової птиці. Виражений вплив комплексного поєднання препаратів на організм курчат-бройлерів *experimental В* полягає у кращому засвоєнні багатьох неорганічних елементів (за підвищенням вмісту Calcium, Phosphorus, Cuprum, Ferrum і Selenium, Magnesium, Manganum); та відповідно зумовлює сталий розвиток метаболічних процесів через превалювання анаболічних над катаболічними (за підвищенням рівня загальних протеїнів на тлі фізіологічного збільшення кількості глобулінових фракцій; включаючи індукцію ендогенної детоксикаційної системи – за зниженням рівня утворення токсичних метаболітів пуринового обміну: сечової кислоти та креатиніну; зменшенням вмісту Chromium; нормалізацією процесів переамінування та уповільнення alkaline phosphatase activity) та імунобіологічних реакцій (за посиленням еритропоезу та гемоглобіноутворення; індукцією лізоцимної, бактерицидної та фагоцитарної активності) відповідно. Запропонована система вирощування молодняка птиці із застосуванням комплексу симбіотичних препаратів у поєднанні із біоцидними засобами сприяє синергічному впливу останніх та їх ефективну дію на організм експериментальних курчат-бройлерів, що веде до підвищення неспецифічної резистентності та відновлення метаболічних реакцій

**Ключові слова:** гематологічні показники, біохімічні показники, мінеральний обмін, природня резистентність, пробіотики, дезінфектанти



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## Histoarchitectonics of the Harderian gland of chickens in the post-vaccination period

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**Abstract.** Understanding the effect of vaccination on the body of chickens is impossible without exploring the morphology of the immune defence organs. The purpose of the study was to identify morphological changes in the Harderian gland of the Haysex Brown chickens aged 1, 15, 25, 50, 75, 100 and 120 days under the influence of vaccination. The following methods were used in the study: anatomical, histological, light-optical, morphometric, and statistical. Histological preparations of the Harderian gland of chickens of different ages (1, 15, 25, 50, 75, 100 and 120 days) of the vaccinated and unvaccinated groups were analysed. The features of the organ structure, its lymphoid structures and their types of forms were explored on histological preparations of the chicken Harderian gland. According to histological studies, it was established that this is a complex tubular lobular gland, which consists of secretory lobules with ducts. The interlobular connective tissue contains a significant number of lymphocytes, plasma cells, and other cells. In vaccinated chickens at 25 days of age, the presence of diffuse lymphoid tissue was noted, which was not observed in the control group, and at 50 days of age - the development of a nodular form of lymphoid tissue, the maximum number of which was observed at 100 days of age. In chickens of 75, 100, and 120 days of the age of the experimental group, the amount of lymphoid tissue in the Harderian gland increased, which was noted in the interlobular connective tissue and secretory lobules. It has been proven that the chicken gland, as a peripheral organ of immune defence, is developed at 50 days of age in both the control and vaccinated groups. The study of morphological changes in the Harderian gland of the poultry of different ages is an important tool for the development of preventive vaccination protocols in modern poultry farming. The results of the study should be considered when improving the technology of rearing and exploitation of chickens to ensure high vitality and, accordingly, productivity

**Keywords:** poultry, histological changes, lymphoid structures, secretory lobules, vaccination



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## INTRODUCTION

The ability to understand the function, pathology, and repair of organ systems is limited without knowledge of their normal structure. The immune defence organs of chickens consist of central and peripheral departments that work in concert to establish protective reactions against external pathogenic factors. The Harderian gland - a peripheral organ of the immune defence of chickens, which is involved in the activation and final differentiation of B-lymphocytes, and plasma cell proliferation. One of the main problems in poultry farming is infectious diseases. Vaccination is an important method of protecting poultry on farms.

Decreased vaccination efficiency and the development of immunodeficiency states are caused by the adverse effects of man-made factors. In many cases, immune disorders are caused by a defective immune system (Song *et al.*, 2021). In birds, a well-functioning immune system is of vital importance, namely, protection against pathogens, and the development of an immune response to vaccination (Nair, 2022). J. Madej *et al.* (2018) indicate that outbreaks of infectious diseases in poultry are associated with an overload of immune defences by virulent vaccine strains. Admittedly, any factor that reduces the immune response affects production parameters. Many factors, including infectious and non-infectious, cause immunosuppression in chickens (Gimeno & Schat, 2018).

Poultry is constantly exposed to various immune stresses, one of which is vaccination. The latter is used both to prevent infection and to reduce morbidity and mortality (Feng *et al.*, 2012). Multiple vaccinations are associated with high stress, which suppresses immune function (Kaab *et al.*, 2018). In poultry farms, inactivated vaccines are frequently used in high doses and repeatedly, with short intervals, which can cause stress to the immune system (Yang *et al.*, 2011; Feng *et al.*, 2012). Stress alters immune responses (Wilkinson *et al.*, 2011; Schat & Skinner, 2022). Immunosuppression in chickens is a very important factor but, therewith, is underestimated in the development of pathology (Schat & Skinner, 2022).

Combination vaccines are mostly preferred for the prevention of chicken diseases, as using a single dose of the drug against two or more infections reduces labour costs and mortality of the bird itself caused by vaccination (Yang *et al.*, 2016; Wit *et al.*, 2017). Mixed infections pose significant obstacles to the organisation of specific infectious disease prevention schemes, which is why a large number of immunisations are used, and the timing of their implementation frequently overlaps. However, immunisation is still the most crucial measure for controlling infections, although the frequent use of live vaccines has contributed to the evolution of new strains (Dey *et al.*, 2019).

According to the study by P. Saelao *et al.* (2018), the resistance of birds to specific diseases, in particular

Newcastle disease, is associated with the immune response of the Harderian gland. According to Frahm and Mohammadpour (2015) and Klecowska-Nawrot *et al.* (2015), the Harderian gland performs various functions: moisturising, cleansing, protecting, and being a source of pheromones. In this case, the immune response is particularly crucial (Jahan *et al.*, 2018). The Harderian gland, along with other peripheral immune defences, is involved in general and local immunity (Jahan *et al.*, 2018).

Microscopic examination of the Harderian gland demonstrated that it is a multilobular gland, with each lobe constructed of secretory acini (Beheiry *et al.*, 2020). The superficial cells of the glandular body produce serous secretion, and the deep cells produce mucous secretion (Mobini, 2012). In their studies, J. Klecowska-Nawrot *et al.* (2016) observed the presence of lymphoid cells in the glandular septa of birds and the secretory lobules, in particular, in their centre. A significant number of plasma cells were located in the glandular part of the organ. Plasma cells are in close contact with epithelial cells and closely envelop the glandular ducts (Nagy *et al.*, 2022). B. Mobini (2012) observed the presence of plasma cells in the interlobular connective tissue trabeculae, under the capsule, and near the main duct. A small number of plasma cells are located in the interlobular connective tissue partitions of the gland. In their studies, R. Beheiry *et al.* (2020) observed that glandular ducts are established from a single layer of prismatic epithelial cells surrounded by myoepithelial cells. Lymphoid cells, namely lymphocytes, macrophages, and granulocytes, are located in the subepithelial layer and the lumen of the glandular lobules (Rana *et al.*, 2020). A fairly large number of lymphocytes and plasma cells are located in the central and apical parts of the secretory lobules, the intercalated part of the gland (Klecowska-Nawrot *et al.*, 2016). Thus, the study of the morphological state of the immune system organs, including the Harderian gland, is of great importance.

The purpose of the study is to establish the cytological and histological features of the development of the Harderian gland of chickens at different stages of multivaccine prevention of infectious diseases. Objectives of the study: to determine the cytological and histological features of the Harderian gland of chickens of 1, 15, 25, 50, 75, 100, and 120 days of age; to determine the histoarchitectonics of the glandular gland of chickens at different vaccination periods.

## MATERIALS AND METHODS

For the experiment, a group of one-day-old Haysex Brown chickens was selected, and reared in the conditions of the "Solotvyn Poultry Farm" branch of the "Green Val" Limited Liability Company in the Staryi Solotvyn village, Berdychiv district, Zhytomyr region, which were divided into two groups of 70 chickens each: control (no vaccinations were

performed) and experimental (chickens were vaccinated according to the vaccination plan for repair stock). The study was conducted in 2020-2022.

The study was conducted in the educational and research clinical diagnostic laboratory of the Polissia National University. The material was the Harderian gland of chickens aged 1, 15, 25, 50, 75, 100, and 120 days selected from the control and experimental groups. The anatomical study included the slaughter and exsanguination of chickens, dissection and removal of organs. Chickens of 1, 15, 25, 50, 75, 100, and 120 days of age were slaughtered using the method of acute exsanguination under ether anaesthesia.

After slaughter, the Harderian gland of chickens was weighed on a Kern ACJ/ACS laboratory balance with an accuracy of 0.001 g. Histological studies were performed according to the generally accepted methods of tissue fixation and histological sections. For histological examination, the Harderian gland of chickens was selected, which was fixed in a 10-12% aqueous solution of neutral formalin for 48 hours, then washed with tap water for 24 hours, dehydrated with ethyl alcohol of increasing concentration (40%, 50%, 70%, 96%, 100%), followed by embedding in paraffin. Histological sections, up to 5-10  $\mu\text{m}$  thick, were made on a sledge microtome. To explore the morphology of cells and tissues, sections of the Harderian gland were stained with hematoxylin and eosin by the Van Gieson method.

To obtain objective data on the structural organisation of the chicken gland, morphometric methods of study were used. The study was performed using a Primo Star light microscope (Carl Zeiss, Germany) and Image Scope software.

Histological specimens were examined and photographed using a digital camera mounted in a Primo Star microscope (Carl Zeiss, Germany) and connected to a personal computer. Statistical processing of the study results was performed on a personal computer using variational and statistical methods using Statistica 6.0 (StatSoft

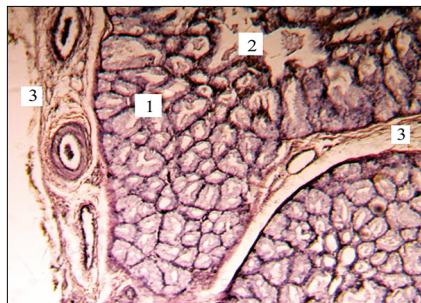
Inc., USA). The reliability of the data obtained was assessed by the Fisher's F test. The difference between the two values was considered significant at  $P < 0.05$ ,  $P < 0.01$ .

When working with animals, the provisions of Article 26 of the Law of Ukraine No. 3447-VI of 10/16/2012 "On the Protection of Animals from Cruelty" (Law of Ukraine No. 3447-VI), "General Ethical Principles for Animal Experiments" approved at the First National Congress on Bioethics (Reznikov, 2003), the requirements of the European Convention for the Protection of Vertebrate Animals Used for Research and Other Scientific Purposes (European Convention, 1986), and the Universal Declaration for the Humane Treatment of Animals (Universal Declaration, 2007).

## RESULTS AND DISCUSSION

The Harderian gland of the experimental and control chickens is located medial to the eyeball, between the orbit and periorbit. Organometric studies have established that the absolute weight of the Harderian gland of one-day-old chickens of the experimental and control groups practically did not vary, but in chickens of 15 days of age (after three times vaccination) this indicator significantly increased in the experimental group compared to the control and amounted to  $0.049 \pm 0.003$  g ( $P < 0.01$ ), while in the control group –  $0.041 \pm 0.002$  g. In addition, a significant increase in the absolute weight of the organ was observed in chickens 50 days of age. Therewith, in this age period, the maximum values of the absolute weight of the organ were noted, which amounted to  $0.095 \pm 0.003$  g ( $P < 0.01$ ) in the experiment and  $0.088 \pm 0.001$  g in the control.

The histological examination established that the gland is covered with a connective tissue capsule, from which the septa extend into the parenchyma of the organ. Van Gieson staining identified collagen fibres in the interlobular connective tissue (Fig. 1). The glandular capsule contains adipose tissue, and elastic, collagen, and reticular fibres.



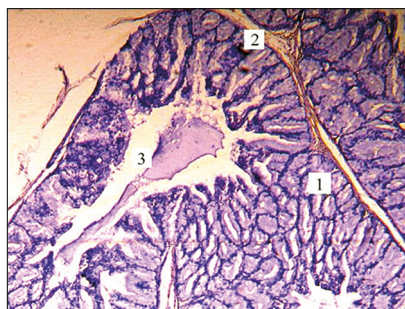
**Figure 1.** The microscopic structure of the Harderian gland of a 15-day-old chicken of the control group:  
1 – secretory lobe; 2 – lumen of the secretory lobe; 3 – interlobular connective tissue

**Note:** Van Gieson method. x 200

**Source:** photo by the authors

Partitions divide the gland parenchyma into secretory lobules. It was established that each lobule of

the organ has a cavity containing a secretion produced by the glandular cells (Fig. 2).



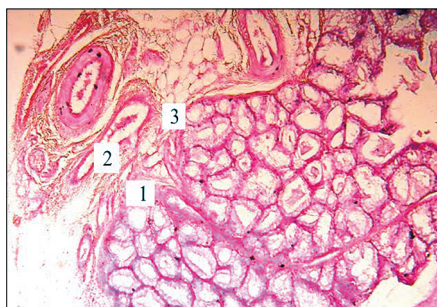
**Figure 2.** The microscopic structure of the Harderian gland of a 25-day-old chicken of the experimental group:  
1 – secretory lobe; 2 – interlobular connective tissue; 3 – lumen of the lobe with secretion

**Note:** Hematoxylin and eosin. x 200

**Source:** photo by the authors

The histological structure of the Harderian gland of the experimental chickens 15 days of age was almost the same as that of the control group. A histological examination of the gland of 15-day-old chickens established that the septa divide the gland into secretory

lobes. A large number of blood vessels are noted in the interlobular connective tissue (Fig. 3). The epithelium of the secretory lobules has a pronounced structure and is evenly coloured, and the ducts contain a small amount of secretion.



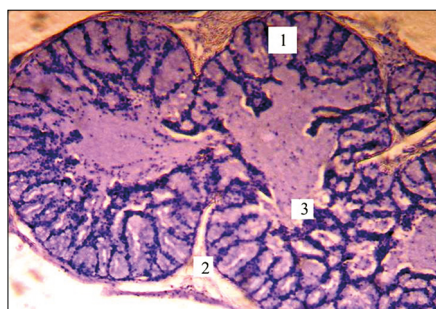
**Figure 3.** The microscopic structure of the Harderian gland of a 15-day-old chicken of the control group:  
1 – secretory lobe; 2 – blood vessels; 3 – interlobular connective tissue

**Note:** Hematoxylin and eosin. x 200

**Source:** photo by the authors

In the group of experimental chickens of 25 days of age (after five times of vaccination), plasma cells appeared in the gland and the appearance of lymphoid clusters was

noted, which were represented by diffuse lymphoid tissue (Fig. 4), and clusters of lymphoid cells were noted in the secretory lobules and the interlobular connective tissue.



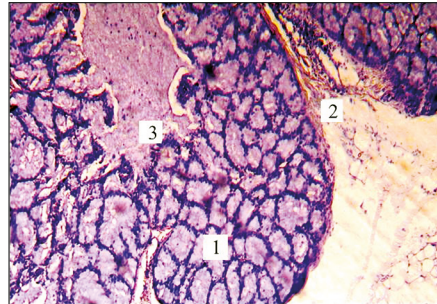
**Figure 4.** The microscopic structure of the Harderian gland of a 25-day-old chicken of the experimental group:  
1 – secretory lobe; 2 – interlobular connective tissue; 3 – diffuse lymphoid tissue

**Note:** Hematoxylin and eosin. x 200

**Source:** photo by the authors

Usually, lymphoid cells are located on the apical part of the glandular lobules. According to these studies, it is during this age period that the ducts of the secretory lobules contain a significant amount of secretion (Fig. 5). Therewith, it was noted that the acini

of the secretory lobules are lined with high columnar epithelium, and their lumens are elongated and somewhat irregular in shape. In this case, the height of the epithelium was  $2.49 \pm 0.11 \mu\text{m}$  and the width was  $1.06 \pm 0.03 \mu\text{m}$ .



**Figure 5.** The microscopic structure of the Harderian gland of the 25-day-old chicken of the experimental group:  
1 – secretory lobe; 2 – interlobular connective tissue; 3 – lumen of the lobe

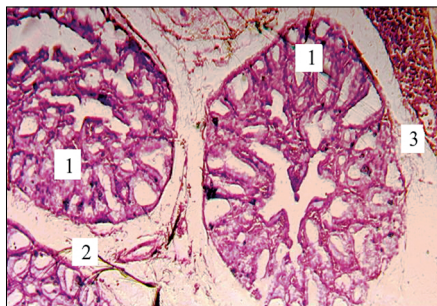
**Note:** Hematoxylin and eosin. x 200

**Source:** photo by the authors

In response to antigenic stimulation, nodular forms of lymphoid tissue appeared in the Harderian gland of the experimental group at 50 days of age (after six vaccinations) (Fig. 6). It was during this period that a significant increase in the thickness of lymphoid structures in vaccinated chickens was observed:

1.11 times ( $P < 0.05$ ) compared to unvaccinated chickens. Therewith, in unvaccinated chickens, this figure was  $20.5 \pm 4.1$  microns, and in vaccinated chickens –  $22.7 \pm 7.4$  microns.

At this age, the ducts of the secretory lobules contain a small amount of secretion (Fig. 7).



**Figure 6.** The microscopic structure of the Harderian gland of a 50-day-old chicken of the experimental group:  
1 – secretory lobe; 2 – interlobular connective tissue; 3 – nodular forms of lymphoid tissue

**Note:** Hematoxylin and eosin. x 100

**Source:** photo by the authors



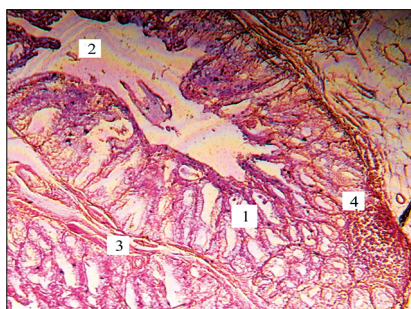
**Figure 7.** The microscopic structure of the Harderian gland of a 50-day-old chicken of the control group:  
1 – secretory lobe; 2 – interlobular connective tissue with diffuse lymphoid tissue; 3 – lumen of the lobe

**Note:** Hematoxylin and eosin. x 200

**Source:** photo by the authors

With the age of the bird, the content of the secretion in the lumen of the lobe decreases, and at 100 and 120 days of age, a small amount of it was determined, or not at all. In the chickens of the experimental group

of 75 days of age (after nine times vaccination), penetration of lymphoid tissue into the secretory lobules of the organ was noted (Fig. 8). It is during this age period that 90% of all planned vaccinations of pullets are performed.



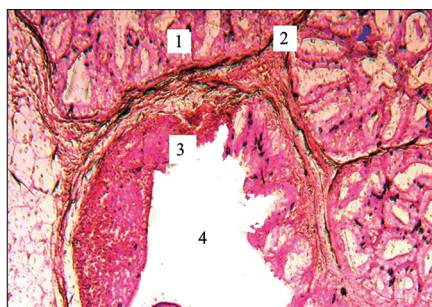
**Figure 8.** The microscopic structure of the Harderian gland of the 75-day-old chicken of the experimental group: 1 – secretory lobe; 2 – lumen of the lobe 3 – interlobular connective tissue; 4 – lymphoid tissue

**Note:** Hematoxylin and eosin. x 200

**Source:** photo by the authors

Histological examination of the Harderian gland of 100- and 120-day-old chickens demonstrated a significant proliferation of connective tissue and a significant amount of lymphoid tissue (Figs. 9, 10). Thus, in vaccinated chickens of 100 days of age, the number of nodular lymphoid tissue ranged from 2 to 4 pieces in

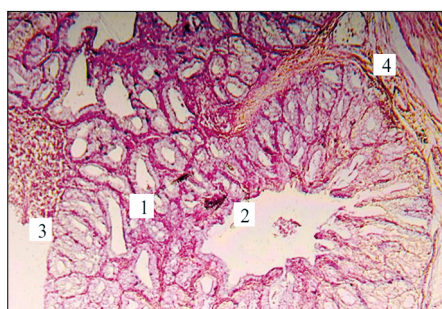
the microscope view (about 10, at 10), and in the control – 1-2 pieces. In addition, when exploring the location of immune formations, their presence was noted in the centre of the lobules, in some cases, the nodular form of lymphoid tissue occupied up to half the area of the secretory lobe of the gland.



**Figure 9.** The microscopic structure of the Harderian gland of a 100-day-old chicken of the experimental group: 1 – secretory lobe; 2 – interlobular connective tissue; 3 – a nodular form of lymphoid tissue; 4 – lumen of the lobe

**Note:** Hematoxylin and eosin. x 200

**Source:** photo by the authors



**Figure 10.** The microscopic structure of the Harderian gland of a 120-day-old chicken of the experimental group: 1 – secretory lobe; 2 – nodular form of lymphoid tissue; 3 – lumen of the lobe; 4 – interlobular connective tissue

**Note:** Hematoxylin and eosin. x 200

**Source:** photo by the authors

In chickens of 75, 100, and 120 days of age, an increase in lymphoid tissue was observed in the postvaccination period both in the interlobular connective tissue and in the secretory lobes of the organ. The results of the study confirm the results of R. Beheiry *et al.* (2020), S. Guralaska *et al.* (2020), who established that the Harderian gland is multilobular, and each lobe consists of secretory acini. In addition, the results of studies by M. Khan *et al.* (2007), according to which this organ of chickens is branched, tubular-alveolar.

In their studies, they noted that the outer capsule of the gland extends inward from the outer capsule of the gland. M. Khan *et al.* (2007) noted that the Harderian gland of the domestic chicken contains thin interlobular connective tissue septa. B. Mobini (2012) observed that the capsule of the organ is constructed of adipose tissue.

The results of the study complement the previous results of S. Guralaska *et al.* (2020), who noted that vaccination of chickens aged 20 days divided the gland parenchyma into secretory lobules. According to the authors, in chickens aged 40 days after vaccination, the appearance of lymphoid tumours, both diffuse and nodular, was noted. According to the results of the study, the diffuse form of lymphoid tissue in chickens in the postvaccination period was already observed at 25 days of age, and the nodular form – was in 50 days old chickens. M. Khan *et al.* (2007) noted in their studies the presence of individual secretory lobules with diffuse lymphoid tissue and nodules. B. Mobini (2012) observed single lymphoid nodules, but they were without germinal centres. P. Bejdic *et al.*, (2014); S. Guralaska & T. Budnik, (2020), S. Guralaska *et al.*, (2020, 2021) in the Harderian gland of chickens up to 40 days of age, no lymph nodes were observed. The gland is rich in densely arranged plasma cells and lymphocytes (Reem & Khattab, 2018; Nagy *et al.*, 2022). According to the results of a morphometric study of the Harderian gland, the number of lymphoid structures is significantly higher in vaccinated chickens. S. Guralaska & T. Budnik, (2020) in their research describe that the size of this gland correlates with the development of lymphoid tissue, since in chickens

in the post-vaccination period, the size of the secretory lobules does not vary significantly from these indicators of intact birds.

According to M.S. Deist & S.J. Lamont (2018), the lymphoid tissue of the gland is understudied, although it is important in local immunity. The Harderian gland has aroused and still arouses interest in the scientific community due to its morphofunctional and phylogenetic characterisation (Santillo *et al.*, 2020; Tybinka *et al.*, 2022). Summarising the results of the studies, it can be noted that the nature of morphological, histological, and morphometric changes in the Harderian gland of chickens in the postvaccination period is most pronounced at 50 and 75 days of age. The analysis of the studies indicates the specifics of the immune response to vaccination inherent in the chicken gland.

## CONCLUSIONS

Postvaccination changes in the histological structure and morphometric parameters in the organ of vaccinated chickens are conditioned upon both the age characteristics of the bird and the frequency of vaccination. Structural changes in the gland of vaccinated chickens indicate the development of humoral and cellular immunity.

It has been established that lymphoid structures of the chicken gland are represented by different levels of organisation of lymphoid tissue, with accumulations of lymphoid structures noted in the interlobular connective tissue and the secretory lobules of the gland. Vaccination stimulates the development of lymphoid tumours, resulting in an increase in their number and size in the glandular gland of chickens, especially at 75, 100 and 120 days of age compared to the control group.

It was established that the ducts of the secretory lobules of the Harderian gland of 25-day-old chickens contain the largest amount of secretion and the smallest amount – at 100 and 120 days of age. In the future, it is planned to conduct a comparative characterisation of the morphological features of the chicken Harderian gland using immunohistochemical and histochemical methods of research.

## REFERENCES

- [1] Beheiry, R.R., Ali, S.A., Aref, M., & Emam, H. (2020). Harderian gland of flying and non-flying birds: Morphological, histological, and histochemical studies. *The Journal of Basic and Applied Zoology*, 81, article number 35. doi: 10.1186/s41936-020-00175-x.
- [2] Bejdic, P., Avdic, R., Amidzic, L., Cutahija, V., Tandir F., & Hadziomerovic, N. (2014). Developmental changes of lymphoid tissue in the harderian gland of laying hens. *Macedonian Veterinary Review*, 37(1), 83-88. doi: 10.14432/j.macvetrev.2014.02.009.
- [3] Deist, M.S., & Lamont, S.J. (2018). What makes the harderian gland transcriptome different from other chicken immune tissues? A gene expression comparative analysis. *Frontiers in Physiology*, 9, article number 492. doi: 10.3389/fphys.2018.00492.
- [4] Dey, S., Pathak D.C., Ramamurthy, N., Maity, H.K., & Chellappa, M.M. (2019). Infectious bursal disease virus in chickens: Prevalence, impact, and management strategies. *Veterinary Medicine: Research and Reports*, 10, 85-97. doi: 10.2147/VMRR.S185159.
- [5] European Convention for the Protection of Vertebrate Animals Used for Experimental and Other Scientific Purposes. (1986, March). Retrieved from <https://rm.coe.int/168007a67b>.

- [6] Feng, Y., Yang, X.J., Wang, Y.B., Li, W.L., Liu, Y., Yin, R.Q., & Yao, J.H. (2012). Effects of immune stress on performance parameters, intestinal enzyme activity and mRNA expression of intestinal transporters in broiler chickens. *Asian-Australasian Journal of Animal Sciences*, 25, 701-707. doi: 10.5713/ajas.2011.11377.
- [7] Frahmmand, S., & Mohammadpour, A.A. (2015). Harderian gland in Canadian ostrich (*Struthio camelus*): A morphological and histochemical study. *Anatomy, Histology, Embryology*, 44(3), 178-185. doi: 10.1111/ahc.12123.
- [8] Gimeno, I.M., & Schat, K.A. (2018). Virus-induced immunosuppression in chickens. *Avian Diseases*, 62(3), 272-285. doi: 10.1637/11841-041318-Review.1.
- [9] Guralaska, S., & Budnik, T. (2020). The morphology of the harderian gland chicken's for vaccination and application of AvesstimTM. *Scientific Horizons*, 1(86), 79-88. doi: 10.33249/2663-2144-2020-86-1-79-88.
- [10] Guralaska, S., Kot, T., Dyshliuk, N., Zaika, S., & Khomenko, Z. (2021). Immune response of the harderian gland in chickens to infectious bronchitis coronavirus. *Agricultural Science and Practice*, 8(1), 58-66. doi: 10.15407/agrisp8.01.058.
- [11] Guralaska, S., Kot, T., Pinskyi, O., Sokalyuk, V., & Budnik, T. (2020). Morphofunctional condition of the harderian gland of chickens during the post-vaccine immunity to infectious bronchitis. *Agricultural Science and Practice*, 7(1), 32-39. doi: 10.15407/agrisp7.01.032.
- [12] Jahan, M.R., Islam, M.N., Khan, M.Z.I., Yanai, A., & Shinoda, K. (2018). Morphometry and expression of immunoglobulins-containing plasma cells in the Harderian gland of Birds. *Journal of Advanced Biotechnology and Experimental Therapeutics*, 1(2), 55-60. doi: 10.5455/jabet.2018.d10.
- [13] Kaab, H., Bain, M.M., & Eckersall, P.D. (2018). Acute phase proteins and stress markers in the immediate response to a combined vaccination against Newcastle disease and infectious bronchitis viruses in specific pathogen free (SPF) layer chicks. *Poultry Science*, 97, 463-469. doi: 10.3382/ps/pex340.
- [14] Khan, M.Z.I., Jahan, M.R., Islam, M.N., Haque, Z., Islam, M.R., & Kon, Y. (2007). Immunoglobulin (Ig)- containing plasma cells in the Harderian gland in broiler and native chickens of Bangladesh. *Tissue Cell*, 39, 141-149. doi: 10.1016/j.tice.2007.02.005.
- [15] Kleckowska-Nawrot, J., Gozdziwska-Harlaiczuk, K., Kowalczyk, A., Lukaszewicz, E., & Nowaczyk, R. (2016). Structural differences of the harderian gland between common pheasants (*Phasianus Colchicus Talischensis*) and hybrids of Italian amber and common pheasants. *Brazilian Journal of Science*, 18(2), 309-318. doi: 10.1590/1806-9061-2015-0059.
- [16] Law of Ukraine No. 3447-IV "On the Protection of Animals from Cruelty". (2006, February). Retrieved from <https://zakon.rada.gov.ua/laws/show/3447-15#Text>.
- [17] Madej, J.P., Wozniakowski, G., & Gawel, A. (2016). Morphology of immune organs after very virulent plus strain of Marek's disease virus infection in vaccinated hens. *Polish Journal of Veterinary Sciences*, 19(2), 325-335. doi: 10.1515/pjvs-2016-0040.
- [18] Mobini, B. (2012). Histological and histochemical studies on the Harderian gland in native chickens. *Veterinarni Medicina*, 57, 404-409. doi: 10.17221/6308-VETMED.
- [19] Nagy, N., Olah, I., & Vervelde L. (2022). Structure of the avian lymphoid system. *Avian Immunology*, 3, 11-44. doi: 10.1016/B978-0-12-818708-1.00027-0.
- [20] Nair, V. (2022). Tumors of the avian immune system. *Avian Immunology*, 3, 457-468. doi: 10.1016/B978-0-12-818708-1.00015-4.
- [21] Rana, J., Banubakode, S.B., Patel, S.K., Patil, D.V., & Agrawal, A. (2020). Gross morphological and morphometrical developmental studies on Harderian gland in chicken. *Journal of Animal Research*, 10(2), 325-328. doi: 10.30954/2277-940X.02.2020.23.
- [22] Reem, R.T., & Khattab, M.A. (2018). Macro anatomical and histochemical studies on the orbital glands (lacrimar and harderian glands) in strich (*Struthio camelus*). *International Journal of Advanced Research in Biological Sciences*, 5(1), 1-11. doi: 10.22192/ijarbs.2018.05.01.XXX.
- [23] Reznikov, O.G. (2003). General moral principles of animal experimentation. First National Congress on Bioethics. *Endocrinology*, 8(1), 142-145.
- [24] Saelao, P., Wang, Y., Gallardo, R.A., Lamont, S.J., Dekkers, J.M., Kelly, T., & Zhou, H. (2018). Novel insights into the host immune response of chicken Harderian gland tissue during Newcastle disease virus infection and heat treatment. *BMC Veterinary Research*, 14, article number 280. doi: 10.1186/s12917-018-1583-0.
- [25] Santillo, A., Chieffi Baccari, G., Minucci, S., Falvo, S., Venditti, M., & Di Matteo, L. (2020). The Harderian gland: Endocrine function and hormonal control. *General and Comparative Endocrinology*, 297, article number 113548. doi: 10.1016/j.ygcen.2020.113548.
- [26] Schat, K.A., & Skinner, M.A. (2022). Avian immunosuppressive diseases and immune evasion. *Avian Immunology*, 3, 387-417. doi: 10.1016/B978-0-12-818708-1.00018-X.
- [27] Song, B., Tang, D., Yan, S., Fan, H., Li, G., Shahid, M.S., Mahmood, T., & Guo, Y. (2021). Effects of age on immune function in broiler chickens. *Journal of Animal Science and Biotechnology*, 12, article number 42. doi: 10.1186/s40104-021-00559-1.

- [28] Tybinka, A., Zakrevska, M., & Shchebentovska, O. (2022). Morphometric and histochemical features of the harderian gland in rabbits with different types of autonomous regulation. *Macedonian Veterinary Review*, 45(2), 157-168. doi: 10.2478/macvetrev-2022-0024.
- [29] Universal Declaration on Animal Welfare. (2007, March). Retrieved from [https://web.archive.org/web/20090219033045/http://animalsmatter.org/downloads/UDAW\\_Text\\_2005.pdf](https://web.archive.org/web/20090219033045/http://animalsmatter.org/downloads/UDAW_Text_2005.pdf).
- [30] Wilkinson, K.G., Tee, E., Tomkins, R.B., Hepworth, G., & Premier, R. (2011). Effect of heating and aging of poultry litter on the persistence of enteric bacteria. *Poultry Science*, 90, 10-18. doi: 10.3382/ps.2010-01023.
- [31] Wit, J.J., Dijkman, R., Guerrero, P., Calvo, J., Gonzalez, A., & Hidalgo, H. (2017). Variability in biological behaviour, pathogenicity, protectotype and induction of virus neutralizing antibodies by different vaccination programmes to infectious bronchitis virus genotype Q1 strains from Chile. *Avian Pathology*, 46(6), 666-675. doi: 10.1080/03079457.2017.1346782.
- [32] Yang, X., Zhou, Y., Li, J., Fu, L., Ji, G., Zeng, F., Zhou, L., Gao, W., & Wang, H. (2016). Recombinant infectious bronchitis virus (IBV) H120 vaccine strain expressing the hemagglutinin-neuraminidase (HN) protein of Newcastle disease virus (NDV) protects chickens against IBV and NDV challenge. *Archives of Virology*, 161(5), 1209-1216. doi: 10.1007/s00705-016-2764-4.
- [33] Yang, X.J., Li, W.L., Feng, Y., & Yao, J.H. (2011). Effects of immune stress on growth performance, immunity, and cecal microflora in chickens. *Poultry Science*, 90, 2740-2746. doi: 10.3382/ps.2011-01591.

## Гістоархітектоніка гардерової залози курей в поствакцинальний період

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**Анотація.** Розуміння впливу вакцинації на організм курей неможливе без вивчення морфології органів імунного захисту. Метою дослідження було виявлення морфологічних змін гардерової залози курей кросу хайсекс браун віком 1, 15, 25, 50, 75, 100 та 120-добового віку за впливу вакцинації. В дослідження було використано наступні методи: анатомічні, гістологічні, світлооптичні, морфометричні, статистичні. Було проаналізовано гістопрепарати гардерової залози курей різного віку (1, 15, 25, 50, 75, 100 та 120 діб) вакцинованої та невакцинованої групи. Було досліджено на гістологічних препаратах гардерової залози курей особливості будови органу, його лімфоїдних утворень та їх типи форм. Згідно гістологічних досліджень було встановлено, що це складна трубчасто-часточкова залоза, яка складається із секреторних часточок із протоками. Міжчасточкова сполучна тканина містить значну кількість лімфоцитів, плазмоцитів та інших клітин. У вакцинованих курей 25-добового віку відмічали наявність дифузної лімфоїдної тканини, якої не відмічали у контрольній групі, а у 50-добовому віці – утворення вузликуватої форми лімфоїдної тканини, максимальна кількість яких спостерігається у 100-добовому віці. У курей 75, 100 та 120-добового віку дослідної групи в гардеровій залозі зростала кількість лімфоїдної тканини, наявність якої відмічали в міжчасточковій сполучній тканині та секреторних часточках. Було доведено, що гардерова залоза курей, як периферичний орган імунного захисту, формується в 50-добовому віці як контрольної, так і вакцинованої групи. Вивчення морфологічних змін у гардеровій залозі птиці різного віку є важливим інструментом формування протоколів профілактичних щеплень у сучасному птахівництві. Отримані результати дослідження необхідно враховувати при удосконаленні технології вирощування, експлуатації курей, щоб забезпечити високу життєдіяльність і відповідно продуктивність

**Ключові слова:** птиця, гістологічні зміни, лімфоїдні утворення, секреторні часточки, вакцинація



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## Monitoring studies of habitats of rare species and tree-dwelling insects in the Emerald Network sites

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**Abstract.** The pine stands of the Vyshcha Dubechnia State Forestry Enterprise in the Emerald Network sites Kyivske Reservoir UA0000094, Kyivske Podesennia UA0000233, Mizhrichynsky Regional Landscape Park UA0000047 are an important reserve that includes species and habitats of insects that are subject to protection. Most of the existing studies in this area were designed to identify and describe individual habitats, while xylophagous insects were not considered. The purpose of the research was to identify rare and endangered species of tree-dwelling insects in unique natural complexes. The research methods included reconnaissance surveys to determine the species composition of insects and their density. The surveys were conducted in 2020-2022, covering 33 plots with a total area of 50.5 hectares. The monitoring was performed through regular surveys of the territories, during which rare species listed in the Red Data Book of Ukraine and the Berne Convention resolution were identified. A desktop analysis of forestry materials was conducted. Rare species of insects subject to protection are encountered, but outside the areas where monitoring observations were conducted. These are mainly water, marsh, meadow lands, etc. Accounting for stem pests such as *Scolytinae* (small pine engraver *Tomicus minor* and pine shoot beetle *Tomicus piniperda*), *Buprestidae* (steelblue jewel beetle *Phaenops cyanea*) and *Cerambycidae* (pine sawyer *Monochamus galloprovincialis* and timberman beetle *Acanthocinus aedilis*). The identified populations of xylophagous insects are described as low to medium density, occurring only on very weakened trees, and species such as *Chrysobothris affinis*, *Cerambyx scopolii*, and *Scolytus ratzeburgi* are rare. The results of the study will serve as an informational base for the development of regional biodiversity conservation programs and the implementation of mechanisms for the sustainable use of forest resources

**Keywords:** protected categories, Bern Convention, Red Data Book of Ukraine, xylophagous insects, number of the young generation, degree of settlement



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## INTRODUCTION

At the current stage of developing a global system of knowledge about the composition and structure of the Earth's biodiversity, local research is gaining importance as a component of international environmental science. In this context, monitoring studies of habitats of rare species and tree-dwelling insects allow the development of a regional source of scientific data on the state of natural populations of these organisms as part of the biodiversity of forest ecosystems around the world. In 2019, 377 objects in Ukraine officially have the status of Emerald Network sites, 15 of which are located within the Kyiv region, which is about 20% of the region's area (Updated list, 2019). The Emerald Network ensures the preservation of areas of conservation importance and ecological value, and its establishment is a dynamic process that requires regular updating of information (Emerald Network of Ukraine; International Union; Polyanska *et al.*, 2017). Monitoring studies with the collection of up-to-date data on the distribution of insect species and habitats in the territory plays a key role.

Tree-dwelling insects are an integral part of forest biocenosis. The most common species are those that bore larval or adult burrows under the bark and in the wood of living and felled trees (Ukrainian Biodiversity Information, n.d.). Meshkova & Borysenko, (2018) demonstrate that there are insects that inhabit the so-called "dead" wood in the forest. Among these insects – "orderlies" that gradually destroy logging residues and dead shoots, annealed bark, stumps and parts of the trunk of storm and wind trees. Basile *et al.* (2020) note the importance of biodiversity conservation as the practice of storing trees with habitats for tree-related species, using assessment and monitoring of the available quantity and diversity of environmental resources for a wide range of animal taxa (and insects in particular) that live in forests. In the presence of "dead" wood, entomophagy and specific types of wood-destroying fungi develop intensively, which are potential competitors for pathogens dangerous to trees such as mushrooms and root sponges. Nordkvist *et al.* (2022) emphasise the potential for increasing species biodiversity in "dead" wood and note that this can result in a risk of increased frequency of insect phytophage outbreaks in pine forests. According to Vasylyshyn *et al.* (2022), the composition and structure of entomophagy and wood-destroying fungi at the local level significantly affect the volume and intensity of mortar accumulation. Soshenskyi *et al.* (2021) note that among the main catalysts for the development of "dead" wood in forest stands are natural and anthropogenic disturbances, among which forest fires play an important role.

Tree-dwelling insects belong to the trophic groups of xylophages and xylomycetophages. Meshkova *et al.* (2017) noted that xylophages are much more frequently monophagous than xylomycetophages, which is connected with the specific chemical composition of dead

tree tissues, inside which their larvae develop. The proportion of wood-dwelling xylophagous insects in the habitat is determined by the composition of forest-forming woody plants, and by the availability of a suitable substrate for larval life during the larval stage, which varies from one to several years. Kuzemko *et al.* (2018) noted that xylomycetophages develop in wood affected by xylotrophic fungi, which has lost a significant part of the specificity of its chemical composition, and their species diversity is determined mainly by the humidity of the habitat. Puzrina *et al.* (2021) explored that xylobiont beetles are one of the most important groups, together with bark beetles and bark beetles, constituting the foundation of complexes of wood-dwelling xylophages of woody plants. Due to their wide species and ecological diversity, they have an essential role in the destruction of wood at all stages of its decomposition.

The purpose of the research was to determine the list of insect species and habitats to be protected in the Emerald Network sites on the territory of the Vyshcha Dubechnia State Forestry Enterprise and to conduct monitoring studies of tree-dwelling insects in the region.

## MATERIALS AND METHODS

Monitoring for tree-dwelling insects was performed during the inspection of the territory where tree drying was observed due to the activity of entomological stem pests. To explore the distribution of tree-dwelling insects, the areas of the Vyshcha Dubechnia State Forestry Enterprise with the presence of xylophagous insects were examined, where model trees were selected. In 2020-2022, the monitoring surveys involved 33 plots with a total area of 50.5 hectares in the territory of Dovhobrodivka, Dachne, Central, Desnianske, Khutirske, and Prymorske forestries.

According to the geobotanical zoning, the territory of the Vyshcha Dubechnia State Forestry Enterprise is located in the left-bank part of Ukrainian Polissia (Eastern Polissia) in the Left-Bank Polissia district of oak-pine, oak, pine forests, floodplain meadows and eutrophic bogs of the Polissia subprovince of the Eastern European province of coniferous-broadleaf and broadleaf forests. According to the botanical zoning of Eastern Polissia, the territory of the enterprise is located in the Dnipro-Nizhnedesnyansky district (Gensiruk, 2002). The relief is described as flat, with elevations ranging from 100 to 120 meters above sea level, and the soil cover is dominated by soddy-weakly podzolic soils. The main forest-establishment species on the vast majority of the company's forestry land is Scots pine (*Pinus sylvestris* L.).

Identification of habitats of insects requiring protection within the Emerald Network sites (Kyivske Reservoir UA0000094, Kyivske Podesennia UA0000233, Mizhrichynskyi Regional Landscape Park UA0000047) and records of tree-dwelling insects was performed by analysing documents (Bern Convention..., 1979; Red Book of Ukraine.

Insects, 2009; Council of Europe, 1998), which describe emerald objects and their comparison with forestry materials, followed by a field reconnaissance survey of the territories. Therefore, the following research methods were used: analysis of forest inventory, planning and mapping materials, analysis of data on the Emerald Network sites and project materials of the territories of the Nature Reserve Fund of Ukraine, analysis of scientific publications, and field reconnaissance surveys of the territories.

These protected areas were designed to preserve rare and endangered species of plants and animals that have international protection status under Resolution 6 of the Bern Convention on the Conservation of Wild Flora and Fauna (Law of Ukraine, 1996), and to preserve natural habitats in Europe, as they contain natural habitats listed in Resolution 4 of the Bern Convention (Law of Ukraine, 1996). A general description of Emerald Network characteristics is presented in Table 1.

**Table 1.** Characteristics of the Emerald Network sites Kyivske Reservoir UA0000094, Kyivske Podesennia UA0000233, Mizhrichynskiy Regional Landscape Park UA0000047

Network object code	Network object name	Area, ha	The number of protected objects (species, habitats), units.					
			Dwellings	Birds	Mammals	Invertebrates	Plants	All taxa
UA0000047	Mizhrichynskiy Regional Landscape Park	102 434		37	2		5	
UA0000233	Kyivske Podesennia	20 621		28				
UA0000094	Kyivske Reservoir	54 422		24	2		2	

**Source:** Emerald Network of Ukraine, (n.d.)

Monitoring of rare species is conducted through regular surveys of the territories, during which rare species of animals and plants listed in the Red Data Book of Ukraine and the Annexes of the Bern Convention are identified (Council of Europe, 1998). The main period for identifying rare plant habitats is the period of active vegetation, which coincides with the period of the active life of rare invertebrate species. Valuable habitats of biotopic diversity (habitats of Emerald Network sites, virgin forests, quasi-virgin forests and old-growth forests) were identified through desk-based analysis of forest inventory materials, followed by a reconnaissance field survey and repeated refinement surveys during the growing season.

During the reconnaissance survey, a general overview of the study areas was performed using existing forest roads, clearings, sightings, etc. Detailed

surveys consisted of determining the species composition of xylophagous insects and settlement density, i.e. the average number of families of different species of tree-dwelling insects per square decimeter of trunk surface (Meshkova, 2020; Puzrina et al., 2021).

The average number of the main families of tree-dwelling insects per square decimeter of the trunk surface was determined after establishing the species composition on dry and drying trees. To determine the species composition of tree-dwelling insects, the model trees were cleared of knots by removing a 10 cm wide strip of bark on the trunk from the base to the top. In fixed areas of settlement for each species, counts were performed using pallets, calculating settlement density by the number of larvae per tree for mustelids and lacewings. The density of tree-dwelling insects was determined according to the indicators presented in Table 2.

**Table 2.** Criteria for assessing the density of tree-dwelling insects

Type	Settlement density, units · dm <sup>-2</sup>		
	Low	Average	High
Pine sawyer <i>Monochamus galloprovincialis</i>	0.2 and less	0.3-0.7	0.8 and more
Steelblue jewel beetle <i>Phaenops cyanea</i>	0.2 and less	0.3-0.5	0.6 and more
Capricorn beetle <i>Cerambyx scopolii</i>	0.1 and less	1.1-4.0	4.1 and more
Gold pit oak splendour beetle <i>Chrysobothris affinis</i>	0.7 and less	0.8-1.5	1.6 and more
Birch bark beetle <i>Scolytus ratzeburgi</i>	6.0 and less	6.1-8.0	8.1 and more

**Source:** Emerald Network of Ukraine, (n.d.)

The distribution of pine beetle (*strigonus*) in the plots was determined by the presence of adults fallen from damage during their additional feeding on pine shoots (Table 3).

**Table 3.** Intensity of additional nutrition and number of young beetles

Average number of shoots per 1 m <sup>2</sup>	Visual assessment of the number of shoots	Numbers of the young generation of beetles
up to 2	Singly	Mild
3-5	Everywhere	Increased
6-10	Plenty	High
Over 10	A great number	Excessive

**Source:** (Meshkova, 2020; Puzrina et al., 2021)

The methodological approaches used allowed for obtaining objective information on habitats in demand of protection within the Emerald Network sites and tree-dwelling insects of the region.

## RESULTS AND DISCUSSION

Potentially, the territory of the forest fund of the Vyshcha Dubechnia State Forestry Enterprise is suitable for the existence of habitats valuable from the environmental standpoint, and populations of several rare species of animals and plants, the necessity of conservation of which is determined by the national legislation of Ukraine and international environmental conventions (Bern Convention..., 1979; Law of Ukraine, 1996). Notably, due to the large size

of the Emerald Network's facilities, a significant part of their territories are outside the forest fund of the Vyshcha Dubechnia State Forestry Enterprise and include the territories of other forest users. In particular, the territory of Mizhrichynskiy Regional Landscape Park (UA0000047) overlaps with the company's territory by 8% or 2,412 hectares (stands of Desnianske Forestry), Kyivske Reservoir UA0000094 by 0.3% or 91 hectares (stands of Dachne Forestry), Kyivskye Podesennia UA0000233 by -1.4% or 420 hectares (stands of Lebedivske, Ostrovske and Desnianske Forestry). The explored sites partially belong to the territory of the Emerald Network sites Kyivske Reservoir UA0000094, Kyivske Podesennia UA0000233, Mizhrichynskiy Regional Landscape Park UA0000047 (Fig. 1).



**Figure 1.** Surveyed areas on the territory of the Vyshcha Dubechnia State Forestry Enterprise

**Source:** photo by the authors

The analysed list of insect species protected in the region allowed establishing that the largest share of species is represented by insects of the order *Lepidoptera* (38 species), *Hymenoptera* (22 species) and *Coleoptera* (21 species) (Bern Convention on the conservation of European wildlife and natural habitats, 1979; Red Book of Ukraine. Insects, 2009). From this list, the most numerous are the Red Data Book species endangered, vulnerable and rare and the species with the status of endangered *Buprestis spendens* goldstreifiger.

The Red Data Book species of the first category (endangered species, species conservation is unlikely if adverse factors continue to act) among *Lepidoptera* include *Polyommatus eroides eroides* blue butterfly, *Zygaena laeta* bloodword burnet, *Eudia spini* sloe emperor moth and *Parnassius apollo*, among *Hymenoptera* – *Bombus fragrans* fragrant bumblebee, among *Orthoptera* – *Bryodemella tuberculata* speckled grasshopper, among *Odonata* – *Leucorrhinia albifrons* dark whiteface. The majority of the region's fauna belongs to category II (vulnerable species

that may be classified as endangered in the future if adverse factors continue to affect them) and category III (rare species, small populations that are not currently classified as endangered or vulnerable, although they are at risk). Among the *Lepidoptera*, these categories include *Acherontia atropos* dead head moth, *Agria tau tau* emperor, *Apatura iris* purple emperor, *Catocala sponsa* dark crimson underwing, *Callimorpha dominula* scarlet tiger moth, *Coenonympha hero* scarce heath, *Coenonympha oedippus* false ringlet, *Cucullia argentea* green silver-spangled shark, *Eudia pavonia* small emperor moth, *Euphydryas aurinia* marsh fritillary, *Hemaris tityus* narrow-bordered bee hawk moth, *Hamearis lucina* duke of burgundy fritillary, *Hipparchia statilinus* tree grayling, *Hypodryas maturna* scarce fritillary, *Iphiclides podalirius* scarce swallowtail, *Lemonia taraxaci* autumn silkworm moth, *Limenitis populi* poplar admiral, *Lopinga achine* yellow-eyed satyr, *Lycaeides argyrognomon* reverdin's blue, *Lycaena dispar* large copper, *Maculinea arion* large blue, *Maculinea nausithous* dusky large blue, *Maculinea teleius* scarce large blue, *Marumba quercus* oak hawk moth, *Papilio machaon* old world swallowtail, *Pericallia matronula* large tiger moth, *Parnassius mnemosyne* clouded Apollo, *Proserpinus proserpina* willowherb hawkmoth, *Periphaenes delphinii* pease blossom, *Saturnia pyri* giant peacock moth, *Staurophora celsia* and *Zerunthia polyxena* southern festoon. The order *Hymenoptera* includes the following species of categories II and III: *Abia nitens* brilliant abia, *Anoplius samariensis* solitary wasps, *Archirilleya inopinata* black archirilleya, *Arge beckeri* Becker's aggrey, *Blasticotoma filiceti* fern blasticotoma, *Bombus argillaceus* clay bumblebee, *Bombus muscorum* moss bumblebee, *Bombus paradoxus* unusual bumblebee, *Bombus pomorum* bright bumblebee, *Caenolyda reticulata* reticulated cenolyda, *Discoelius zonalis* zonal discoelia, *Dolichomitus cephalotes* headed dolichomitus, *Formica rufa* red wood ant, *Ibalia rufipes* giant nutcracker, *Janus femoratus* red-legged janus, *Megarhyssa superba* pearl megarhyssa, *Melitturga clavicornis* mace melitturga, *Orussus abietinus* parasitic orussus, *Polochrum repandum* sapiga polochrum, *Siobla sturmi* balsam siobla, *Xylocopa violaceae* violet carpenter bee and *Xylosora valga* common xylocopa (carpenter bee).

Among the *Coleoptera* there are *Aromia moschata* musk beetle, *Bolbelasmus unicornis*, *Boros schneideri* smal skuggbagge, *Calosoma sycophanta* European calosoma beetle, *Carabus menetriesi* Menetrius' carabus, *Cerambyx cergo* great capricorn beetle, *Cucujus cinnabarinus* red flat bark beetles, *Dorcadion equestre* black dorcadion, *Emus hirtus* rove beetle staphylin, *Eurythyrea aurata* golden eurythyrea, *Lucanus cervus* deer beetle, *Neopristilophus depressus*, *Onthophagus furcatus* horned dung beetle, *Oryctes nasicornis* European rhinoceros beetle, *Osmoderma barnabita* hermit beetle, *Rosalia alpina* alpine moustache and hooded beetles *Stephanopachys linearis* linearis and striped *Stephanopachys substriatus* powderpost beetles in the region. The categories II and III of the *Odonata* dragonflies include *Aeschna viridis* green hawkler, *Anax imperator* emperor dragonfly, *Calopteryx virgo* beautiful demoiselle, *Cordulegaster boltoni* golden-ringed dragonfly, *Leucorrhinia pectoralis* large white-faced darter, *Stylurus flavipes* yellow-legged dragonfly, *Sympecma braueri* common winter damselfly, *Sympetrum pedemontanum* bandaged dragonfly, *Diptera*: *Asilus crabroniformis* robber fly and *Satanas gigas* giant robber fly, *Orthoptera*: one species of *Poecilimon ukrainicus* Ukrainian pollen-tail and two species of *Neuroptera*: *Mantispa styriaca* styrian mantis and *Myrmeleon formicarius* common ant lion.

Insects of Category IV (unspecified species that are classified as "endangered", "vulnerable" or "rare" in the absence of reliable information on their status) are the least numerous and include one species from the *Hymenoptera* *Scolia makulata* mammoth wasp and the *Homoptera* *Porphyropha polonica*, two species from *Coleoptera*, namely *Dytiscus latissimus* and *Graphoderus bilineatus* predaceous diving beetles.

Accordingly, not all species and habitats subject to protection at these sites are represented in the study area (Table 4). Some rare species of animals and plants and habitats from the list of those to be protected in the Emerald Network sites are found on the territory of the Vyshcha Dubechnia State Forestry Enterprise, however, outside the areas subject to monitoring observations of tree-dwelling insect species.

**Table 4.** List of insect species to be protected in the Emerald Network sites (Kyivske Reservoir UA0000094 (KR), Kyivske Podesennia UA0000233 (KP), Mizhrichynskiy Regional Landscape Park UA0000047 (MRLP))

Species name	Availability on the territory			Characteristic habitat
	KR	KP	MRLP	
Class <i>Coleoptera</i>				
<i>Boros schneideri</i>	+		+	Woods
<i>Dytiscus latissimus</i>	+		+	Woods
<i>Leucorrhinia pectoralis</i>	+			Meadows, reservoirs
<i>Graphoderus bilineatus</i>			+	Reservoirs
<i>Cerambyx cerdo</i>			+	Old woods
<i>Lucanus cervus</i>			+	Old woods

Table 4, Continued

Species name	Availability on the territory			Characteristic habitat
	KR	KP	MRLP	
<i>Stephanopachys linearis</i>			+	Woods
<i>Stephanopachys substriatus</i>			+	Woods
Class <i>Lepidoptera</i>				
<i>Hypodryas maturna</i>			+	Fields, meadows
<i>Lycaena dispar</i>		+		Fields, meadows

**Source:** developed by the authors based on the Red Book of Ukraine, (n.d.); International Union..., (2022); Godlevskaya, (2010)

The most numerous representatives of the protected categories in the study area are *Coleoptera*, in particular, in the forest stands of the Vyshcha Dubechnia State Forestry Enterprise there are populations of the *Cerambyx cerdo*, *Lucanus cervus*, *Osmoderma eremita*, *Boros schneideri* and hooded beetles: *Stephanopachys linearis* and *Stephanopachys substriatus*.

The species composition of wood-dwelling xylophagous insects in pine forests of different geographical regions is quite uniform. The least weakened trees are colonised by aggressive xylophagous species – *Tomicus piniperda* L. pine shoot beetle and *Tomicus minor* Hrtg. small pine engraver, *Ips acuminatus* Gill sharp-toothed bark beetle, *Phaenops cyanea* Fabr. steelblue jewel beetle and whisker moths of the genus *Monochamus*. As the

trees become weaker, they are colonised by less aggressive species: *Ips sexdentatus* Boern. six-toothed bark beetle, *Acanthocinus aedilis* L. timberman beetle, *Trypodendron lineatum* L. two-striped timber beetle, and severely weakened and drying trees are colonised by the longhorn beetle *Asemum striatum* L., *Rhagium inquisitor* L., *Spondylis buprestoides* L. and *Criophalus* L. The physiological damage to living trees caused by xylophagous insects is the destruction of the plant's conductive system by their movements, damage to individual organs during additional nutrition, and the transfer of pathogens. Technical damage caused by stem pests to trees and harvested timber is the presence of wide and deep passages ("wormholes") and, accordingly, a decrease in wood quality (Fig. 2).



**Figure 2.** Passages and exit holes of tree-dwelling insects on Scots pine

**Source:** photo by the authors

The monitoring surveys of the habitats of tree-dwelling insects covered Dovhobrodivka, Dachne, Central, Desnianske, Khutirske and Prymorske forests, and explored some areas of the territory of the Vyshcha Dubechnia State Forestry Enterprise for the presence of endangered and valuable insect species listed in the resolution of the Bern Convention and of international importance (Bern Convention, 1979).

During the survey of areas dominated by Scots pine, tree-dwelling insects were identified on a small part of the trees (no more than 5-10%), most of which belong to category IV (weakened by stem pests), such as Scolytinae (*Tomicus minor* and *Tomicus piniperda*), Buprestidae (*Phaenops cyanea*) and Cerambycidae (*Monochamus galloprovincialis* and *Acanthocinus aedilis*) (Table 5).

**Table 5.** Degrees of colonisation by tree-dwelling xylophagous insects

Type	Settlement density, pcs·dm <sup>-2</sup> / average number of shoots per 1 m <sup>2</sup>	Degree of infestation / number of young beetles
<b>2020</b>		
<i>Monochamus galloprovincialis</i>	0.2 ± 0.1	Low
<i>Acanthocinus aedilis</i>	0.4 ± 0.2	Low
<i>Phaenops cyanea</i>	0.5 ± 0.3	Average
<i>Scolytus ratzeburgi</i>	4.5 ± 0.2	Low
<i>Chrysobothris affinis</i>	0.5 ± 0.2	Low
<i>Cerambyx scopolii</i>	0.9 ± 0.2	Low
<b>2021</b>		
<i>Monochamus galloprovincialis</i>	0.6 ± 0.3	Average
<i>Acanthocinus aedilis</i>	0.4 ± 0.2	Average
<i>Phaenops cyanea</i>	0.5 ± 0.2	Average
<i>Tomicus minor</i>	2 (singly)	Normal (up to 5 thousand beetles per 1 ha)
<i>Tomicus piniperda</i>	2 (singly)	Normal (up to 5 thousand beetles per 1 ha)
<i>Scolytus ratzeburgi</i>	3.4 ± 1.4	Low
<i>Chrysobothris affinis</i>	0.5 ± 0.2	Low
<b>2022</b>		
<i>Monochamus galloprovincialis</i>	0.5 ± 0.4	Average
<i>Acanthocinus aedilis</i>	0.3 ± 0.1	Low
<i>Phaenops cyanea</i>	0.5 ± 0.2	Average
<i>Tomicus minor</i>	3 (everywhere)	Increased (10-20 thousand beetles per 1 ha)
<i>Tomicus piniperda</i>	3 (everywhere)	Increased (10-20 thousand beetles per 1 ha)
<i>Scolytus ratzeburgi</i>	3.8 ± 0.6	Low
<i>Cerambyx scopolii</i>	1.0 ± 0.1	Low
<i>Chrysobothris affinis</i>	0.7 ± 0.3	Low

**Source:** developed by authors

As can be seen from the above data, the population of *Monochamus galloprovincialis* in 2020 was characterised by a low degree of settlement at a density of 0.2 pcs·dm<sup>-2</sup>, in 2021 an average degree of settlement was recorded at a density of 0.6 and 0.5 pcs·dm<sup>-2</sup>, which indicates a potential increase in the number of the species. The population of *Phaenops cyanea* did not demonstrate a sharp increase in density during the study period. The detection of populations of *Tomicus minor* and *Tomicus piniperda* was performed by the presence of signs of pest feeding (the so-called “crown cutting”) and was first noted during the 2021 surveys, in 2022 an increased number of young beetles of the younger generation up to 10-20 thousand per 1 ha was detected, which can indicate a potential increase in numbers.

During the survey of plots with a share of deciduous trees (oak, birch, alder), the presence of *Buprestidae* (gold pit oak splendour beetle *Chrysobothris affinis*), *Cerambycidae* (capricorn beetle *Cerambyx scopolii*) and *Scolytinae* (birch bark beetle *Scolytus ratzeburgi*)

was noted on trees weakened by xylophagous insects (Fig. 3).

Notably, in the development of centres of mass reproduction of xylophagous insects, phases are developed, each of which is characterised by a specific number (Seredyuk & Puzrina, 2019), thus in the surveyed plantations, tree-dwelling insects are in the phase of concentration or increase in numbers due to the development of populations with low density. Meshkova *et al.* (2017) consider that chronic foci are characterised by a long period of development, a slightly increased level of insect abundance and the size of current mortality compared to healthy stands. Episodic foci, or outbreaks, are characterised by a relatively short (3-5 years) developmental period, elevated abundance levels and the size of the current mortality rate. With the development of chronic and episodic foci, reversible and irreversible reactions of stands are possible, usually, with mass reproduction of tree-dwelling insects, their destruction is observed. To

find new habitats and expand the food base, migration centres are usually established near mass breeding areas with excessive population density. In these foci,

the final dispersal of the population occurs within a few years and it returns to its original level of population size (Puzrina *et al.*, 2021).



**Figure 3.** Passages, larvae, flight and larval holes of tree-dwelling insects on deciduous tree species

**Source:** photo by the authors

According to research by Wyatt (2021), biodiversity loss is one of the main elements of damage caused by human activities. Wildlife protection and conservation policies such as the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention) are attempts to halt the loss of wildlife.

At the stage of establishing and implementing the Emerald Network, which is currently underway in Ukraine, the description of the natural complex of each particular territory is becoming increasingly important. Therewith, notably, the studies frequently involve phytosociological characterisation of habitats of populations of vascular plant species with protected status in Europe (Tymochko *et al.*, 2022) and clarification of data on the occurrence of species with protected status (Vasyliuk *et al.*, 2022) with a set of data on the occurrence of species listed in Annex I of Resolution 6 of the Bern Convention (1996) and the Red Data Book of Ukraine. The study by Bezrodnova *et al.* (2021) covered the botanical and forestry features of the Mozh River Valley as an Emerald Network site and determined the state of populations of rare vascular plant species of different zoological status. Studies by Kuzemko & Borysenko (2019), Kuzemko *et al.* (2018) on the design and conservation of the Emerald Network and the catalogue of habitats in Ukraine allow estimating the habitats of species with protected status.

The investigation of insect species classified as protected and monitoring studies allowed for summarising the available information on the habitats of rare and tree-dwelling insect species in the study area.

## CONCLUSIONS

During the research, the list of insect species to be protected was analysed and summarised, and monitoring of rare species and tree-dwelling insects in the Emerald Network sites (Kyivske Reservoir UA0000094, Kyivske Podessennia UA0000233, Mizhrichynskiy Regional Landscape Park UA0000047) in the Vyshcha Dubechnia State Forestry Enterprise was conducted. Insects subject to protection in forest stands include *Cerambyx cerdo*, *Lucanus cervus*, *Osmoderma eremita*, *Boros schneideri*, *Stephanopachys linearis* and *Stephanopachys substriatus*. Some rare species of insects and habitats from the list of those to be protected in the Emerald Network sites on the territory of the Vyshcha Dubechnia State Forestry Enterprise are located in areas that are indirectly related to the forest environment – water, marsh, meadow, etc.

During the survey of areas dominated by Scots pine, tree-dwelling insects with different settlement densities were identified, namely as small pine engraver *Tomicus minor* and pine shoot beetle *Tomicus piniperda*, steelblue jewel beetle *Phaenops cyanea*, timberman beetle *Acanthocinus aedilis* and pine sawyer *Monochamus*

*galloprovincialis*, and on deciduous woody species, gold pit oak splendour beetle *Chrysobothris affinis*, capricorn beetle *Cerambyx scopolii* and capricorn beetle *Scolytus ratzeburgi* were observed sporadically. In addition, recent climate change and the effects of military operations on the territory of Ukraine can cause significant changes in the structure of forests, potentially affecting

habitat opportunities and trophic resources for many species. Therefore, the prospects for further research will be monitoring changes in the species composition of insects of protected categories and tree-dwelling insects of the region in the Emerald Network sites (Kyivske Reservoir UA0000094, Kyivske Podesennia UA0000233, Mizhrichynskiy Regional Landscape Park UA0000047).

## REFERENCES

- [1] Basile, M., Asbeck, T., Jonker, M., Knuff, A.K., Bauhus, J., Braunschweig, V., Mikusiński, G., & Storch, I. (2022). What do tree-related microhabitats tell us about the abundance of forest-dwelling bats, birds, and insects? *Journal of Environmental Management*, 264, article number 110401. doi: 10.1016/j.jenvman.2020.110401.
- [2] Bern Convention "On the Conservation of Wild Flora and Fauna and Natural Habitats in Europe". (September, 1979). Retrieved from [https://zakon.rada.gov.ua/laws/show/995\\_032#Text](https://zakon.rada.gov.ua/laws/show/995_032#Text).
- [3] Bezrodnova, O., Tymochko, I., Senchylo, O., & Solomakha, V. (2021). Forest typological and botanical features of "Mozh river valley" as the object of Emerald Network. *Agroecological Journal*, 1, 54-67. doi: 10.33730/2077-4893.1.2021.227240.
- [4] Council of Europe. (1998). *Revised Annex I of Resolution 6 (1998) of the Bern Convention listing the species requiring specific habitat conservation measures (year of revision 2011)*. Retrieved from <https://rm.coe.int/1680746347>.
- [5] Emerald Network of Ukraine. (n.d.). Retrieved from <http://emerald.net.ua/>.
- [6] Gensiruk, S.A. (2002). *Forests of Ukraine*. Lviv: UkrDLTU.
- [7] Godlevskaya, O. (2010). *Fauna of Ukraine: Protective categories. Reference book*. Kyiv: National Ecological Center of Ukraine.
- [8] International Union for Conservation of Nature's Red List of Threatened Species. (2022). Retrieved from <https://www.iucnredlist.org/>.
- [9] Kuzemko, A., & Borysenko, K. (Eds.). (2019). *Design and conservation of the Emerald Network*. Kyiv: LAT & K.
- [10] Kuzemko, A., Didukh, Ya., Onishchenko, V., & Sheffer, Ya. (Eds.). (2018). *National biotope catalog of Ukraine*. Kyiv: FOP Klymenko Yu.
- [11] Law of Ukraine No. 436/96-BP "On Accession of Ukraine to the 1979 Convention on the Protection of Wild Flora and Fauna and Natural Habitats in Europe". (October, 1996). Retrieved from <https://zakon.rada.gov.ua/laws/show/436/96-%D0%B2%D1%80#Text>.
- [12] Meshkova, V.L. (2020). *Methodological guidelines for monitoring, recording and forecasting the spread of forest pests and diseases for the flat part of Ukraine*. Kharkiv: Planeta-print.
- [13] Meshkova, V.L., & Borysenko, O.I. (2018). Prediction for bark beetles caused desiccation of pine stands. *Forestry and Forest Melioration*, 132, 155-161. doi: 10.33220/1026-3365.132.2018.155.
- [14] Meshkova, V.L., Kochetova, A.I., Zinchenko, O.V., & Skrylnik, Yu.Ye. (2017). *Biology of multivoltine bark beetles species (Coleoptera: Scolytinae) in the North-Eastern Steppe of the Ukraine*. *The Bulletin of Kharkiv National Agrarian University. Series "Phytopathology and Entomology"*, 1-2, 117-124.
- [15] Nordkvist, M., Jonsson, S., Jonsell, M., & Klapwijk, M.J. (2022). Effects of retained dead wood on predation pressure on herbivores in young pine forests. *PLoS ONE*, 17(9), article number e0273741. doi: 10.1371/journal.pone.0273741.
- [16] Polyanska, K.V., Borysenko, K.A., & Pawlaczyk, P. (2017). *Involvement of the public and scientists in the design of the Emerald network in Ukraine*. Retrieved from <https://uncg.org.ua/zaluchennia-do-proektuvannia-emerald/>.
- [17] Puzrina, N.V., Meshkova, V.L., Myronyuk, V.V., Bondar, A.O., Tokarieva, O.V., & Boiko, H.O. (2021). *Monitoring of harmful organisms of forest ecosystems: Training manual*. Kyiv: NUBIP.
- [18] *Red Book of Ukraine. Insects*. (2009). Kyiv: Global Consulting.
- [19] Seredyuk, O.O., & Puzrina, N.V. (2019). *Assessment of the condition of European spruce trees in the NUBiP Botanical Garden of Ukraine*. *Journal of Forest and Wood Science*, 288, 125-134.
- [20] Soshenskyi, O., Zibtsev, S., Gumeniuk, V., Goldammer, J.G., Vasylyshyn, R., & Blyshchik, V. (2021). The current landscape fire management in Ukraine and strategy for its improvement. *Environmental & Socio-economic Studies*, 9(2), 39-51. doi: 10.2478/environ-2021-0009.
- [21] Tymochko, I.Ya., Solomakha, I.V., Shevchyk, V.L., Maliarenko, V.M., & Solomakha, V.A. (2022). Ecological and coenotic features of the Syrovatka river basin in the Emerald network of the Sumy region. *Environmental and Socio-Economic Studies*, 10(3), 12-21. doi: 10.2478/environ-2022-0013.
- [22] Ukrainian Biodiversity Information Network (n.d.). Retrieved from <https://www.ukrbin.com>.

- [23] Updated list of officially adopted Emerald sites. (2019). Retrieved from <https://rm.coe.int/updated-list-of-officially-adopted-emerald-sitesdecember-2019-/168098ef51>.
- [24] Vasyliuk, O., Prylutskyi, O., Marushchak, O., Kuzemko, A., Kutsokon, I., Nekrasova, O., Raes, N., & Rusin, M. (2022). An extended dataset of occurrences of species listed in Resolution 6 of the Bern Convention from Ukraine. *Biodiversity Data Journal*, 10, article number 84002. doi: 10.3897/BDJ.10.e84002.
- [25] Vasylyshyn, R., Lakyda, I., Lakyda, M., & Blyshchuk, V. (2022). Net primary production of forest vegetal biomass in Kyiv region. *Ecological Engineering and Environmental Technology*, 1, 38-45. doi: 10.12912/27197050/154908.
- [26] Wyatt, T. (2021). The Bern Convention and CITES in the UK: An exploration of norms and ambiguities. *Revista Catalana De Dret Ambiental*, 12(1), 1-34. doi: 10.17345/rcda3073.

## Моніторингові дослідження оселищ рідкісних видів та деревоживучих комах в об'єктах Смарагдової мережі

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**Анотація.** Соснові насадження Державного підприємства «Вищедубечанське лісове господарство» в об'єктах Смарагдової мережі Київське Reservoir UA0000094, Київське Подесення UA0000233, Mizhrichynskyi Regional Landscape Park UA0000047 є важливим резерватом, що включає види та оселища комах, які підлягають охороні. Більшість існуючих досліджень даної території були спрямовані на виявлення та опис окремих біотопів, тоді як комахи-ксилофаги залишилися поза увагою. Метою досліджень було встановлення рідкісних видів деревоживучих комах і таких, що перебувають під загрозою зникнення в унікальних природних комплексах. Методи досліджень включали рекогносцирувальні обстеження з визначенням видового складу комах, щільності їх поселення. Дослідження проводились упродовж 2020–2022 років, під час яких було охоплено 33 ділянки загальною площею 50,5 га. Моніторинг проведено шляхом регулярного обстеження територій, під час яких ідентифікувалися рідкісні види, які занесені до Червоної книги України та до резолюції Бернської конвенції. Здійснений камеральний аналіз лісотаксаційних матеріалів. Рідкісні види комах, що підлягають охороні трапляються, проте поза межами ділянок, на яких проводилися моніторингові спостереження. Це переважно водні, болотяні, лучні угіддя тощо. Обліковано стовбурових шкідників, таких як короїди Scolytinae (малий *Tomicus minor* та великий *Tomicus piniperda* соснові лубоїди), златки *Vuprestidae* (синя соснова златка *Phaenops cyanea*) та вусачі *Cerambycidae* (чорний сосновий вусач *Monochamus galloprovincialis* та сірий довговусий вусач *Acanthocinus aedilis*). Виявлені популяції комах-ксилофагів характеризуються низьким і середнім ступенем заселення, вони відмічені лише на дуже ослаблених деревах, а такі види як *Chrysobothris affinis*, *Cerambyx scopolii* та *Scolytus ratzeburgi* зустрічаються поодинокі. Результати дослідження будуть слугувати інформаційною основою для формування регіональних програм збереження біорізноманіття та впровадження механізмів сталого використання лісових ресурсів

**Ключові слова:** охоронні категорії, Бернська конвенція, Червона книга України, комахи-ксилофаги, чисельність молодого покоління, ступінь заселення



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## Sea buckthorn gall mite (*Aceria hippophaena* Nal.) in the orchards of sea buckthorn (*Hippophae rhamnoides* L.) and elements of its control agrotechnology

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**Abstract.** The presented research allowed for covering more features of new varieties of sea buckthorn, demonstrating the bio-ecological potential of their plants against damage by sea buckthorn gall mites, which is no less urgent today among the pests of sea buckthorn orchards. Thus, the species *Aceria hippophaena* Nalepa (synonym *Eriophyes hippophaenus* Nalepa), which belongs to the genus *Artacris* Keifer, 1970, is one of the dangerous representatives of four-legged mites towards plants of the genus *Hippophae* L. The purpose of the study was to explore the biological and ecological features of the above-mentioned mite and to develop measures for its control in buckthorn orchards. During the research, field and laboratory methods were used according to the methodology for conducting a qualification examination of forest plant species varieties for their suitability for distribution in Ukraine. It was established that the range of sea buckthorn gall mites covers large areas of Western, and Northwestern Europe and the northern regions of Eastern Europe, including Ukraine. In the conditions of the northern part of the Forest-Steppe of Ukraine, bioecological features and the level of damage of sea buckthorn gall mites on plants of the studied crop were explored in the gardens of early-, mid- and late-ripening varieties of sea buckthorn. It was noted that the sea buckthorn gall mite leads a hidden lifestyle, feeding inside the buds and leaves of buckthorn plants. It has been established that this parasite severely damages sea buckthorn plants in the initial stages of their ontogeny. In addition, severely damaged leaves are deformed, dry out prematurely and fall off, which frequently results in their death. It was established that the mite infestation and damage to plants of early-ripening varieties is less than that of medium- and late-ripening varieties. The practical value of the work is that it has been proven that two- or three-fold mechanised tillage in the inter-row and near-stem zone significantly reduces damage to sea buckthorn plants by gall mites

**Keywords:** four-legged mite, biological and ecological features, harmfulness, sea buckthorn plants, methods of pest control



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## INTRODUCTION

Among the many tasks in fruit gardening, the implementation of effective measures to protect plants from unfavourable biotic environmental factors is no less important to achieve the desired effect. Notably, due to the growing relevance of fruit crops, fruit plants that are not common in culture, including buckthorn (*Hippophae rhamnoides* L.), whose yield and fruit quality are not always stable and are frequently low and of poor quality caused by pests, are becoming increasingly important. The most probable pests that reduce the productivity and quality of sea buckthorn fruit include the following species: sea buckthorn honeydew (*Psylla hippophaeana* Cl.); sea buckthorn leaf miner (*Archips hippophaeana* Heyd.); sea buckthorn borer (*Zeuzera pyrina* L.); sea buckthorn fly (*Rhagoletes batava obscuriosa* Hering); southern grey weevil (*Tanymecus dulaticollis* Gyll.), odd silkworm (*Ocneria dispar* L.), sea buckthorn gall mite (*Eriophyes hippophaeanus* Nal.) etc.

Until 2007, no targeted research on the species and structural diversity of sea buckthorn pests was conducted in Ukraine. And due to the increase in the area under sea buckthorn orchards, the level of spread and harmfulness of phytophagous insects will increase. A serious pest of the sea buckthorn garden is the sea buckthorn gall mite (*Aceria hippophaena* Nalepa), whose parasitism on host plants results in gall development, a pathological process that is expressed in the growth and change of plant tissues. The above-mentioned species of four-legged mites is one of the representatives of numerous and functionally significant components of the entomofauna of cultivated and natural cenoses. The study of gall-developing pests is of practical importance since the latter significantly affects the condition of host plants by inducing galls on them. The range of *Aceria hippophaena* Nalepa covers large areas of Western, Northwest and North-Eastern Europe, including Ukraine (Goud *et al.*, 2021; GBIF Secretariat, 2019).

Faunal research on applied acarology is of great relevance. Acarology scientists note that new species of mites are increasingly appearing in census crops, which pose a threat to plants. For example, Hemmatzadeh-Khorshidabadi *et al.* (2022) note that new species of *Aceria* eryophyid mites have been identified on fodder plants, which they believe may worsen the condition of pasture producers. European scientists, in particular, Ripka *et al.*, (2021), have recorded three species of mites of the *Aceria* family that parasitise ornamental shrub species of *Salicaceae*. Other researchers (Elhalawany & Ueckermann, 2022) do not note any symptoms of damage to cultivated plants when detecting new tick species but emphasise that this is only in the initial stages of newly introduced plants.

Chinese scientists, in particular Wu *et al.* (2022), proved the harmfulness of the gall mite on goji plants. The establishment of vesicular galls, thickening and deformation of fodder crop leaves under the parasitic

influence of ticks was noted by Ruan *et al.* (2021). Frequently, gall mites are accompanied both by damage to vegetative organs and generative organs, in particular, to the fruits of European olive, as noted by Sergio & Moraes (2020). The double adverse effect of ticks on plants was noted by Albrecht *et al.* (2022), which manifests itself in the deterioration of the physiological state of crops and their damage by viral diseases. According to de Almeida Paz-Neto *et al.* (2022), gall development on plant leaves caused by mites provides shelter and an abundance of other pests, including moths.

Admittedly, the parasitising efficiency of ticks on cultivated plants depends on weather and climatic conditions and human economic activity. Changing temperature conditions, as noted by Karpicka-Ignatowska *et al.* (2021), determine the number of populations of erythrophoid ticks, which transmit viruses. As for economic activity, acaricides are a deterrent to tick development. According to Revynthi *et al.* (2022), chemical control of mites is an effective and cost-efficient measure in plant care. Although scientists Elhalawany *et al.* (2021) consider it expedient to identify their biological characteristics and timely use of acarifages in the fight against gall mites. Thus, the study of biological and ecological features of sea buckthorn gall mite and the development of measures for its control in sea buckthorn orchards is an urgent task that will allow early diagnosis of this pest and timely control measures.

The purpose of the research was to explore the bioecological features of *Aceria hippophaena* Nal. and to develop measures to reduce its populations in the orchards of buckthorn.

## MATERIALS AND METHODS

Observations of sea buckthorn plant damage by gall mites were conducted at the experimental plots of the Institute of Horticulture of the National Academy of Agrarian Sciences of Ukraine and its research network during 2019-2021. Sea buckthorn varieties of Ukrainian breeding were used to explore the degree of plant damage: Rannya, Morkvyana, Osoblyva and Adaptyvna. Observations and records of plants were performed in May-September according to the methods (Methodology of qualification examination..., 2016; Grynyk *et al.*, 2020). The leaves of the studied varieties were sampled twice during the growing season. In early September, 50 leaves were collected from 5 trees of each variety (10 leaves x 5 replicates). The material was collected in cloth bags. A label was attached to each sample of a particular sea buckthorn plant variety, indicating the sample number, place and time of collection. Visual inspections were performed in the basal part and on the periphery along the entire vertical of the plant crown. Each leaf sample was placed in plastic bags with the date and place of collection, and the name of the variety, and stored in a refrigerator at 3-4°C for stepwise

analysis in the laboratory. The assessment of damaged plants by gall mites was performed in points according to the percentage of leaf surfaces covered with galls: 0 points (0%) – resistant; 0.1-1.0 points (up to 1%) – relatively resistant; 2.1-3.0 (11-30%) – moderately damaged; 3.1-4.0 (31-50%) – severely damaged; 4.1-5.0 (over 50%) – very severely damaged.

The study used sources for the identification and biological characteristics of sea buckthorn gall mites (Kamali *et al.*, 2016), economic importance and distribution (Orlova-Bienkowskaja, 2016). Statistical data processing was performed using the computer program Statistica-6.0.

## RESULTS AND DISCUSSION

The gall mite spreads both under the influence of abiotic factors – wind, precipitation, and biological factors – insects, birds, and anthropogenic factors. Damage to sea buckthorn by the gall mite in the northern part of the Forest-Steppe has been observed in individual plants since 2017, but, in 2020, significant outbreaks of mass reproduction were noted locally for the first time. It was established that the mite leads a hidden life, feeding inside the buds and leaves. It is particularly harmful to young, vigorously growing trees or bushes. Severely damaged leaves are deformed, dry out prematurely and fall off, which frequently results in their death (Moskalets *et al.*, 2021). In 2020, the pest infested both the leaves of some sea buckthorn varieties and the shoots, which resulted in their distortion and weakened growth. Thus, the degree of damage, dynamics and duration of infestation of young leaves by gall midge depends on the varietal characteristics of the host plant.

During the growing season of sea buckthorn plants, four-legged mites multiply very quickly. In the Northern Forest-Steppe, the peak number of gall mites reaches the end of June - beginning of July, and, depending on weather conditions, the peak number of larvae living in leaves is observed about a month later – in the second decade of August. It has been established that in hybrid sea buckthorn nurseries, gall mites are mainly spread with planting material – seedlings and cuttings.

Reserves for these phytophages are wild forms of sea buckthorn, which were selected as breeding sources of economically valuable traits in the protective strips of orchards, forest belts, and fallow lands, where ticks accumulate intensively, as in shady, wind-protected habitats, where they, in turn, get from orchards.

It was established that these pests are distributed by the wind at a distance of 50 meters or more and get into new sea buckthorn plants grown from cuttings that have been treated with acaricides with rain splashes. According to the literature (Moskalets *et al.*, 2021), the sea buckthorn gall mite is microscopic (female body length 0.2-0.22 mm, male about 0.18 mm), its body is milky white, wormlike, ringed, dorsal and abdominal half-rings are the same in width, with two pairs of legs. On the underside of the body, three pairs of abdominal bristles are arranged one after the other, and at the end, there is one pair of tail bristles.

Adult females hibernate under the covering scales of the kidneys, one of which can contain from one to several thousand individuals. In early spring, during the period of bud swelling, mites begin to lay eggs in wintering areas in the galls they form. The hatching larvae feed inside the buds, as a result of which the leaves of sea buckthorn plants that have not yet opened are completely covered with gall swellings. When the first leaves bloom (at an average daily temperature of more than 9°C and an average air humidity of 75-80%), females of the new spring generation appear, which, together with old females, move to young leaves, then concentrate mainly near the central vein, make injections and drain cell sap, eventually form galls in these places, and inhibit plant growth and development. Subsequent generations establish galls on the leaves, where the females lay eggs and the larvae that hatch from them settle on young leaves and shoots. The rounded-flat, 2-8 mm long galls first become light green, then yellowish-brown or brown, and eventually blacken and dry out. In case of severe damage, the leaves can be completely covered with galls (Fig. 1).



**Figure 1.** Leaves of sea buckthorn plants of the *Adaptyvna* variety damaged by sea buckthorn gall mite, the experimental field of the Institute of Horticulture of the National Academy of Sciences of Ukraine, 2020

**Source:** photo by the authors

In the autumn (September-October), ticks move under the scales of newly established buds, where they

feed for some time and remain for the winter. In a temperate or temperate continental climate, sea buckthorn

gall mite develops in 2-3 generations during the growing season of sea buckthorn plants, and this gives a signal to take preventive countermeasures in sea buckthorn breeding agrocenoses. It is known that gall mites quickly develop pesticide-resistant populations, and therefore it is necessary to alternate drugs belonging to different chemical groups.

Notably, four-legged ticks are actively destroyed by their natural enemies – predatory ticks or acarifages (*Amblyseius finlandicus* Oudemans, 1915; *Paraseiulus soleiger* Ribaga, 1904), *Phytoseiulus persimilis* (Athias-Henriot, 1957), thrips (*Scolothrips sexmaculatus* Pergande, 1891), blind bugs (*Blepharidopterus angulatus* Fallén, 1807; *Macrolophus nubilis* V. Putshkov, 1978), goldenrod (*Chrysoperla carnea* Stephens, 1836), phytopathogenic fungi (*Beauveria bassiana* (Balsamo-Crivelli), Vuillemin, 1912; *Streptomyces avermectinius* Takahashi et al., 2002) that cause epizootics, which should be

considered when planning protective measures in sea buckthorn orchards.

Sea buckthorn gall mite (*Aceria hippophaena* or *Eryophyes hippophaenus* Nalepa, 1898) belongs to the genus *Aceria* Keifer, 1944. This pest has a spindle-shaped body of light yellow colour, which is approximately 0.25 mm long. Both adults and larvae have two pairs of limbs. The phytophage damages the buds and leaves of the plant. Tumours or swellings (galls) with a diameter of 0.5 cm appeared on the affected leaves, inside which the mites are located.

Since sea buckthorn gall mites are microscopic, about 0.25 mm long, and cannot be seen with the naked eye, it is easier to determine their presence by the galls on the plants. In this regard, studies were conducted to determine the presence of leaves with galls and to group sea buckthorn varieties by resistance to the above pest (Table 1).

**Table 1.** Time of detection and recording of the presence of leaves of sea buckthorn plants with galls *Eryophyes hippophaenus* Nal

No.	Variety name	Maturity group	Damaged sea buckthorn leaves (presence of galls)*									
			2019				2020				Average for 2 years	
			I decade of June		I decade of September		I decade of June		I decade of September		I decade of June	I decade of September
			%	Points	%	Points	%	Points	%	Points	%	%
1	Rannya	em	3	1.3	15	2.2	0.5	1.0	10	2.0	1.7	12.5
2	Morkvyana	mm	7	1.7	23	2.6	5.1	1.5	17	2.3	6	20.0
3	Osoblyva	lm	6	1.6	30	3.0	5.2	1.5	48	3.9	5.5	39.0
4	Adaptyvna	lm	11	2.0	33	3.1	15	2.2	56	5	13	44.5

**Note:** em – early maturing, mm – medium maturing, lm – late maturing

**Source:** developed by authors

Table 1 demonstrates that plants of the late-maturing varieties Osoblyva and Adaptyvna are heavily damaged by gall mites (in 2020, the leaves and stems of Adaptyvna

plants were damaged by more than 50%), while plants of the early-maturing varieties Rannya and mid-season Morkvyana are medium resistant or moderately damaged (Fig. 2).

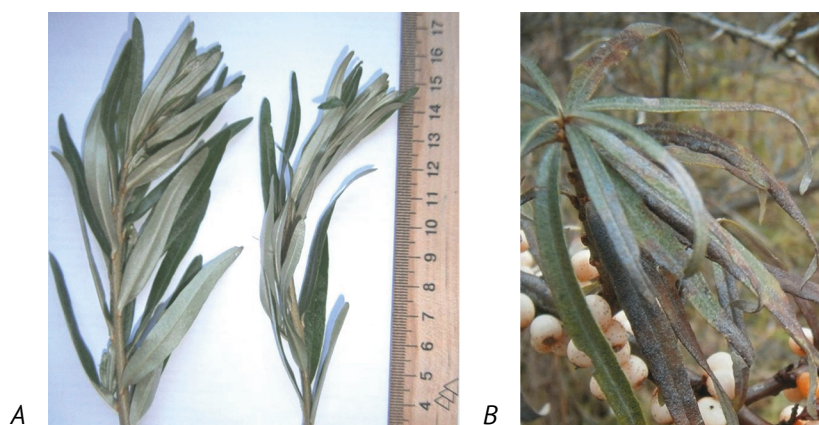


**Figure 2.** Leaves of plants of the variety Morkvyana with signs of damage by sea buckthorn gall mite

**Source:** photo by the authors

To reduce the spread and damage caused by gall mites to sea buckthorn plants, several measures were implemented in 2020-2021, including various types of pruning (mainly rejuvenation (stimulating the growth of young healthy shoots), restoration (restoring a neglected bush) and regulatory (maintaining the crown in good condition, thinning, lighting)) and near-trunk and inter-row soil loosening. According to the results of the surveys on the presence of sea buckthorn with galls on the leaves after the agricultural measures, it became clear that the number of galls on the leaves significantly depends on a particular measure, regardless of the variety and maturity group.

For sea buckthorn varieties, regardless of the maturity group, using elements of agricultural technology both individually and in combination significantly reduces damage to plants by sea buckthorn gall mites. In particular, this can be observed most clearly for the early maturing variety Rannya, the mid-maturing variety Morkvyana, and the late maturing variety Osoblyva (Fig. 3). Notably, the plants of these varieties are more tree-like, in particular, this is characteristic of the Rannya variety, thus, in the agricultural technology of cultivation, it is advisable to compulsorily loosen the soil near the trunk (Table 2).



**Figure 3.** Leaves of sea buckthorn plants of the variety Osoblyva in the 1 decade of June (A) and 1 decade of September (B) without signs of galls caused by sea buckthorn gall mite

**Source:** photo by the authors

**Table 2.** Damage to sea buckthorn leaves by gall mites depending on the maturity group and elements of agricultural technology

No.	Variety name	Maturity group	Agri-event							
			Control		Cutting branches		Soil loosening		Cutting + Soil loosening	
			Average data on damage to sea buckthorn leaves (presence of galls), %							
			I decade of June	I decade of September	I decade of June	I decade of September	I decade of June	I decade of September	I decade of June	I decade of September
1	Rannya	em	0.5	10	0.7	9.5	0.4	0.8	0.8	0.9
2	Morkvyana	mm	5.1	17	3.7	12.2	3.2	4.4	3.5	2.5
3	Osoblyva	lm	5.2	48	4.1	32.3	21.5	15.8	11.7	9.5
4	Adaptyvna	lm	15	56	9.8	35.8	19.4	23.5	8.8	10.6

**Note:** em – early maturing, mm – mid-season, lm – late maturing; \*\* $p \geq 0.95$

**Source:** developed by authors

The Morkvyana and Adaptyvna varieties are bushy, and annual soil loosening near the trunk promotes additional development of root shoots, which increases the possibility of overwintering of adult mites. But the plants of these varieties are more plastic to cutting, and, thus, annual gradual cutting of branches during the spring and summer period contributes to the reduction of sea

buckthorn gall mite damage and increase of productivity, including fruit size and weight.

In 2021, all studied varieties were less damaged compared to 2020 (Table 3). In particular, the early maturing sea buckthorn variety Rannya is the least damaged by the gall mite due to the absence of gall development compared to all the varieties studied.

**Table 3.** Damage to sea buckthorn leaves by gall mites depending on the maturity group and elements of cultivation technology, 2021

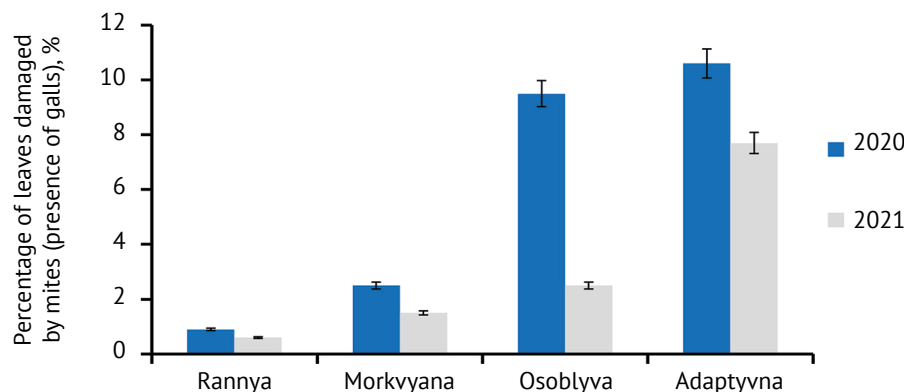
No.	Variety name	Maturity group	Agri-event							
			Control		Cutting branches		Soil loosening		Cutting + Soil loosening	
			Average data on damage to sea buckthorn leaves (presence of galls), %							
			I decade of June	I decade of September	I decade of June	I decade of September	I decade of June	I decade of September	I decade of June	I decade of September
1	Rannya	em**	2,2**	10.3	1.9	3.5	0.7	1.8	0.5	0.6
2	Morkvyana	mm	4.9	27.5	1.7	2.9	2.6	9.4	0.5	1.5
3	Osoblyva	lm	8.5	51.5	3.1	2.7	4.5	4.8	1.1	2.5
4	Adaptyvna	lm	15.4	47.2	3.8	5.5	6.4	13.5	2.5	7.7

**Note:** em – early maturing, mm – mid-season, lm – late maturing; \*\* $p \geq 0.95$

**Source:** developed by authors

According to Table 3, the introduction of such elements of agrotechnology as pruning and soil loosening and their application in combination significantly reduces the development of galls in the fall by 66.0, 82.5 and 94.2%, respectively. For the Morkvyana variety, these data are 89.5, 65.8 and 94.5%, for the late-maturing varieties Osoblyva and Adaptyvna – 94.8, 90.7 and

95.1 and 88.3, 71.4 and 83.7%, respectively. It was established that the annual application of the elements of agricultural technology for cutting and loosening the soil in the complex contributes to a significant reduction in damage to the leaves of sea buckthorn plants (the presence of gall development, etc.), as evidenced by the comparison of data for 2020 and 2021 (Fig. 4).



**Figure 3.** The presence of gall development on the leaves of sea buckthorn plants under the complex application of different types of cutting and soil loosening by years, %

**Source:** developed by the authors

Biological infestations of agricultural pests can have adverse effects, including reduced yields and economic costs. Thus, collecting and analysing information on biological and ecological features, in particular the ability to spread, is crucial in the model prediction of pests, in particular for the sea buckthorn gall mite. As Kuczyński *et al.* (2020) note, exploring the dispersal process is particularly challenging when the emphasis is on microscopic organisms such as gall mites, which are passively dispersed. Thus, the study of the appearance of gall development on the leaves and stems of different sea buckthorn varieties was the most simplified way to study the ecological and biological characteristics of

the mite to the host plant. Authors Li *et al.* (2016), Mukweho *et al.* (2017), and Bondareva *et al.* (2022) conducted surveys of gall development on plants as signs of pest parasitism, including gall mites, which allows assessing the level of leaf damage and the condition of plants in general. Thus, the conducted surveys of gall mites on sea buckthorn do not contradict the methodology of research on the ecological and biological features of gall mites. The research notes that mites' vital activity depresses the condition of plants. These aspects are noted in several works by other researchers (Kołataj, 2019; Yanovskyi *et al.*, 2021), which demonstrate that tick parasitism results in plant stunting.

The research discusses the efficiency of agrotechnical measures to control pests. In addition, Moskalets et al. (2021; Melnyk, 2016) highlight these issues and confirm their feasibility. Other scientists and producers, in particular Yanovskyi et al. (2022), consider it advisable to apply biological measures, in particular, to conduct a maximum of 10 sprayings of trees (bushes) with biological acaricides, in particular in mother and graft plantations. Some authors (Omelchuk, 2019; Grynyk, 2020) suggest not considering the possibility of significant colonisation of plants by the mite, and selecting cuttings for propagation, disinfecting them with a 0.4% working concentration of Actofit, 0.2% emulsion concentrate when treated for 20-30 minutes, or a 0.5% solution, but for 8-11 minutes. Yanovskyi et al. (2022) propose to use chemical acaricides in the nursery system when 2-3 or more generations of the above pest are developing, during budding, before or after flowering, after harvesting and when deutergynous females of the mite leave the galls to settle and overwinter in the diapause stage. Similar studies by the authors of the presented research on using biological and chemical preparations, and using increased doses of mineral fertilisers, which, by the way, contribute to the osmotic pressure of cell sap in the leaves, which adversely affects the life of the mite, are only at the initial stages and are ongoing in sea buckthorn orchards for mite control. Using tick-resistant varieties is suggested by De Lillo et al. (2018), who consider reducing economic costs in the cultivation of fruit and berry crops.

In general, the study of the vital activity of gall mites on many fruit and berry crops is relevant, since failure to consider this dangerous biotic factor in the 3-6<sup>th</sup> year of plant life results in a decrease in their drought and frost resistance, and a decrease in yield by 50 per cent or more.

Thus, due to the significant demand for sea buckthorn and the increase in its area in Ukraine, it is necessary to control the manifestation of pests, in particular the population of gall mites, which as obligate parasite feeds on the buds, leaves and shoots of plants, causing nutrient deficiencies and various physiological disorders and can probably transmit pathogenic organisms to plants, in particular of a viral nature, with serious consequences for the healthy state and productivity of plants of the above crop, which from the economic standpoint makes sea buckthorn gall mite a dangerous phytophagous pest of sea buckthorn orchard.

## CONCLUSIONS

The biological and ecological features of sea buckthorn gall mites in the orchards of buckthorn in the Northern Forest-Steppe of Ukraine were determined. In the third decade of May to September-October, depending on the ripeness group of the sea buckthorn variety, signs of the harmfulness of *Eryophyes hippophaenus* Nal mites can be observed on infected plants. The usual symptoms are curling of the leaf edges, the appearance of blisters or growths 5 mm in diameter on the upper side of the blade, and discolouration of the leaf blade. Parasitism of sea buckthorn gall mites distorts annual shoots of plants.

In hybrid nurseries of the studied crop, sea buckthorn gall mites are mostly spread with planting material (seedlings, cuttings). In addition, it was noted that wild forms of sea buckthorn serve as reserves for gall mite populations, in protective strips of gardens, forest belts, and fallow lands, where they localise numerous populations. In the conditions of the northern part of the Forest-Steppe of Ukraine in sea buckthorn orchards, the most characteristic manifestation of sea buckthorn gall mite damage was observed on late-maturing varieties compared to early- and mid-maturing ones. It was established that the absence of planned cutting and soil loosening measures significantly increases the signs of tick parasitism on sea buckthorn plants, regardless of the variety maturity group.

Studies allowed suggesting that there may be a specific relationship between gall mites and endophytic fungi (in particular, the genera *Alternaria*, *Cladosporium*, *Botrytis*, *Mycosphaerella*, etc.), which was observed in late summer on plants 5-7 years old, manifested in the appearance of light or dark brown spots around the galls, and the death and loss of leaf tissue and the development of perforated leaves. Depending on the age of the plants, shaping, rejuvenating (in spring), restoring (in spring, summer) and regulating (in summer) cutting and soil loosening, mainly for tree-like plants, significantly reduces damage to the leaf surface and annual stems of sea buckthorn plants by gall mites.

Further widespread targeted introduction of sea buckthorn varieties in agroecosystems will increase the yield with the introduction of medium-resistant varieties and elements of cultivation technology, including mandatory shaping, thinning and sanitary cutting and soil loosening, which will reduce the number of pests, including sea buckthorn gall mites in sea buckthorn orchards.

## REFERENCES

- [1] Albrecht, T., White, S., Layton, M., Stenglein, M., Haley, S., & Nachappa, P. (2022). Occurrence of wheat curl mite and mite-vectored viruses of wheat in Colorado and insights into the wheat virome. *Plant Disease*, 106(10), 2678-2688. doi: 10.1094/PDIS-02-21-0352-RE.
- [2] Bondareva, L., Chumak, P., & Zavadzka, O. (2022). Degree of damage of pear varieties (*Pyrus communis* L.) and control *Eriophyes pyri* Pgst. (Acari: Eriophyoidea) in the Fomin Botanical Garden. *Biological Systems: Theory and Innovation*, 13(1-2), 80-88. doi: 10.31548/biologiya13(1-2).2022.003.
- [3] de Almeida Paz-Neto, A., Costa Calvet, E., da Silva Melo, J.W., de Lima, D.B., Guedes Correa Gondim Júnior, M., & Janssen, A. (2022). Mite damage provides refuges and affects preference and performance of a subsequent herbivorous moth. *Journal of Applied Entomology*, 146(8), 930-941. doi: 10.1111/jen.13013.

- [4] De Lillo, E., Pozzebon, A., Valenzano, D., & Duso, C. (2018). An intimate relationship between eriophyoid mites and their host plants – A review. *Frontiers in Plant Science*, 9, article number 1786. doi: 10.3389/fpls.2018.01786.
- [5] Elhalawany, A.S., & Ueckermann, E.A. (2022). Description of three new species and a new record of eriophyid mites (*Acari: Eriophyoidea*) from Egypt. *Systematic and Applied Acarology*, 27(6), 1000-1019. doi: 10.11158/saa.27.6.3.
- [6] Grynyk, I., Moskalets, V., & Moskalets, T. (2020). *Methodological aspects of evaluating sea buckthorn genotypes according to ecological and adaptive indicators for priority areas of selection*. Kyiv: Publishing house "Agrarian Science".
- [7] Hemmatzadeh-Khorshidabadi, H., Lotfollahi, P., Mehrvar, A., Shiri, J., & De Lillo, E. (2022). Two new *Aceria* species (*Acari: Eriophyidae*) from Meshginshahr rangelands, Iran. *Systematic and Applied Acarology*, 27(9), 1687-1701. doi: 10.11158/saa.27.9.1.
- [8] Kamali, H., Sirjani, M., & Bazoobandi, M. (2016). Biological characteristics of almond bud mite, *Acalitus phloeocoptes* (Nalepa) (*Acari: Eriophyoidea*) in Khorasan-e-Razavi Province. *Plant Pest Research*, 6(2), 63-74.
- [9] Karpicka-Ignatowska, K., Laska, A., Rector, B.G., Skoracka, A., & Kuczyński, L. (2021). Temperature-dependent development and survival of an invasive genotype of wheat curl mite, *Aceria tosichella*. *Experimental & Applied Acarology*, 83(4), 513-525. doi: 10.1007/s10493-021-00602-w.
- [10] Kołataj, K. (2019). Observations of leaf blister mites from the genus *Eriophyes* (*Acari: Eriophyoidea*) infesting pear trees of Konferencja cultivar. *Progress in Plant Protection*, 59(2), 106-118. doi: 10.14199/ppp-2019-015.
- [11] Kuczyński, L., Radwańska, A., Karpicka-Ignatowska, K., Laska, A., Lewandowski, M., Rector, B.G., Majer, A., Raubic, J., & Skoracka, A. (2020). A comprehensive and cost-effective approach for investigating passive dispersal in minute invertebrates with case studies of phytophagous eriophyid mites. *Experimental & Applied Acarology*, 82(1), 17-31. doi: 10.1007/s10493-020-00532-z.
- [12] Li, F.-L., Li, T., Su, J., Yang, Sh., Wang, P., & Zhang, J.-P. (2016). Temporal and spatial differences in gall induction on *Haloxylon* by *Aceria haloxylonis* (*Acari: Eriophyidae*) in the Gurbantüggüt Desert. *Systematic and Applied Acarology*, 21(12), 1670-1680. doi: 10.11158/saa.21.12.8.
- [13] Melnyk, S.I. (Ed.). (2016). *Methodology for examination of varieties of decorative, medicinal and essential oil, forest plant varieties for suitability for distribution*. Kyiv: UIEVP.
- [14] Methodology of qualification examination of varieties of forest plant species. (2016). Retrieved from <https://sops.gov.ua/uploads/page/5a5f413bb9be6.pdf>.
- [15] Moskalets, V., Grynyk, I., Moskalets, T., Shevchuk, I., Pelekhatyi, V., Marchenko, A., Liubych, V., & Moskalets, Z. (2021). *Bioecological features of phytophagous pests in agroecosystems of sea buckthorn and scientifically based methods of their control*. Kyiv: Publishing House "Center of Educational Literature". doi: 10.36495/2312-0614.2021.2.12-18.
- [16] Mukwevho, L., Olckers, T., & Simelane, D.O. (2017). Establishment, dispersal and impact of the flower-galling mite *Aceria lantanae* (*Acari: Trombidiformes: Eriophyidae*) on *Lantana camara* (*Verbenaceae*) in South Africa. *Biological Control*, 107, 33-40. doi: 10.1016/j.biocontrol.2017.01.009.
- [17] Omelchuk, S.T. (Ed.). (2019). *Pesticides*. Kyiv: Interservice.
- [18] Orlova-Bienkowskaja, M.Ja. (2016). Is it possible to distinguish alien species of beetles (Coleoptera) from native ones? *Entomological Review*, 96(3), 318-331. doi: 10.1134/S001387381603009X.
- [19] Revynthi, A.M., Cruz, L.F., Canon, M.A., Crane, J.H., Kendra, P.E., Mannion, C., & Carrillo, D. (2022). Evaluation of abamectin as a potential chemical control for the Lychee Erinose Mite (*Acari: Eriophyidae*), a new invasive pest in Florida. *Florida Entomologist*, 105(1), 1-5. doi: 10.1653/024.105.0101.
- [20] Ripka, G., Kiss, E., Kontschán, J., & Szabó, Á. (2021). Three new gall mite records (*Acari: Acariformes: Eriophyoidea*) from Hungary and supplementary description of two species. *Acta Phytopathologica et Entomologica Hungarica*, 56(1), 81-98. doi: 10.1556/038.2021.00005.
- [21] Ruan, H.-Y., Hu, L., Cui, X.-Y., & Tan, M.-C. (2021). Three new species of eriophyoid mites (*Acari: Eriophyoidea*) associated with *Melicope pteleifolia* from Guangxi Zhuang Autonomous Region, China. *Systematic and Applied Acarology*, 26(2), 353-366. doi: 10.11158/saa.26.2.3.
- [22] Sergio, L., & Moraes, G.J.De. (2020). Redescription of *Aceria oleae* (Nalepa, 1900) (*Acari: Eriophyidae*) using SEM, life cycle and damage caused to leaves and fruits of *Olea europaea* cv. *arauco* in La Rioja province, north-western Argentina. *Systematic and Applied Acarology*, 25(11), 2003-2017. doi: 10.11158/saa.25.11.7.
- [23] Wu, P., Ge, Y., He, J., Haseeb, M., & Zhang, R. (2022). Positive interactions between *Aceria pallida* and *Bactericera gobica* on goji berry plants. *Insects*, 13(7), article number 577. doi: 10.3390/insects13070577.
- [24] Yanovskiy, Y.P., Sukhanov, S.V., Krykunov, I.V., Bandura, L.P., & Fomenko, O.O. (2021). Apple gall mite (*Eriophyes mali* Nal): Features of biology and measures to limit its harmfulness in apple orchards of Ukraine. *Quarantine and Plant Protection*, 4, 3-9. doi: 10.36495/2312-0614.2021.4.3-9.
- [25] Yanovskiy, Y.P., Sukhanov, S.V., Krykunov, I.V., Bandura, L.P., & Fomenko, O.O. (2022). Pear gall mite (*Eriophyes pyri* Pgst.): Features of biology and measures to limit its harmfulness in pear plantations of Ukraine. *Quarantine and Plant Protection*, 1, 21-26. doi: 10.36495/2312-0614.2022.1.21-26.

**Обліпиховий галовий кліщ (*Aceria hipporphaena* Nal.)  
в садах обліпихи крушиноподібної (*Hipporphae rhamnoides* L.)  
та елементи агротехнології його контролю**

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**Анотація.** Представленні дослідження дозволили більше розкрити особливості нових сортів обліпихи крушиноподібної, демонструючи біоекологічний потенціал їх рослин щодо пошкодження обліпиховим галовим кліщем, який сьогодні є не менше актуальним серед шкідників обліпихового саду. Тому вид *Aceria hipporphaena* Nalera (синонім *Eriophyes hipporphaenus* Nalera), який належить роду *Artacris* Keifer, 1970, є одним із небезпечних представників чотириногих кліщів по відношенню до рослин роду *Hipporphae* L. Мета роботи передбачала дослідження біоекологічних особливостей вищезазначеного кліща і розробки заходів його контролю в садах обліпихи крушиноподібної. Під час досліджень використовували польовий і лабораторний методи згідно методики проведення кваліфікаційної експертизи сортів лісових видів рослин на придатність до поширення в Україні. З'ясовано, що ареал обліпихового галового кліща охоплює значні території країн Західної, Північно-Західної Європи та північні райони Східної Європи, в т.ч. України. В умовах північної частини Лісостепу України в садах ранньо-, середньостиглих і пізньостиглих сортів обліпихи крушиноподібної досліджували біоекологічні особливості і рівень шкодочинності обліпихового галового кліща на рослинах досліджуваної культури. Відмічено, що обліпиховий галовий кліщ веде прихований спосіб життя, харчується всередині бруньок і листків рослин обліпихи крушиноподібної. З'ясовано, що цей паразит сильно шкодить рослинам обліпихи на початкових етапах їх онтогенезу. При чому сильно пошкоджені листки деформуються, передчасно всихають і опадають, що нерідко призводить до їх загибелі. Встановлено, що заселеність і пошкодження кліщем рослин ранньостиглих сортів менша, ніж середньо- і пізньостиглих. Практична цінність роботи полягає в тому, що було доведено, що дво- або трьохкратний механізований обробіток ґрунту в міжрядді і у при стовбуровій зоні, формуюча, омолоджувальна (навесні), відновлювальна (навесні, влітку) і регулююча (влітку) обрізки істотно зменшують пошкодження рослин обліпихи галовим кліщемі

**Ключові слова:** чотириногий кліщ, біоекологічні особливості, шкодочинність, рослини обліпихи, способи контролю шкідника

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## Varietal features of elements of organic soybean cultivation technology

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**Abstract.** A reliable element of the technology for growing environmentally friendly products of early-ripening soybean varieties, and improving soil fertility, is the introduction of environmentally friendly growing technology based on the optimal functioning of the symbiotic system, without using mineral fertilisers, in particular nitrogen and pesticides. The purpose of the research was to explore the effect of inoculation of seeds of diverse soybean varieties with nitrogen-fixing and phosphorus-mobilising preparations, foliar fertilisation and their combination on growth, plant development and productivity under organic cultivation technology. The research was conducted using generally accepted methods, the field method, and the method of statistical evaluation of results. Experimental studies have established that with the introduction of high-yielding soybean varieties, using post-harvest residues (straw, stubble and root residues), green manure and legumes in a short rotation crop rotation, 136 kg of nitrogen and 142 kg of biologically fixed nitrogen enters the soil. It was demonstrated that seed treatment with AgriBacter inoculant and soybean fertilisation with Nanovit Super complex fertiliser ensures a yield of 4.08 t/ha for Mentor and leaves almost 30% of biological nitrogen in the soil. Studies have demonstrated that an integrated approach to the treatment of soybean seeds of the tested varieties with AgriBacter and Phosphoenterin inoculants, a strain of bacteria that decomposes hardly soluble organic phosphates, which in turn contributes to better nutrition of soybean plants, development of the root system, and has a positive effect on the development of an optimal stem density of 410-490 thousand units/ha, which provides an increase in the yield of soybean varieties by 1.88 t/ha. It was established that simultaneous inoculation of seeds and foliar feeding of soybeans with the biologically active complex Nanoactiv with the addition of magnesium sulfate in the macrostage BBCH 60-63 provides the highest yield of Niagara variety – 4.08 t/ha and Astor variety – 2.88 t/ha. Thus, in a short-rotation 4-season crop rotation saturated with legumes, using nitrogen-fixing, phosphorus-mobilising preparations and the active growth stimulator Nanovit Super + Magnesium sulfate, soil fertility increases and the nitrogen content in the soil doubles. The scientific results can become the foundation for improving soil fertility, which will ensure sustainable yields in organic soybean cultivation

**Keywords:** varietal composition, soil fertility, seed inoculation, foliar fertilisation, soybean yield



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## INTRODUCTION

Maintaining soil fertility by using biological air nitrogen in organic soybean cultivation is an urgent issue in modern agricultural production. According to the Law of Ukraine No. 2496-VIII "On Basic Principles and Requirements for Organic Production, Accounting and Sales of Organic Products" (2018), organic biotechnology in crop production, environmental protection, and rural development is a key factor influencing the development of agriculture. In the organic farming system, legumes are one of the tools that can mitigate ecosystem deficiencies and reduce nutrient imbalances, but in most European farms, there is a decrease in legume acreage without a satisfactory explanation. Organic and inorganic legume residues have a positive effect on crop yields, and increase soil fertility and nitrogen content (Haryati *et al.*, 2021; Hussain *et al.*, 2021).

Petrychenko *et al.* (2016; 2020) note that a reliable element of the technology for growing environmentally friendly soybean products, and for increasing soil fertility, the main task in modern agricultural production is the introduction of environmentally friendly cultivation technology based on the optimal functioning of the symbiotic system, without using mineral fertilisers, especially nitrogen and pesticides. Khomenko *et al.* (2019) and Mazur *et al.* (2017) consider the development and implementation of appropriate modern models of soybean cultivation technologies to be the main task in implementing the genetic potential of the varietal composition. Carkner *et al.* (2017) demonstrate that most non-genetically modified soybean varieties are grown and tested under conventional conditions but rarely on organic farms. The introduction of varieties and hybrids adapted to specific soil and climatic conditions, as indicated by Kravchuk *et al.* (2015), and using microbiological preparations are mandatory for soybean cultivation. After analysing the studies by Nahorny, (2009); Magrini *et al.* (2016), it is believed that in recent years, microbial biological products that are environmentally friendly and contribute to the preservation of organic matter in the soil, the decomposition of which by microorganisms results in the development of more complex organic matter, including humus, have been increasingly used in agriculture. Inoculation of legumes with Rhizobium strains, as indicated by Albareda *et al.* (2009), is a necessary agricultural practice on most European soils that are free of soybean-specific rhizobia. And in organic soybean production, as Mandal *et al.* (2009) and Zimmer *et al.* (2016) have demonstrated, the establishment of an effective rhizobial symbiosis is crucial for soybean production and, in general, for improving soil fertility, grain yield, and protein content, and yield.

Nahorny (2009) considers seed bacterisation to be the main component of modern soybean cultivation technologies, an important element of ecologisation and energy saving. It is essential that the processes of photosynthesis and biological fixation of air nitrogen

do not inhibit each other, as this significantly affects the nutritional conditions of soybean plants. O. Marushchak proved that the activity of the symbiotic apparatus affects the yield of soybeans and subsequent crops in the crop rotation, soil fertility and nitrogen content in it in a straightforward way. It is possible to obtain high yields of different soybean varieties without inoculation, but according to Marushchak's (2013) research, this dramatically increases the removal of nitrogen from the soil. To fully provide soybean plants with available forms of nutrients, Novytska *et al.* (2017) suggest using multi-component chelated foliar fertilisers such as Polyfid, Vuksal, Plantafol, Crystalon, Reakom and others, which have a fairly high absorption rate, in addition to seed inoculation during the growing season.

The purpose of these studies was to explore the development of high production of soybean varietal composition due to the elements of organic cultivation technology. The main objectives were to explore the impact of nitrogen-fixing and phosphorus-mobilising preparations and foliar fertilisation on plant growth, development, biological nitrogen accumulation, and soybean yield.

## MATERIALS AND METHODS

The research was conducted during 2019-2022 on the experimental field of Polissia National University in the conditions of Right-Bank Polissia of Ukraine in a short-rotation 4-crop rotation: perennial legumes on one mowing (clover); winter wheat – by-products and root residues and green manure; soybeans – straw, crop and root residues and soil incorporation; barley with addition of legumes.

The type of soil is a light grey forest soil. The area of the sowing plot is 39.6 m<sup>2</sup> (3.6x11 m), and the accounting plot is 25 m<sup>2</sup> (2.5x1.0 m), replicated four times. The research was conducted on soybean varieties Mentor, Tanais, Niagara, Astor during seed treatment with nitrogen-fixing and phosphorus-mobilising preparations and foliar fertilisation with Nanovit Super multicomponent fertiliser and magnesium sulfate. Inoculation of seeds in the first 3 variants was performed with AgriBacter at a rate of 1.25 l/t, Phosphoenterin – 3 kg/t, and in a combination of AgriBacter 1.25 l/t + Phosphoenterin 3 kg/t. In the 5<sup>th</sup> variant of the research, in the flowering phase of soybean plants, foliar fertilisation was performed with the biological preparation Nanovit Super at a rate of 3 kg/ha + magnesium sulfate 2 kg/ha. In variants 6 and 7, inoculation of soybean seeds and foliar feeding were combined. In variant 6, soybean seeds were treated only with AgriBacter inoculant 1.25 l/t and foliar fertilisation with Nanovit Super 3 kg/ha + Magnesium sulfate 2 kg/ha was performed. In the 7<sup>th</sup> variant of the research, seeds were inoculated with AgriBacter 1.25 l/t + Phosphorus Ester 3 kg/t and foliar fertilisation with Nanovit Super 3 kg/ha + Magnesium Sulfate 2 kg/ha (Table 1).

Table 1. Research options

No. s/n	Variants Mentor	Varietal composition of soybeans		
		Tanais	Niagara	Astor
1	Control	–		
2	AgriBacter	No fertilisers		
3	Phosphoenterine	1.25 l/t		
4	AgriBacter + Phosphoenterine	3 kg/t		
5	Nanovit Super + Magnesium sulfate	1.25 l/t + 3 kg/t		
6	AgriBacter + Nanowit Super + Magnesium sulfate	(3 + 2) kg/ha		
7	AgriBacter + Phosphoenterine + Nanowit Super + Magnesium sulfate	1.25 l/t + 3 kg/ha + 2 kg/ha		
		1.25 l/t + 3 kg/t + 3kg/ha + 2 kg/ha		

Source: developed by authors

Inoculant AgriBacter is a preparation based on nitrogen-fixing bacteria (*Bradyrhizobium japonicum*, strain 532 C), has a liquid form, and has a multifunctional effect on the growth and development of soybeans. Nitrate nitrogen is not deposited in plant tissues, but rather is used for protein synthesis. Nitrogen-fixing bacteria enter the root system and secrete mucus, resulting in the development of long infectious threads that penetrate deep into the root parenchyma and begin to multiply intensively, which contributes to the development of nodules. The nodules fix airborne nitrogen  $N_2$  and convert it into a highly available form for plants –  $NH_4$ . Nitrogen fixation lasts until the soybean plants begin to ripen, which allows absorbing up to 100-200 kg of nitrogen during the growing season. Phosphoenterin is an inoculant for improving phosphorus nutrition and intensive plant growth and development. The bacterial strain included in the product is capable of decomposing hardly soluble organic phosphates and converting them into more accessible forms for plants.

Nanovit Super – a highly effective multicomponent fertiliser based on the unique biologically active

complex Nanoactiv, which contains a large amount of nitrogen, potassium and magnesium, trace elements, amino acids, phytohormones, polysaccharides, organic acids, etc. Magnesium sulfate with trace elements  $MgS\ 23-33$ ,  $ZMgO - 23, 33\%$ ,  $(SO_3)$  soluble in water (chelates) and trace elements 0.1% boron and 0.2% zinc.

The number and weight of nodules and the duration of general and active symbiosis were determined according to the method of G.S. Posypanov (1991). The biometric evaluation of soybean varieties was performed on 50 plants from each plot in two non-contiguous replications. Plant density was determined by taking average samples of 100 plants in duplicate from two non-contiguous plots (Ermantraut *et al.*, 2013).

## RESULTS AND DISCUSSION

The results of long-term studies have established that in equivalent weather conditions of the growing season, using soybean cultivation technology without using synthetic fertilisers and pesticides, the field germination of different varieties was within 70-79% (Table 2).

Table 2. Development of soybean plant density depending on varietal composition and elements of organic cultivation technology

Variant*	Varietal composition											
	Mentor			Tanais			Niagara			Astor		
	Field germination, %	Plant density, thousand units/ha	Survival rate, %	Field germination, %	Plant density, thousand units/ha	Survival rate, %	Field germination, %	Plant density, thousand units/ha	Survival rate, %	Field germination, %	Plant density, thousand units/ha	Survival rate, %
1	2	3	4	5	6	7	8	9	10	11	12	13
1	70	300	71	75	324	72	75	388	86	79	369	88
2	75	313	75	80	360	75	85	412	89	84	405	90

Table 2, Continued

1	2	3	4	5	6	7	8	9	10	11	12	13
3	73	310	72	75	360	80	78	406	87	82	397	91
4	73	350	82	78	385	82	88	468	89	84	439	93
5	72	335	77	76	370	80	74	403	91	84	431	96
6	75	380	84	80	418	87	87	477	92	87	424	95
7	79	410	86	87	454	90	88	490	92	91	439	94

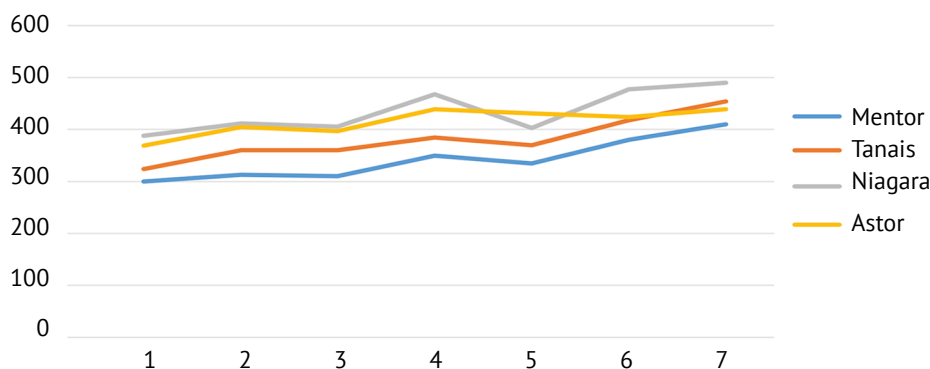
**Note:** \*1 – No fertiliser, 2 – AgriBacter, 3 – Phosphorus, 4 – AgriBacter + Phosphorus, 5 – Nanowit Super + Magnesium sulfate, 6 – AgriBacter + Nanowit Super + Magnesium sulfate, 7 – AgriBacter + Phosphorus + Nanowit Super + Magnesium sulfate

**Source:** developed by authors

When seeds were inoculated with the nitrogen-fixing preparation AgriBacter at a rate of 1.25 l/t, field germination of soybean plants increased by 6-13%, while treatment of soybean seeds with Phosphoenterin at a rate of 3 kg/ha increased this indicator by only 3-4%. The combination of AgriBacter and Phosphoenterin during seed inoculation provided the highest field germination of soybean seeds in the Niagara variety – 17% more compared to the control variant; in the Mentor and Tanais varieties – 4%, Astor variety – 6%. In the 5<sup>th</sup> variant of the research, where in the flowering phase of soybean plants foliar fertilisation with the biological preparation Nanovit Super and magnesium sulfate at a rate of 3 kg/ha + 2 kg/ha was performed, no significant increase in field germination was observed except for Astor variety by 6%, and even a decrease in this indicator by 1.5% in Niagara variety. With the simultaneous inoculation of soybean seeds and foliar fertilisation, field germination increased by 6-16% in variant 6, and by 12-17% in variant 7 compared to the variant without fertilisation.

In the control variant, the stem density of soybean varieties Mentor, Tanais, Niagara and Astor ranged from 300-324-388-369 thousand units/ha. Pre-sowing treatment of seeds with AgriBacter inoculant, due to the assimilation of air nitrogen, provided an increase in plant density during the growing season by 13-36-24-36

thousand pcs/ha, respectively, with plant survival within 75-84-90%. When treating the seeds with phosphorus-mobilising preparation Phosphoenterin, the density of soybean plants of different varietal composition increased by 10-36-18-28 thousand pcs/ha, respectively. Simultaneous treatment of seeds with nitrogen-fixing and phosphorus-mobilising preparations contributed to an increase in plant density by 50-80 thousand units/ha compared to the control variant and by 25-56 thousand units/ha compared to variants 2 and 3, where these preparations were used separately. Foliar fertilisation with Nanovit Super and Magnesium Sulfate biological products provided an increase in stem density by 15-62 thousand units/ha compared to the 1<sup>st</sup> variant, and their combination with inoculation of soybean seeds with AgriBacter, respectively, by 55-94 thousand units/ha. Foliar feeding of soybeans during the critical period of growth and development with multicomponent preparations of organic origin and inoculation of seeds with nitrogen-fixing and phosphorus-mobilising preparations contributes to the formation of the largest non-laying stem of Mentor – 410, Tanais – 454, Niagara – 490 and Astor – 439 thousand units/ha, which is 110-130-102-70 thousand units/ha more than in the variant without fertilisation and 10-30% more than in the case of these preparations alone (Fig. 1).



**Figure 1.** Development of plant density depending on varietal composition and elements of organic soybean cultivation technology

**Note:** \*1 – No fertiliser, 2 – AgriBacter, 3 – Phosphorus, 4 – AgriBacter + Phosphorus, 5 – Nanowit Super + Magnesium sulfate, 6 – AgriBacter + Nanowit Super + Magnesium sulfate, 7 – AgriBacter + Phosphorus + Nanowit Super + Magnesium sulfate

**Source:** developed by authors

In addition, elements of organic soybean cultivation had a significant impact on plant survival. During the growing season, soybeans of the Mentor variety increased this indicator from 71% in the control variant to 86% in 7; Tanais – from 72% to 90%; Niagara – from 86% to 92% and Astor – from 88% to 94%.

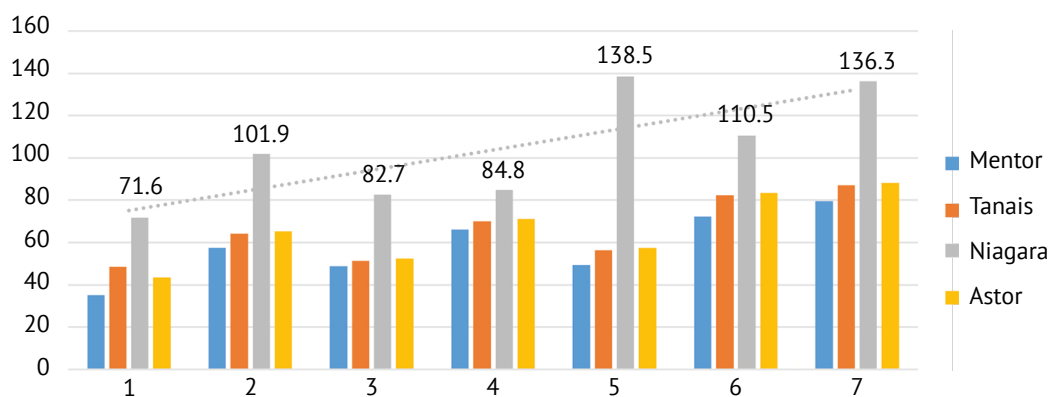
The results of research on the effect of biological products on the development of nodule bacteria of different varietal composition conducted during 2019-2022

at the experimental field of Polissia National University demonstrated that in the variant without using agrochemicals, up to 100 nodules developed on one plant, and their weight is only 0.56 g. During the growing season, their weight reaches 180-300 kg/ha, and the fixation of symbiotic nitrogen from the air is 47-72 kg/ha. When seeds are inoculated with the biological preparation AgriBacter, the mass of nodules on the root system doubles (Table 3, Figure 2, 3).

**Table 3.** Development of biological nitrogen depending on varietal composition and elements of organic cultivation technology, nitrogen kg/ha

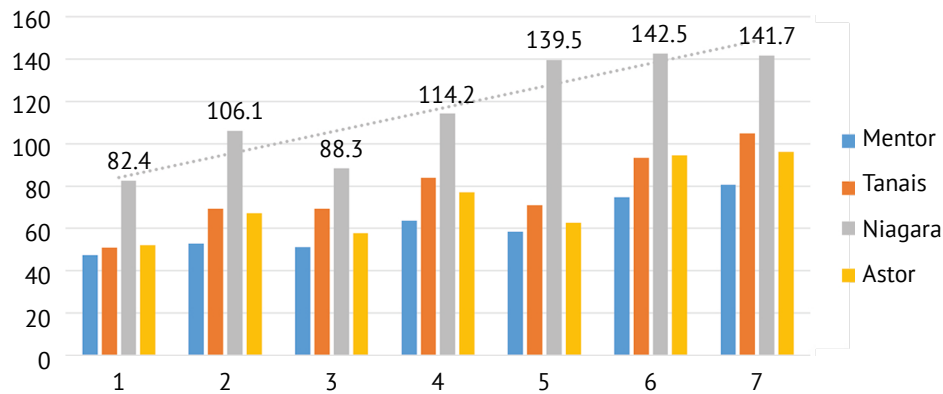
Variant*	Varietal composition											
	Mentor			Tanais			Niagara			Astor		
	Organic residues	Biologically fixed	Total	Organic residues	Biologically fixed	Total	Organic residues	Biologically fixed	Total	Organic residues	Biologically fixed	Total
1	35.2	47.5	82.7	48.6	51.0	99.6	71.6	82.4	154.0	43.6	52.1	95.7
2	57.5	52.8	110.3	64.1	69.3	133.4	101.9	106.1	208.0	65.2	67.1	132.3
3	48.8	51.1	99.9	51.4	69.3	120.7	82.7	88.3	171.0	52.5	57.7	110.2
4	66.1	63.7	129.8	70.0	84.0	154	84.8	114.2	199.0	71.1	77.1	148.2
5	49.5	58.4	107.9	56.5	70.9	127.4	138.5	139.5	278.0	57.6	62.8	120.4
6	72.4	74.7	147.1	82.4	93.4	175.8	110.5	142.5	253.0	83.5	94.5	178.0
7	79.5	80.5	160	87.2	105.0	192.2	136.3	141.7	278.0	88.1	96.1	184.2
Average	58.4	61.2	119.7	65.7	77.6	143.3	103.8	116.4	220.1	65.9	72.5	138.4

**Note:** \*1. – No fertiliser, 2. – AgriBacter, 3. – Phosphorus, 4. – AgriBacter + Phosphorus, 5. – Nanowit Super + Magnesium sulfate, 6. – AgriBacter + Nanowit Super + Magnesium sulfate, 7. – AgriBacter + Phosphorus + Nanowit Super + Magnesium sulfate  
**Source:** developed by authors



**Figure 2.** Nitrogen of by-products, kg/ha

**Note:** \*1 – No fertiliser, 2 – AgriBacter, 3 – Phosphorus, 4 – AgriBacter + Phosphorus, 5 – Nanowit Super + Magnesium sulfate, 6 – AgriBacter + Nanowit Super + Magnesium sulfate, 7 – AgriBacter + Phosphorus + Nanowit Super + Magnesium sulfate  
**Source:** developed by authors



**Figure 3.** Nitrogen of by-products, kg/ha

**Note:** \*1 – No fertiliser, 2 – AgriBacter, 3 – Phosphorus, 4 – AgriBacter + Phosphorus, 5 – Nanovit Super + Magnesium sulfate, 6 – AgriBacter + Nanovit Super + Magnesium sulfate, 7 – AgriBacter + Phosphorus + Nanovit Super + Magnesium sulfate  
**Source:** developed by authors

AgriBacter is an inoculant, a two-component preparation of the genus *Bradyrhizobium*, which initiates the massive establishment of nitrogen-fixing bacteria at the macro stage of BBCH 13-19 according to the *Sadokca* classification (Zadoks scale) and during this period of active symbiosis develops biologically fixed nitrogen of the Mentor 52.8 kg, Tanais variety – 69.3 kg, Niagara variety – 106.1 kg and Astor variety – 67.1 kg, which is higher than the control variant by 5.3-33.4 – 23.7-15.0 kg/ha, respectively. The joint inoculation of soybean seeds with AgriBacter and Phosphoenterin increases nitrogen development by 6.2-18.3-0.9-0.56 kg.

Foliar feeding of soybeans at the macro stage BBCH 60-65 (the name of the first flower buds) before 50% of the flowers open, with Nanovit Super complex fertiliser, promotes the intensive development of nodule bacteria and, accordingly, the increase in biologically fixed air nitrogen in the Niagara variety increases

by 57.1 kg compared to the AgriBacter inoculant. The highest results of symbiotic nitrogen accumulation of all soybean varieties were obtained in the variant of pre-sowing inoculation of seeds with nitrogen-fixing and phosphorus-mobilising preparations, followed by foliar fertilisation with the multicomponent Nanovit Super in a mixture with magnesium sulfate: in the Mentor variety, it is 33 kg, in the Tanais variety – 54, in the Niagara variety – 60.1 and the Astor variety – 44 kg/ha.

Figures 2 and 3 demonstrate the symbiotic fixation of air nitrogen by soybean varieties depending on biological products. Considering the supply of nitrogen with by-products (straw, stubble and root residues), the soil is provided with biological nitrogen in the range of 115-220 kg/ha and is used specifically for feeding soybean plants and generating a yield increase in the Niagara variety – 0.11-0.38 t/ha compared to the Mentor, Tanais and Astor varieties (Table 4).

**Table 4.** Yields of soybean varieties depending on treatment with organic products, t/ha (2019-2022)

No. s/n	Variant		Variety				Average per drug	Crop growth. t/ha
			Mentor	Tanais	Niagara	Astor		
1	No fertilisers	–	1.10	1.24	2.15	1.69	1.54	0.44
2	AgriBacter	Inoculation	1.44	1.66	3.02	1.94	2.01	0.57
3	Phosphoenterine		1.28	1.45	2.49	1.85	1.77	0.49
4	AgriBacter + Phosphoenterine		1.27	1.33	2.92	1.99	1.88	0.61
5	Nanovit Super + Magnesium sulfate	Foliar fertilisation	1.70	1.95	2.88	2.03	2.14	0.44
6	AgriBacter + Nanovit Super + Magnesium sulfate	Inoculation + foliar fertilisation	1.86	2.05	3.31	2.39	2.40	0.54
7	AgriBacter + Phosphoenterine + Nanovit Super + Magnesium sulfate		2.45	2.25	4.08	2.88	2.91	0.46
Average by variety			1.59	1.70	2.98	1.97	2.09	0.50
Deviation from the average			0.49	0.46	0.89	0.28	0.55	0.06
LSD <sub>05</sub>			0.043	0.07	0.13	0.5	–	–

**Source:** developed by authors

Seed treatment with AgriBacter inoculant has a positive effect on soybean nutrition and provides an average yield increase of 0.57 t/ha for varieties, with Niagara at 0.87, Tanais – 0.42 and Mentor – 0.34 t/ha. Combined treatment of soybean seeds with AgriBacter inoculant and Phosphoenterin provides a yield increase of –1.88 t/ha.

Foliar feeding of soybeans with a highly effective multicomponent fertiliser with a high content of macro- and microelements based on the unique biologically active complex Nanoactiv, which includes amino acids, phytohormones, polysaccharides, organic acids in a mixture with the preparation Magnesium sulfate with trace elements based on chelate, restores the development of nodule bacteria in the macro stage of BBCH 60-63, which provides an average yield of 2.4 t/ha, Niagara – 3.31 and Astor – 2.4 t/ha, and the increase to the inoculation of seeds with AgriBacter varies within 0.42-0.39-0.29-0.45 t/ha, respectively, for varieties Mentor, Tanais, Niagara and Astor. The highest yields over the years of research were obtained in varieties Niagara – 2.98 and Astor – 1.97 t/ha in the 7<sup>th</sup> variant of the study.

Didur *et al.* (2019), and Zabolotnyi *et al.* (2020), having conducted an energy analysis in the conditions of the Right-Bank Forest-Steppe on grey forest soils, confirm that the cultivation of soybean varieties using the technology that involves the application of mineral fertilisers at a dose of  $N_{30}P_{60}K_{60}$ , seed treatment (150 g/t) and foliar feeding in the budding phase (0.5 kg/ha) with a complex of microelements Microfol Combi provides the highest coefficient of complex assessment for competitiveness in the Gorlytsia variety – 1.25 and the Vinnychanka variety – 1.24 and clearly expressed intensive growth and development of plants. According to Semenyaka (2010), bioorganic fertilisers significantly improve the mineral nutrition of plants, stabilise and restore soil fertility, and increase soybean yields. Khomeenko *et al.* (2019) indicate that nitrogen-fixing bacterial fertilisers should be used on soybean crops: foliar feeding of soybeans on the green leaf with chelated growth stimulants is recommended as an environmentally friendly element of cultivation technology, which significantly improves the formation of nodule bacteria and nitrogen accumulation in the soil. According to Nahorny (2010), soybeans are the best precursor for many crops, as they can, in symbiosis with nodule bacteria of the *Bradyrhizobium japonicum* species, leave behind 90-280 kg of biologically fixed nitrogen and a weed-free field, while simultaneously meeting the nitrogen requirements of soybean plants. According to research by Toileikiene *et al.* (2021), in a wet year, inoculated soybeans accumulate a large number of nodules, which increases the yield of soybean seeds by 98% on average over two sowing dates and significantly improves grain quality and protein content.

Research by Naryi (2009) confirmed that soybean plants should be nodulated with specific strains of *Bradyrhizobium japonicum* to maintain nitrogen fixation

efficiency. Zimmer *et al.* (2016) confirm the effectiveness of inoculation with *Bradyrhizobium* strains, which significantly increases grain yield, protein content and protein yield. The average yield of soybean variety Merlin in trials with organic treatment with *Bradyrhizobium* strains in Germany in 2012-2013 reached 1.6 t/ha (Zimmer, 2016), and worldwide it was 2.3 t/ha Bujak (2009), which is 57% more than the control variant. According to Kushmetova's research (2020), the application of the bacterial fertiliser Rizotorfin during sowing increases soybean yields. Soybeans treated with rhizotorphin leave more nitrogen-rich residues on the field and are therefore an excellent predecessor.

According to the research of Peleh (2021), the highest seed yield of soybean varieties SG Anzer and Cardiff at the level of 2.79-3.02 t/ha was obtained with two-time fertilising in the budding phase and in the phase of green bean establishment with multicomponent microfertiliser Vuksal Microplant, which is 0.37-0.51 t/ha more than in the control variant. Trace elements in sufficient quantities, together with seed inoculation, contribute to better growth and development of plants, and increase stress resistance to external factors (low or high temperatures, uneven moisture, diseases). It is confirmed by Babych & Babych-Poberezhna (2011), who reported that the simultaneous introduction of microelements on the background of inoculation resulted in an increase in soybean yield by 0.26 c/ha.

Thus, the choice of soybean variety is important when growing soybeans, as most of them are suitable for growing only in certain soil and climatic conditions and are characterised by narrow ecological adaptability.

## CONCLUSIONS

According to the results of long-term scientific research conducted at Polissia National University on light grey medium nutrient-rich soils, it was established that under equivalent weather conditions of the growing season, using soybean cultivation technology without using synthetic fertilisers and pesticides, the density of soybean stems of Mentor, Tanais, Niagara and Astor varieties ranged from 300 to 369 thousand units/ha. Pre-sowing treatment of seeds with inoculants and foliar feeding provided an increase in plant density during the growing season of Mentor variety from 313 to 410 thousand pcs/ha; Tanais – 360-454 thousand pcs/ha; Niagara variety – 412-490 thousand pcs/ha and Astor variety – 405-439 thousand pcs/ha, the highest rates were observed in variant 7, where all measures were combined. In addition, elements of organic soybean technology increased plant survival from 7 to 25% compared to the control variant.

Pre-sowing inoculation of seeds with nitrogen-fixing and phosphorus-mobilising preparations, followed by foliar fertilisation with the multi-component preparation Nanovit Super in a mixture with magnesium sulfate, stimulated biological processes in soybean plants,

contributed to an increase in chlorophyll content, restoration of the rhizobial system, reduction of pest infestation, and the greatest accumulation of symbiotic nitrogen of all varieties: Mentor – 33 kg, Tanais – 54 kg, Niagara – 60.1 kg, and Astor – 44 kg/ha.

The highest soybean yield over the years of research was obtained by managing the processes of growth and development during the growing season in variant 7 with simultaneous seed inoculation and foliar feeding in Niagara – 4.08 and Astor – 2.88 t/ha, which is 1.7-2 times more than in the control variant. In the

varieties Mentor and Tanais, the yield increased by 1.8-2.2 times compared to the variant without fertiliser and amounted to 2.45-2.25 t/ha.

The prospect of further research will be the soybean variety Niagara, which is prone to lodging at a plant density of 490 thousand units/ha, thus it is necessary to conduct field studies to explore inhibitors that suppress the growth process and their impact on plant resistance to lodging. The results of field germination and plant survival should be considered when calculating seeding rates for soybean varieties and hybrids.

## REFERENCES

- [1] Albareda, M., Rodriguez-Navarro, D.N., & Temprano, F.J. (2009). Soybean inoculation: Dose, N fertilizer supplementation and rhizobia persistence in soil. *Field Crops Research*, 113(3), 352-356. doi: 10.1016/j.fcr.2009.05.013.
- [2] Babych, A.O., & Babych-Poberezhna, A.A. (2011). *Selection, production, trade and use of soybean in the world*. Kyiv: Agrarian Science.
- [3] Bujak, K., & Frant, M. (2009). Influence of mixtures of herbicides on yielding and weed infestation of five cultivars of soybean. *Acta Agrophysica*, 13(3), 601-613.
- [4] Carkner, M.K., & Entz, M.H. (2007). Growing environment contributes more to soybean yield than cultivar under organic management. *Field Crops Research*, 207, 42-51. doi: 10.1016/j.fcr.2017.02.019.
- [5] Didora, V., & Kluchevych, M. (2021). Soybean productivity depending on the elements of organic cultivation technology in the short-term crop rotation of Ukrainian Polissia. *Scientific Horizons*, 24(2), 77-83. doi: 10.48077/scihor.24(2).2021.77-83.
- [6] Didur, I.M., Tsyhanskyi, V.I., Tsyhanska O.I., Malynka, L.V., Butenko, A.O., & Klochkova, T.I. (2019). The effect of fertilizer system on soybean productivity in the 228 conditions of right bank forest-steppe. *Ukrainian Journal of Ecology*, 9(1), 76-80.
- [7] Ermantraut, E.R., Malinovsky, A.S., Didora, V.G., Smagliy, O.F., Gudz, V.P., Rybak, M.F., Sayuk, O.A., Orlovsky, M.J., & Derebon, I.J. (2013). *Methods of scientific research in agronomy*. Kyiv: Center for Educational Literature.
- [8] Haryati, Y., Sari, R., Noviana, I., & Sunandar, N. (2021). Adaptive technology for soybean varieties cultivation in dry season. *IOP Conference. Series: Earth and Environmental Science*, 648, article number 012067. doi: 10.1088/1755-1315/648/1/012067.
- [9] Hussain, H., Men, S., & Hussain, S. (2019). Interactive effects of drought and heat stresses on morpho-physiological attributes, yield, nutrient uptake and oxidative status in maize hybrids. *Scientific Reports*, 9, article number 3890. doi: 10.1038/s41598-019-40362-7.
- [10] Khomenko, T.O., Datsko, A.O., & Kosolap, M.P. (2019). Seed treatment with biologics is a promising direction in improving elements of soybean cultivation technology. In *Organic production and food safety* (pp. 292-296). Zhytomyr: ZNAEU.
- [11] Kravchuk, V., Kushnarov, A., Tarhonia, V., Pavlyshyn, M., & Husar, V. (2015). *Biosphere and agricultural technologies: Engineering solutions*. Doslidnytske: UkrNDIPVT named after L. Pohorilyi.
- [12] Kushmetov, Z.M., Yormatova, D.Y., & Jumaniyazov A. (2020). The main elements of the technology of soybean varieties cultivation on low saline soils in Khorezm region, Uzbekistan. *Journal of Critical Reviews*, 7(12), 108-116. doi: 10.31838/jcr.07.12.18.
- [13] Law of Ukraine No. 2496-VIII "On the Basic Principles and Requirements for Organic Production, Accounting and Marketing of Organic Products". (2018, July). Retrieved from <https://zakon.rada.gov.ua/laws/show/2496-19#Text>.
- [14] Magrini, M.-B., Anton, M., Cholez, C., Corre-Hellou, G., Duc, G., Jeuffroy, M.-H., Meynard, J.-M., Pelzer, E., Voisin, A.-S., & Walrand, S. (2016). Why are grain-legumes rarely present in cropping systems despite their environmental and nutritional benefits? Analysing lock-in in the French agrifood system. *Ecological Economics*, 126, 152-162. doi: 10.1016/j.ecolecon.2016.03.024.
- [15] Mandal, K.G., Hati, K.M., & Misra, A.K. (2009). Biomass yield and energy analysis of soybean production in relation to fertilizer-NPK and organic manure. *Biomass Bioenergy*, 33(12), 1670-1679. doi: 10.1016/j.biombioe.2009.08.010.
- [16] Marushchak, O. (2013). Growing soybeans with inoculants. *Agronomist*, 1, 152-153.
- [17] Mazur, V.A., Palamarchuk, V.D., Polishchuk, I.S., & Palamarchuk, O.D. (2017). *Latest technologies in crop production*. Vinnytsia.
- [18] Nahorny, V.I. (2010). The influence of sowing dates and methods on the productivity of soybean varieties. *Fodder and Fodder Production*, 66, 96-103.
- [19] Naryi, V.I. (2009). Yield and agroecological adaptability of soybean varieties in the conditions of the north-eastern Forest-Steppe of Ukraine. *Collection of Scientific Works of Uman State Technical University*, 72, 153-160.

- [20] Novytska, N.V., & Dzhemesiuk, O.V. (2017). The formation of soybean productivity under the influence of inoculation and feeding. *Bulletin of Poltava State Agrarian Academy. Agriculture. Plant growing*, 1-2, 43-47.
- [21] Peleh, L.V. (2021). The influence of elements of cultivation technology on the formation of soybean productivity in the conditions of the right-bank forest-steppe. *Agriculture and Forestry*, 2(21), 109-119. doi: 10.37128/2707-5826-2021-2-9.
- [22] Petrychenko, V.F., & Lykhochvor, V.V. (2020). *Plant growing. New technologies for field crops cultivation*. Lviv: Ukrainian Technologies.
- [23] Petrychenko, V.F., Lykhochvar, V.V., & Markov, V.L. (2016). *Soybean: A culture of unique opportunities*. Kyiv: Univest Media.
- [24] Posypanov, H.S. (1991). *Methods of studying biological fixation of air nitrogen: Reference manual*. Moscow: Agropromizdat.
- [25] Semenyaka, I.M. (2010). Effectiveness of microbial preparations, macro- and micro-fertilizers for growing corn. *Collection of Scientific Works of Institute of Engineering of Ukrainian Academy of Sciences*, 3, 84-91.
- [26] Toleikiene, M., Slepetyš, J., & Sarunaite, L. (2021). Soybean development and productivity in response to organic management above the northern boundary of soybean distribution in Europe. *Agronomy*, 11(2), article number 214. doi: 10.3390/agronomy11020214.
- [27] Zabolotnyi, H.M., Mazur, V.A., Tsyhanska, O.I., Didur, I.M., Tsyhanskyi, V.I., & Pantsyryeva, H.V. (2020). *Agrobiological basics of soybean cultivation and ways to maximize its productivity*. Vinnytsia: VNAU.
- [28] Zimmer, S., Messmer, M., Haase, T., Piepho, H.-P., Mindermann, A., Schulz, H., Habekuß, A., Ordon, F., Wilbois, K.-P., & Heß, J. (2016). Effects of soybean variety and Bradyrhizobium strains on yield, protein content and biological nitrogen fixation under cool growing conditions in Germany. *European Journal of Agronomy*, 72, 38-46. doi: 10.1016/j.eja.2015.09.008.

### Сортові особливості елементів органічної технології вирощування сої

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**Анотація.** Надійним елементом технології вирощування екологічно чистої продукції ранньостиглих сортів сої, а також підвищення родючості ґрунту є впровадження у виробництво екологічно безпечної технології вирощування, яка базується на оптимальному функціонуванні симбіотичної системи, без використання мінеральних добрив, особливо азотних та пестицидів. Метою роботи було вивчення впливу інокуляції насіння різних сортів сої азотфіксуючими і фосформобілізуючими препаратами, позакореневого підживлення та їх поєднання на ріст, розвиток рослин і продуктивність за органічної технології вирощування. При виконанні досліджень використовували загальноприйняті методи, польовий метод, метод статистичного оцінювання результатів. У результаті виконаних експериментальних досліджень встановлено, що за впровадження високоврожайних сортів сої, використання післяжнивних решток (соломи, стерньових і кореневих решток), сидератів та бобових трав в короткоротаційній сівоzmіні в ґрунт надходить 136 кг азоту та 142 кг біологічно фіксованого азоту. Було досліджено, що обробка насіння інокулянтном АгріБактер та проведення підживлення сої комплексним добривом Нановіт Супер забезпечує врожайність сорту Ментор 4,08 т/га та залишає в ґрунті майже 30 % біологічного азоту. Дослідженнями було доведено, що комплексний підхід до проведення обробки насіння сої досліджуваних сортів інокулянтами АгріБактер та Фосфороентерином, штам бактерій яких розкладає важкорозчинні органічні фосфати, що в свою чергу сприяє кращому живленню рослин сої, розвитку кореневої системи, позитивно впливає на формування оптимальної густоти стеблестою 410–490 тис. шт./га, що забезпечує приріст урожайності сортів сої на 1,88 т/га. Встановлено, що одночасна інокуляція насіння та позакореневе підживлення сої біологічно-активним комплексом Nanoactiv з додаванням Сульфат магнію у макростадії BBCH 60–63 забезпечує найвищу врожайність сорту Ніагара 4,08 т/га та сорту Астор – 2,88 т/га. Таким чином, в короткоротаційній 4-х пільній сівоzmіні насиченій зернобобовими культурами при застосуванні азотфіксуючих, фосформобілізуючих препаратів та активного стимулятора росту Нановіт Супер + Сульфат магнію підвищується родючість ґрунту, а вміст азоту в ньому подвоюється. Наукові результати можуть стати основою для вдосконалення родючості ґрунту, що забезпечить формування сталих врожаїв за органічного вирощування сої

**Ключові слова:** сортовий склад, родючість ґрунту, інокуляція насіння, позакореневе підживлення, урожайність сої



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## Improvement of methods for controlling power oil of cooling tower recycling water supply units at Rivne nuclear power plant

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**Abstract.** The relevance of the study is conditioned upon the fact that at nuclear power plants, water pumping units using energy oils are operated in the heat exchange equipment of power units. The diagnostic criteria of oils allow identifying defects in the operation of technological equipment. The purpose of the work – to increase the reliability of the operation of oil-filled power equipment by improving the monitoring of the physical and chemical properties of power oil TP-30. The main attention is devoted to increasing the reliability of the operation of oil-filled power equipment by improving the monitoring of the physical and chemical properties of TP-30 power oil. Experimental studies were conducted by chromatography, and gas and liquid extraction using appropriate laboratory equipment. When exploring the content of chemical elements in the segments of the thrust bearing of the cooling tower pumping unit, which is based on Sn, an increase in the content of copper Cu and Sb was observed, which exceeded the standard by an average of 1.2 and 1.1 times, respectively. Most of the analysed physical indicators of oil quality (water content, kinematic viscosity, flash point, acid number) did not demonstrate deviations from the standard values. Only an increase in the mass fraction of mechanical impurities by 0.0026% relative to the standard was noted during the incoming inspection of TP-30 oil. The results of the operational control of the oil in terms of a set of physical indicators fully complied with the established technological standards. The highest content of soluble gases in the oil (0.56% by volume) was recorded for propylene (C<sub>3</sub>H<sub>6</sub>). It is recommended to use the relative content of soluble gases in Tp-30 oil to C<sub>3</sub>H<sub>6</sub> when identifying degradation processes. The absence of residuals of circulating power oil TP-30 in the surface waters of the Styr River during the operational event was established. Generalisations have been generalised about the necessity of expanding the diagnostic criteria for the quality of TP-30 oil, in particular, expanding the list of its physical indicators. In practical terms, the results obtained can be useful for monitoring the quality of other brands of petroleum oils in the systems of turbine units of nuclear power plants, which is important in terms of the safe operation of heat exchange equipment

**Keywords:** safety of nuclear power plants, operational event, bearing, soluble gases, oil products, surface water



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## INTRODUCTION

The nuclear industry contributes to the conservation of natural resources by producing clean energy. However, from the very beginning of the operation of nuclear power plants (NPPs), the main task is to control and maintain the safety of their operation. According to generally accepted principles of international law and IAEA requirements, NPP safety is designed to protect the environment and people from the consequences of undesirable emergencies that can occur at any stage of the life cycle of nuclear facilities and their process equipment.

Tripathi & Singh (2020) report that one of the causes of undesirable consequences of NPP non-radiation safety can be operational events in the cooling water circulation cycles in the heat exchange equipment of power units during the operation of evaporative cooling towers with water pumping units. In the operation of this equipment, the established levels of reliability and safety are ensured by technical systems for circulating energy oils. The experience of Kyshnevskiy (2021) proves that the quality indicators of circulating energy oils used in equipment can be used as an information medium. It refers to the presence of particular diagnostic components (dissolved gases, water, additives, mechanical impurities, etc.) in the oils that reflect the presence of defects in the friction surfaces and erosion and corrosion damage to heat exchange equipment.

Xiaojie *et al.* (2022) characterised the presence of such diagnostic components as the content of soluble gases, water, ionol additive, and mechanical impurities in mineral turbine oils (MTO) to determine the presence of defects in NPP equipment in the friction surface areas under the influence of point effects of high temperatures. Lovrec & Tič (2014) use a similar information environment of energy oils to establish levels of reliability indicators for cooling equipment operation under vibration. Moosavi *et al.* (2015) use diagnostic oil components to determine the effect of electric current on the reliability and safety of technical water circulation systems. Kindrachuk *et al.* (2017) and Balitskii *et al.* (2020) demonstrate the possibility of detecting hydrogen wear in heat exchange equipment using MTO diagnostic criteria.

Grosu *et al.* (2018), Da Costa *et al.* (2016) argue that monitoring the values of physicochemical and thermophysical properties of MTO allows timely implementation of the necessary preventive and regulatory measures to ensure and improve the reliability of environmental safety of power plant equipment. In addition, Srivastava *et al.* (2020) confirm that the quality of MTO in the circulating supply system is very important for the reliable and uninterrupted operation of the NPP power system. These authors note that defects in the oil-filled equipment of recycled water systems can result in the ingress of mineral oils into recycled water and, when discharged into water bodies, affect surface water and the environment.

The stability of MTOs in the environment is affected by a number of their physical and chemical characteristics. Monge *et al.* (2015) explored the processes of sludge development during the oxidation of turbine oils, and Aganbi *et al.* (2019) studied the presence of persistent organic pollutants in turbine oil residual products entering drainage and groundwater near a power plant. Both studies conclude that the compliance of turbine oils with the physical and chemical characteristics of regulations is one of the guarantees of the safe operation of power plants. For example, Narcisi *et al.* (2023) explored that an increase in the temperature of the water coolant poses a risk of increasing the concentration of tritium in the power plant cooling system. Thus, as reported by Lin *et al.*, (2022), the operation of NPP cooling equipment should provide for continuous safety monitoring, including a set of diagnostic criteria for its components at different stages of equipment wear.

Interesting are the results of research by Boczkaj *et al.* (2013), in which, by establishing a mathematical model for describing the anti-wear properties of oils, the optimal concentrations of additives were established to ensure effective anti-wear action of oils. Saidi *et al.* (2020) emphasise the importance of the colloidal stability of the MTO and argue that it specifically affects the hydrophobic properties of oils and reduces their friction coefficients. Hu *et al.*, (2017) emphasise the importance of establishing the tribological response of MTOs by determining such parameters as morphology, size, crystal structure, and additive concentration.

Boichenko & Kalmykova (2020), when exploring the operating modes of turbine units and pumping units in the circulation systems of motor vehicle maintenance, noticed a simultaneous energy and environmental effect when using diagnostic methods with "Oil" additives. Saeed (2022) notes that the issue of expanding diagnostic parameters to control turbine oil degradation is characterised by the lack of detailed experimental results. In addition to the unresolved part of the problem, the opinion of Pioro & Duffey (2019) should be mentioned, who emphasise the significance of research on the consequences and ways to prevent the impact of MTO on environmental objects, in particular water bodies, in the case of oil from NPP effluent.

The objectives of the study were to identify the cause of the failure of the cooling tower pumping unit at Rivne NPP Unit 1 by monitoring the physical and chemical properties of TP-30 power oil, tracking the accumulation of soluble gases in power oil in the cooling tower circulation cooling system, and controlling the flow of oil into the surface waters of the Styr River with the return water of the nuclear power plant.

## MATERIALS AND METHODS

Experimental studies of the physical and chemical properties of TP-30 power oil were performed using

measuring equipment in the Separate Division of the Rivne Nuclear Power Plant (RNPP) during 2021-2022. With the permission of the SD RNPP, it is possible to publish the results of the study in open sources (SD RNPP Act No. 036-21-A-Zv of 24.11.2022).

The content of chemical elements in the segments of the thrust bearing of the cooling tower unit of power unit No. 1 was determined by the X-ray fluorescence method (ISO 9516-1:2003, 2003) using a SPECNROxSORT analyser. The results were expressed as a percentage. For the established values for each segment, the arithmetic mean and standard deviation were determined with statistical significance ( $P \leq 0.05$ ) using the Student's t-test, within the Statistica 8.0 software package (Kostiuk, 2015). The actual content of the elements was compared with the regulations (DSTU 4383:2015, 2015).

The modelling of ultrasonic irradiation (US) exposure to the operation of power oil in the pumping unit was performed at frequencies of 35-125 kHz and an ultrasonic emitter power of 20 W, the temperature was maintained by a thermostat in the range of  $57.0 \pm 2.0^\circ\text{C}$ . The content of soluble gases after ultrasonic irradiation was determined by the method of chromatographic analysis of soluble gases (CASG). The limit concentrations of hydrocarbon, CO, CO<sub>2</sub>, and hydrogen gases were based on the standards for defective gases for transformer oils (SOU-N EE 46.501:2006, 2006).

The determination of the physicochemical properties of TP-30 oil was performed by flame ionisation and chromatographic methods (DSTU 3985-2000, 2000) on a Crystal-5000 chromatograph with thermal conductivity detectors (TCD) using a licensed computer program. The calibration characteristic of the gas content was established using standard samples of the verification gas mixture (GMS) 4.6\_UMTS\_44/071-12, with a standardised gas content: CH<sub>4</sub> –  $0.0048 \pm 0.0002\%$ , C<sub>2</sub>H<sub>4</sub> –  $0.0047 \pm 0.0002\%$ , C<sub>2</sub>H<sub>2</sub> –  $0.0046 \pm 0.0002\%$ , C<sub>2</sub>H<sub>6</sub> –  $0.0048 \pm 0.0002\%$ , H<sub>2</sub> –  $0.0081 \pm 0.0004\%$ , O<sub>2</sub> –  $0.124 \pm 0.005\%$ , N<sub>2</sub> –  $0.130 \pm 0.005\%$ , CO<sub>2</sub> –  $0.121 \pm 0.006\%$ , CO –  $0.0233 \pm 0.001\%$ .

The values of the coefficients of the ratio of the content of soluble gases in TP-30 oil, which corresponded to the onset of the operational event of the cooling tower pumping unit shutdown, were calculated for each pair of gases to the gas with the highest content using the formula:

$$K_i = \frac{C_i}{C_{max}} \quad (1)$$

where:  $C_i$  – current content of the soluble gas component, %;  $C_{max}$  – current content for the gas component with the maximum content, %. The component with the highest content was propylene C<sub>3</sub>H<sub>6</sub>, whose concentration was the most significant according to the analysis.

The components were extracted using gas and liquid extraction methods. An ultra-thermostat UT-15 was used to maintain the temperature. The researchers used TP-30 mineral oil turbine oil, the quality indicators of which corresponded to the current standard conditions (DSTU 9972-74, 1974).

In the course of the research, standardised oil performance indicators were used, which allowed changes compared to fresh oil (SOU NAEK 085:2020, 2020). In particular, it was considered that during the operation of oil-filled equipment, changes in the quality of energy oils may occur, primarily in terms of the content of ionol and water additives.

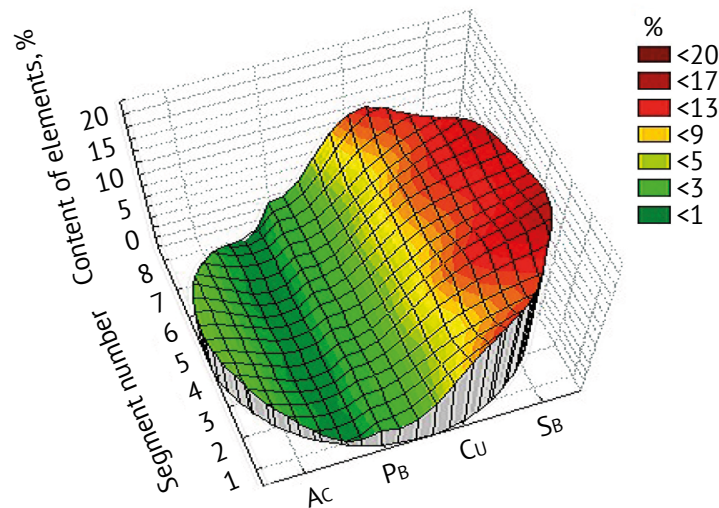
The flow of oil into the Styr River was monitored by the mass concentration of oil products in the return water of the recycling system and surface waters of the river before and after the discharge of SD RNPP wastewater. The content of oil products in return and surface water was determined by the fluorimetric method (DSTU 20847:2009, 2009) using a "Fluorat-02U" liquid analyser. The content of oil products in the surface waters of the Styr River was analysed based on the results of monitoring by the SD RNPP Environmental and Chemical Laboratory during the operational event and the dynamics of previous years.

## RESULTS AND DISCUSSION

In 2021, the SD RNPP experienced a shutdown of the cooling tower pumping unit of power unit No. 1 due to defects in the bearing assemblies lubricated with circulating power oil of the TP-30 brand in the 1MB-1 oil tank. When determining the reasons for the failure, it was assumed that this event could have occurred due to the deterioration of the oil quality.

Examination of the damaged unit identified: a sharp increase in the temperature of the segments of the thrust bearing of the pump motor; failure of the "oil wedge" between the pump base and the segments of the thrust bearing at a temperature of  $57^\circ\text{C}$ ; partial destruction of the babite liner; local partial melting of the metal of the babite liner. All of this resulted in lengthy repair work. During the technical analysis of the failure of the cooling tower pumping unit of power unit No. 1, it was established that the standardised indicators of oil grade TP-30 of the 1MB-1 oil tank corresponded to the operational standards for circulating power oils (SOU NAEK 085:2020, 2020). Therefore, evidently, to control the degradation of TP-30 fuel oil, it is necessary to expand the list of its physical and chemical parameters.

The material of the bearing alloy is tin babite grade B-83, the chemical composition of which complies with the current established standards (DSTU 4383:2015, 2015). Prolonged exposure to friction and temperature caused mechanical erosion damage to the thrust bearing surface and a change in the chemical composition of the bearing alloy (Fig. 1).



**Figure 1.** Content of chemical elements in segments of the thrust bearing of the cooling tower pumping unit of power unit No. 1

**Source:** developed by authors

Thus, for the eight segments analysed, the content of arsenic (As) in the segments of the thrust bearing of the pump unit averaged  $0.02 \pm 0.01\%$  ( $p = 9.4 \cdot 10^{-5}$ ), which fully corresponded to the standardised content of chemical elements in bearing alloys (DSTU 4383:2015, 2015), which for As should not exceed 0.05%. The lead (Pb) content averaged  $0.22 \pm 0.05\%$  ( $p = 7.4 \cdot 10^{-6}$ ), which was within the range of permissible values for this element ( $<0.35\%$ ). The copper (Cu) content in the analysed segments was  $7.84 \pm 1.05\%$  ( $p = 1.3 \cdot 10^{-7}$ ), which exceeded the standard (5.5-6.5%) by 1.2 times relative to the upper limit. The content of stibium (Sb) in the bearing segments had an average value of  $13.21 \pm 1.14\%$  ( $p = 6.5 \cdot 10^{-8}$ ), which exceeded the permissible levels for stibium (10-12%) by 1.1 times relative to the upper limit. Note that

the bearing is based on steel (Sn). Consequently, the friction of the surfaces and the accompanying temperature effect caused intensive wear of the soft base of the thrust bearing with loss of the base metal of the Sn alloy, which increased the content of Sb and Cu and exceeded the established requirements. Such a change in the chemical composition of the bearing alloy confirms the long-term exposure to the operating factors of friction, vibration and temperature. According to the results of the operational control, for Tp-30 oil, only the mass fraction of mechanical impurities increased (Table 1), within the normalised value (SOU NAEK 085:2020, 2020). This fact allowed assuming that this scope of control is not enough to monitor the degradation processes of TP-30 oil.

**Table 1.** Results of incoming and operational inspection\* of TP-30 oil in the 1MB-1 oil tank of the cooling tower pumping unit of RNPP Unit 1

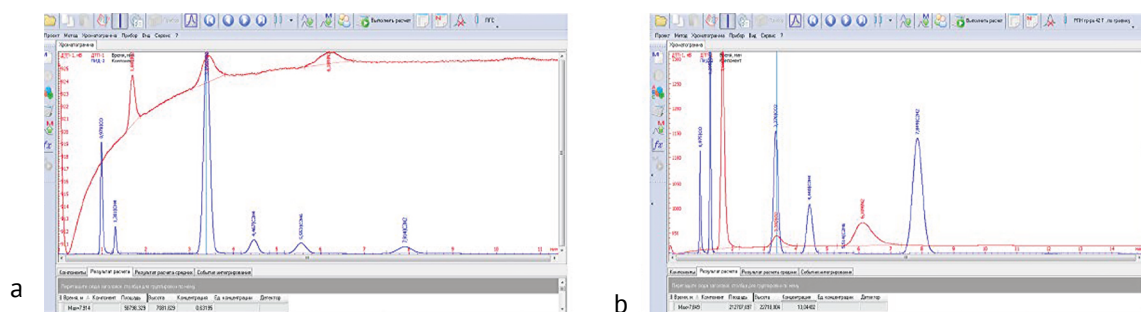
Indicator name	Measurement units	Results of incoming control		Results of operational control	
		Normalised value	Measurement result	Normalised value	Measurement result
Content of mechanical impurities	%	Absence	Absence (0.0026)	No more than 0.005	Absence (0.0028)
Water content	%	Absence	Absence	No more than 0.3	Absence
Kinematic viscosity at 40 °C	mm <sup>2</sup> /s	41.4-50.6	46.2	41.0-60.7	46.58
Flash point in an open crucible	°C	Not lower than 190	212	Not lower than 185	212
Acid number	mgKOH/g	No more than 0.5	0.023	No more than 0.6	0.025

**Note:** the sample was taken from the oil tank 1MB-1 of the pumping unit of the cooling tower of SD RNPP Unit 1, in operation since 2020

**Source:** the normalised value is presented according to ASTM Standard D 4768-11 (2019); the measurement result – developed by the authors

During the chromatographic separation of gases, the establishment of the calibration characteristic of the results using the standard sample PGS 4.6\_UMTS\_44/071-12 (Fig. 2, a) allowed recording symmetrical

chromatographic peaks characterised by high resolution in terms of retention time of components, followed by quantitative and qualitative identification of soluble gas components in the TP-30 service oil (Fig. 2, b).



**Figure 2.** Visualisation of the determination of soluble gases in TP-30 oil using a "Crystal-5000" chromatograph: a – calibration characteristics; b – identification of soluble gas components

**Source:** developed by authors

According to the results of modelling the effect of ultrasonic irradiation and temperature on the operation of power oil in a pumping unit, it was established that

with an increase in the time of ultrasonic irradiation, the content of soluble gases in TP-30 oil increased, which indicates the processes of oil degradation (Table 2).

**Table 2.** Results of measuring the content of soluble gases in TP-30 oil as a function of the duration of ultrasonic irradiation of TP-30 oil during experimental tests

Hour, s	Gas content, % vol.								
	CH <sub>4</sub>	C <sub>2</sub> H <sub>4</sub>	H <sub>2</sub>	C <sub>2</sub> H <sub>6</sub>	C <sub>2</sub> H <sub>2</sub>	CO	CO <sub>2</sub>	C <sub>3</sub> H <sub>6</sub>	C <sub>3</sub> H <sub>8</sub>
0	0.003	0.006	0	0	0	0.001	0.005	0	0
200	0.09	0.33	0.19	0.03	0.06	0.03	0.02	0.44	0.06
600	0.20	0.45	0.35	0.06	0.09	0.06	0.023	0.55	0.08
1000	0.29	0.93	0.49	0.07	0.13	0.092	0.028	0.66	0.10
1500	0.51	1.55	0.58	0.13	0.15	0.104	0.029	1.3	0.16

**Source:** developed by authors

Thus, for 1500 s, the greatest increase was observed for ethylene (C<sub>2</sub>H<sub>4</sub>) and propylene (C<sub>3</sub>H<sub>6</sub>), the content of which in the ultrasonically irradiated oil increased by 1.54% vol. and 1.3% vol. respectively. In addition, the increase in hydrogen (H<sub>2</sub>) content by 0.58% vol. and methane (H<sub>2</sub>) by 0.51% vol. was noticeable.

The increase in the content of other gases ranged from 0.02% by volume to 0.16% by volume.

When measuring the content of soluble gases in fresh and used TP-30 oil, it was noticed that during the operation of the oil, soluble gases accumulate: hydrocarbons, CO, CO<sub>2</sub>, and hydrogen (Table 3).

**Table 3.** Results of measuring the content of soluble gases in fresh and service oil TP-30

Control object	Gas content, % vol.								
	CH <sub>4</sub>	C <sub>2</sub> H <sub>4</sub>	H <sub>2</sub>	C <sub>2</sub> H <sub>6</sub>	C <sub>2</sub> H <sub>2</sub>	CO	CO <sub>2</sub>	C <sub>3</sub> H <sub>6</sub>	C <sub>3</sub> H <sub>8</sub>
Fresh oil TP-30	0	7,4·10 <sup>-5</sup>	1·10 <sup>-5</sup>	0	0	0.0013	0.0051	0	0
Operating oil TP-30	0.0056	8·10 <sup>-3</sup>	0.01	0.05	0.034	0.026	0.028	0.56	3·10 <sup>-3</sup>

**Note:** taken from the oil tank 1MB-1 of the pumping unit of the cooling tower of SD RNPP Unit 1 in 2020

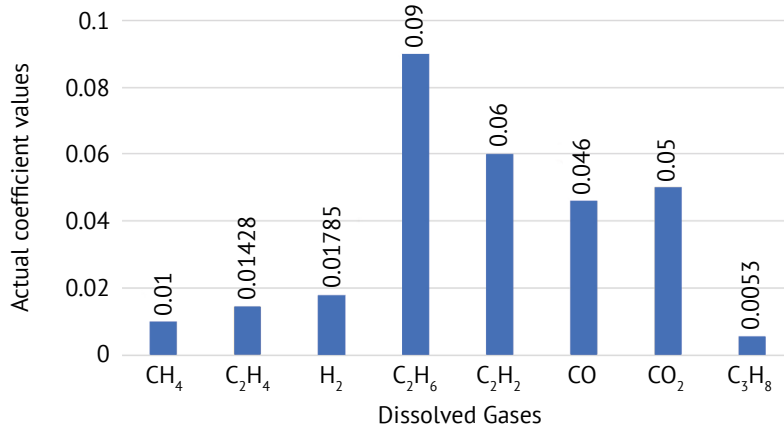
**Source:** developed by authors

Thus, during the degradation of TP-30 oil, a significant accumulation of propylene (C<sub>3</sub>H<sub>6</sub>) is observed, which is characterised by the maximum content of this gas in TP-30 service oil.

The actual values of the coefficients of the ratio of each of the soluble gases in TP-30 oil to the content of propylene (C<sub>3</sub>H<sub>6</sub>), the concentrations of which were the most significant, indicate that ethane (C<sub>2</sub>H<sub>6</sub>)

accounted for the largest share in their composition, slightly lower was the content of acetylene ( $C_2H_2$ ), carbon dioxide ( $CO_2$ ) and carbon monoxide (CO), even lower was the content of hydrogen ( $H_2$ ), ethylene ( $C_2H_4$ ) and methane ( $CH_4$ ), and quite insignificant was the content

of propane ( $C_3H_8$ ) (Fig. 3). The accumulation of other hydrocarbons was minimal, with the ratio to propylene ranging from 0.005% to 0.09%. The ratio of carbon dioxide and carbon monoxide content to propylene content was 0.05%.



**Figure 3.** Actual values of soluble gas coefficients in TP-30 oil characterising the presence of defects in friction zones  
**Source:** developed by authors

Since the defect of the oil-filled TP-30 pumping unit of cooling tower No. 1 of the SD RNPP was characterised by defects in the friction zones, as evidenced by the results of a visual and instrumental examination of the thrust bearing, the indicated coefficients and dynamics can be characterised as typical of defects in the friction zones.

The SD RNPP cooling water recirculation system includes a circulating technical water supply system, and technical water supply systems for responsible and non-responsible consumers. The return water of the recirculating cooling system of the SD RNPP is discharged into the Styr River. According to the implemented design solution, there is no background cooling pond for the SD RNPP, which means that pollutants, including oil products, can enter the Styr River, a water body for fisheries purposes. Thus, diagnostics of defects in the oil-filled equipment of RNPP recirculating cooling systems is important from an environmental standpoint to prevent the discharge of oil products exceeding the permissible approved concentration under the terms of the permit for special water use of SD RNPP into the Styr River with return water.

Therewith, to prevent the discharge of by-product pollutants into the Styr River from the SD RNPP process equipment, their content in the wastewater is standardised. The maximum acceptable concentration (MAC) of oil products in SD RNPP discharge wastewater is  $0.104 \text{ mg/dm}^3$  and the maximum permissible discharge (MPD) is 1.91 tons per year (Permit for special water use, 2020). In addition, mineral oils are included in the class of petroleum products for which the maximum permissible concentration in fishery water bodies ( $MPC_{\text{fishery}}$ ) is  $0.05 \text{ mg/dm}^3$  (Water Quality Standards of Fisheries, 1999) and in domestic and drinking water –  $0.3 \text{ mg/dm}^3$  (Order of the Ministry of Health of Ukraine No. 721, 2022).

The analysis of the average annual values of the mass concentration of oil products in the discharge waters of the SD RNPP and the Styr River (Reports on the assessment of the impact of non-radiation factors..., 2022) demonstrates that the actual values of the concentration of oil products in the discharge waters for 2018-2021 were significantly lower than the MAC (Table 4). Their values ranged from 16-50% of the MAC values of oil products in the discharge waters.

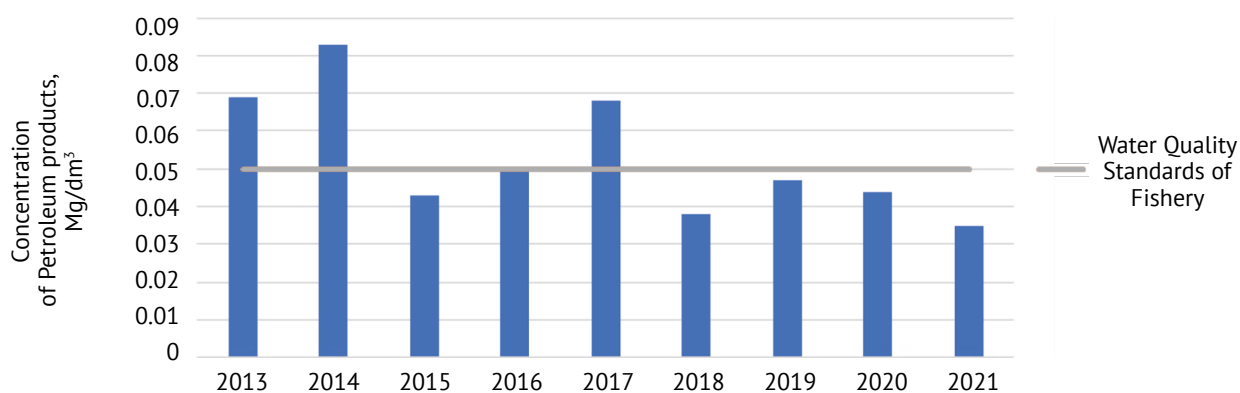
**Table 4.** Average annual values of mass concentration of oil products in SD RNPP discharge waters and the Styr River

Year	MPC for fishery and agricultural oil products, $\text{mg/dm}^3$	MAC of oil products, $\text{mg/dm}^3$	Mass concentration of oil products, $\text{mg/dm}^3$		
			r. Styr to discharge	Wastewater of the SD RNPP	r. Styr after discharge
2018	0.05	0.32	0.032	0.052	0.038
2019		0.32	0.030	0.051	0.047
2020		0.104	0.043	0.053	0.044
2021		0.104	0.058	0.050	0.035

**Source:** developed by authors

In some years, the mass concentration of oil products in the Styr River after SD RNPP discharge exceeded the  $\text{fishery MPC}$ , in particular in 2013, 2014 and 2017. In these years, a similar exceedance of the  $\text{fishery MPC}$

was observed in the water of the Styr River before SD RNPP discharge. Instead, in 2015, 2016, and 2018-2021, these exceedances were not observed (Fig. 4).



**Figure 4.** Mass concentration of oil products in the Styr River after SD RNPP effluent discharge

**Source:** developed by authors

Thus, during the operational event, the content of oil products in the Styr River, below the discharge of wastewater from the Rivne NPP, was within the permissible values. This fact indicates that there is no contamination of the river's surface waters with this group of substances, and therefore allows asserting that there is no supply of TP-30 circulating power oil residues with RNPP effluents after the shutdown of the cooling tower pumping unit of power unit No. 1 due to defects in the bearing units.

As rightly noted by Šimić *et al.* (2022) and Hyvärinen *et al.* (2022), NPP operation involves a complex interaction of various subsystems consisting of technical and human factors, and together these interactions form the fundamental basis of nuclear safety. Thus, evidently, the considered operational event of oil wedge failure, which caused the shutdown of the cooling tower pumping unit of SD RNPP Unit 1, was one of the components of the overall safety of the power plant. The gradual development of such events is described in Tripathi & Singh (2020), Corzo *et al.* (2023), who, similarly to the author's conclusion, call prolonged exposure to vibration and elevated temperatures the causes of wear of cooling system equipment. As a result of the research, it was established that the development of the bearing defect occurs due to the gradual wear of its soft base, which is confirmed by Rodiouchkina *et al.* (2018) and Jayakanth *et al.* (2020). According to Mathews *et al.* (2022), this, in turn, can cause changes in the chemical composition of the bearing material. However, in the operational event considered by the authors, there was only a 1.2 and 1.1-fold increase in the content of Cu and Sb relative to the standard values, respectively. The overall chemical composition of the bearing material remained unchanged.

According to this research, the content of soluble gases is an indicative diagnostic criterion for monitoring

turbine oil degradation processes, which is confirmed by de Faria *et al.* (2015). The data obtained by the authors on the content of soluble gases under ultrasonic irradiation of fresh TP-30 oil were comparable to the data for TP-30 oil that was in operation. This situation can be explained by the relationship between operating time, oil degradation processes, and soluble gas development for transformer oil, which was observed by Wani *et al.* (2021) and Dou *et al.* (2022). The authors identified the presence of soluble hydrocarbon gases, CO, CO<sub>2</sub>, and hydrogen in samples of TP-30 service oil. Consider this as the consequence of defects that occurred during the failure of the oil wedge of the cooling tower pumping unit of SD RNPP Unit 1 in the operational event of 2021 (Kuznetsov *et al.*, 2022). This statement is supported by the results of Faig *et al.* (2018), who noted that the content of soluble gases, in particular hydrocarbons, CO, CO<sub>2</sub>, and hydrogen in energy oils characterise the presence of defects in the friction surface areas. Notably, the presence of soluble hydrocarbon gases, CO, CO<sub>2</sub>, and hydrogen affects the content of the antioxidant additive, and in the process of their development, oil wear occurs with a loss of protective properties (Zaitsev *et al.*, 2015).

The results of the authors' monitoring of the gas content in TP-30 oil indicate that all recommended control levels of gas content except for carbon monoxide in TP-30 oil are exceeded. It allows concluding that there is an intensive process of oil degradation. According to Velmurugan *et al.* (2020), oil degradation can be caused by an external physical factor, in particular, a defect in the friction surfaces under the influence of vibration. By analogy with the regulatory requirements for transformer oils (SOU-N EE 46.501:2006, 2006), it is recommended to set the control level of gas content in TP-30 oil: hydrogen – 0.005%; methane, ethane, ethylene 0.0015%; acetylene – 0.0003%; carbon monoxide – 0.02%;

carbon dioxide – 0.1%. It is assumed that the current content of soluble hydrocarbon gases, CO, CO<sub>2</sub>, and hydrogen in the TP-30 service oil examined by the authors has decreased the content of the antioxidant additive ionol. This will be the subject of further research since when control levels of gases in turbine oil are exceeded, it is recommended to conduct a technical analysis of the operation of NPP units as an “initial event” (Chen *et al.*, 2023) and conduct an additional determination of mechanical impurities by the particle size distribution method for an extended assessment of oil quality (Boichenko *et al.*, 2019).

In general, for transformer oils, the ratios of individual gas pairs have specific regulatory values (SOU-N EE 46.501:2006, 2006) and, according to Fei *et al.* (2009), it is the individual gas pairs that determine the type of major defects. In the authors' research, it was observed that the developed ethane (C<sub>2</sub>H<sub>6</sub>) had a ratio of 0.09% to propylene (C<sub>3</sub>H<sub>6</sub>). The accumulation of acetylene (C<sub>2</sub>H<sub>2</sub>) was characterised by a ratio of 0.06%, carbon dioxide (CO<sub>2</sub>) and carbon monoxide (CO) 0.05% in both cases. Therefore, the results obtained by the authors indicate the presence of a defect in TP-30 oil, characterised by the accumulation and development of a significant amount of propylene (C<sub>3</sub>H<sub>6</sub>).

The absence of exceedances of oil products in SD RNPP effluent and surface waters of the Styr River in 2021 indicates that defects in the oil-filled equipment of the technical water supply system did not result in the discharge of oil products into the water process media of the recycled water supply and SD RNPP effluent. However, according to Aganbi *et al.* (2019) and Xiaojie *et al.* (2022), the detected cases of excessive oil content in surface waters necessitate their constant monitoring. Thus, the author believes that continued monitoring of the content of oil products in the surface waters of the Styr River will be an essential foundation for taking measures to ensure the environmentally safe use of TP-30 oil in the operation of SD RNPP turbines.

## CONCLUSIONS

The content of chemical elements in the segments of the thrust bearing of the pump unit, which is based on Sn, was within the normalised content for such elements as As (0.02 ± 0.01%) and Pb (0.22 ± 0.05%). The Cu content (7.84 ± 1.05%) exceeded the standard by an average of 1.2 times. The Sb content (13.21 ± 1.14%) exceeded the

permissible levels by 1.1 times. Such a change in the chemical composition of the bearing alloy indicates prolonged exposure to friction, vibration and high temperatures.

The determination of a set of physical parameters of TP-30 oil identified an increase in the mass fraction of mechanical impurities only based on the results of the incoming inspection. In particular, their content amounted to 0.0026%, while the normalised requirement was their complete absence. The remaining indicators did not demonstrate deviations, which suggests the necessity of expanding their list for monitoring the degradation processes of TP-30 oil.

Chromatographic determination of the content of soluble gases in TP-30 heating oil identified the highest content of propylene (C<sub>3</sub>H<sub>6</sub>), which was 0.56% by volume. The ratio of other soluble gases to the C<sub>3</sub>H<sub>6</sub> content, in descending order, was as follows: ethane (C<sub>2</sub>H<sub>6</sub>), acetylene (C<sub>2</sub>H<sub>2</sub>), carbon dioxide (CO<sub>2</sub>) and carbon monoxide (CO), hydrogen (H<sub>2</sub>), ethylene (C<sub>2</sub>H<sub>4</sub>), methane (CH<sub>4</sub>), propane (C<sub>3</sub>H<sub>8</sub>). Such a distribution in the ratio of soluble gases indicates bearing defects in the friction zones due to oil degradation. To identify the degradation processes of TP-30 oil, characterised by the influence of vibration friction of surfaces, it is recommended to diagnose the oil by the accumulation of propylene (C<sub>3</sub>H<sub>6</sub>) and the ratio of such gases as ethane (C<sub>2</sub>H<sub>6</sub>), acetylene (C<sub>2</sub>H<sub>2</sub>), and carbon dioxide and carbon monoxide (CO<sub>2</sub>, CO).

The content of petroleum products in the return water of the SD RNPP recirculating cooling system did not exceed 16-50% of the approved permissible concentrations during the monitoring period. In the dynamics of mass concentration of oil products in the Styr River before and after SD RNPP wastewater discharge, the fishery MPC was exceeded in 2013, 2014 and 2017. In 2015, 2016, and 2018-2021, there were no exceedances. It indicated the absence of residues of circulating energy oil TP-30 of the pumping units of the cooling towers of the recycled water supply system of the SD RNPP into the surface waters of the Styr River during the operational event in 2021.

The obtained research results prove the importance of the optimal selection of diagnostic criteria for the operation of TP-30 mineral oil in turbine units and have the prospect of continuing in terms of additional determination of physical indicators to deepen the monitoring of oil degradation and safety in the technological cycles of nuclear power plants.

## REFERENCES

- [1] Mathews, J.A., Sietsma, J., Petrov, R.H., & Santofimia, M.J. (2022). Influence of chemical segregation on bainitic microstructures in a carburized bearing steel. *Materials & Design*, 223, article number 111232. doi: 10.1016/j.matdes.2022.111232.
- [2] Aganbi, E., Iwegbue, C.M.A., & Martincigh, B.S. (2019). Concentrations and risks of polychlorinated biphenyls (PCBs) in transformer oils and the environment of a power plant in the Niger Delta, Nigeria. *Toxicology Reports*, 6, 933-939. doi: 10.1016/j.toxrep.2019.08.008.

- [3] ASTM Standard D 4768-11. (2019). *Standard test method for analysis of 2,6-ditertiary-butyl para-cresol and 2,6-ditertiary-butyl phenol in insulating liquids by gas chromatography*. Retrieved from <https://www.astm.org/d4768-11r19.html>.
- [4] Balitskii, O.A., Kolesnikov, V.O., Balitskii, A.I., Elias, J.J., & Havrylyuk, M.R. (2020). Hydrogen effect on the high-nickel surface steel properties during machining and wear with lubricants. *Archives of Materials Science and Engineering*, 2(104), 49-57. doi: 10.5604/01.3001.0014.4894.
- [5] Boczkaj, G., Jaszczott, M., Przyjazny, A., & Kamiński, M. (2013). Application of normal-phase high-performance liquid chromatography followed by gas chromatography for analytics of diesel fuel additives. *Analytical and Bioanalytical Chemistry*, 405(18), 6095-6103. doi: 10.1007/s00216-013-7038-3.
- [6] Boichenko, S., Pushak, A., & Topilnytskiy, P. (2019) *Olives. Motor, turbine, hydraulic and transmission: Properties and quality*. Kyiv: Publishing House "Center of Educational Literature". doi: 10.18372/38010.
- [7] Boichenko, S.V., & Kalmykova, N.H. (2020). Cause and consequence analysis of losses of petroleum products in the tank park. *Science-Based Technologies*, 2(46), 218-235. doi: 10.18372/2310-5461.46.14810.
- [8] Chen, G.W., Liang, H.C., Wang, W.S., Wang, T.C., & Wu, S.C. (2023). On-site simulator-based initiating event detection and identification in NPPs. *Progress in Nuclear Energy*, 156, article number 104553. doi: 10.1016/j.pnucene.2022.104553.
- [9] Corzo, S.F., Ugarte, R., Godino, D.M., & Ramajo, D.E. (2023). Loss of flow accident analysis in Atucha II nuclear power plant using RELAP5 model. *Nuclear Engineering and Design*, 402, article number 112108. doi: 10.1016/j.nucengdes.2022.112108.
- [10] Da Costa, C., Whitmarsh, S., Lynch, T., & Creaser, C.S. (2016). The qualitative and quantitative analysis of lubricant oil additives by direct analysis in real time-mass spectrometry. *International Journal of Mass Spectrometry*, 405, 24-31. doi: 10.1016/j.ijms.2016.05.011.
- [11] de Faria, H., Costa, J.G.S., & Olivas, J.L.M. (2015). A review of monitoring methods for predictive maintenance of electric power transformers based on dissolved gas analysis. *Renewable and Sustainable Energy Reviews*, 46, 201-209. doi: 10.1016/j.rser.2015.02.052.
- [12] Dou, P., Zheng, P., Jia, Y., Wu, T., Yu, M., Reddyhoff, T., Liao, W.-H., & Peng, Z. (2022). Ultrasonic measurement of oil film thickness in a four-layer structure for applications including sliding bearings with a thin coating. *NDT & E International*, 131, article number 102684. doi: 10.1016/j.ndteint.2022.102684.
- [13] DSTU 3985-2000. (2000). *Gas chromatography. Terms and definitions*. Kyiv: Derzhspozhyvstandart of Ukraine.
- [14] DSTU 20847:2009. (2009). *Oil products. Determination of the sulfur content in automotive fuel by energy-dispersive X-ray fluorescence spectrometry*. Kyiv: Derzhspozhyvstandart of Ukraine.
- [15] DSTU 4383:2015. (2015). *Plain bearings. Multilayer materials for thin-walled plain bearings*. Kyiv: Derzhspozhyvstandart of Ukraine.
- [16] Faig, J.J., Zhang, Y., Ng, M.K., Luo, S., Shough, A.M., Schilowitz, A., Dierolf, M., & Urich, K.E. (2018). Thermocleavable friction modifiers for controlled release in lubricants. *Tribology International*, 120, 58-69. doi: 10.1016/j.triboint.2017.11.030.
- [17] Fei, S.W., Liu, C.I., & Miao, Y.B. (2009). Support vector machine with genetic algorithm for forecasting of key-gas ratios in oil-immersed transformer. *Expert Systems with Applications*, 36(3), 6326-6331. doi: 10.1016/j.eswa.2008.08.012.
- [18] DSTU 9972-74. (1974). *Petroleum turbine oils with additives. Technical conditions*. Kyiv: Derzhspozhyvstandart of Ukraine.
- [19] Grosu, Y., Ortega-Fernández, I., López del Amo, J.M., & Faik, A. (2018). Natural and by-product materials for thermocline-based thermal energy storage system at CSP plant: Compatibility with mineral oil and molten nitrate salt. *Applied Thermal Engineering*, 136, 657-665. doi: 10.1016/j.applthermaleng.2018.03.034.
- [20] Hu, E.Z., Xu, Y., Hu, K.H., & Hu, X.G. (2017). Tribological properties of 3 types of MoS<sub>2</sub> additives in different base greases. *Lubrication Science*, 29(8), 541-555. doi: 10.1002/ls.1387.
- [21] Order of the Ministry of Health of Ukraine No. 721 "On Hygienic Water Quality Standards of Water Bodies to Meet Drinking, Household and Other Needs of the Population". (May, 2022) Retrieved from <https://zakon.rada.gov.ua/laws/show/z0524-22#Text>.
- [22] Hyvärinen, J., Vihavainen, J., Ylönen, M., & Valkonen, J. (2022). An overall safety concept for nuclear power plants. *Annals of Nuclear Energy*, 178, article number 109353. doi: 10.1016/j.anucene.2022.109353.
- [23] DSTU 9516-1. (2016). *Iron ores. Determination of the content of various elements using X-ray fluorescence spectrometry. Part 1. Unified methodology*. Kyiv: Derzhspozhyvstandart of Ukraine.
- [24] Jayakanth, J.J., Chandrasekaran, M., & Pugazhenth, R. (2020). Impulse excitation analysis of material defects in ball bearing. *Materials Today: Proceedings*, 39(1), 717-724. doi: 10.5772/intechopen.68592.
- [25] Johnson, D.W. (2017). Applications of mass spectrometric techniques to the analysis of fuels and lubricants. In M. Aliofkhaeaei (Ed.), *Mass spectrometry*. London: InTechOpen. doi: 10.5772/intechopen.68592.

- [26] Kindrachuk, M.V., Vol'chenko, D.A., Vol'chenko, N.A., Stebeletskaya, N.M., & Voznyi, A.V. (2017). Influence of hydrogen on the wear resistance of materials in the friction couples of braking units. *Materials Science*, 53, 282-288. doi: 10.1007/s11003-017-0073-z.
- [27] Kostiuk, V.O. (2015). *Applied statistics: Study guide*. Kharkiv: O.M. Beketov National University of Urban Economy in Kharkiv.
- [28] Kuznetsov, P.M., Tikhomirov, A.Yu., & Zaitsev, S.V. (2022). Improvement of methods of control of turbine oil of pumping units circulating water supply of cooling towers of the Rivne NPP. In *Collection of abstracts of the 16<sup>th</sup> international scientific and technical conference of young scientists and specialists "Problems of modern nuclear energy"* (pp. 46-47). Kyiv: The Ukrainian Nuclear Society and the Council of Young Scientists at the Department of Physical and Technical Problems of Energy of the NAS of Ukraine.
- [29] Kyshnevskiy, V.P. (2021). *Hybrid technologies of water conditioning in energy*. Odesa: Ekolohiia.
- [30] Lin, S.R., Chou, H.W., & Chen, J.J. (2022). International case survey and literature review of maintenance strategy for decommissioning nuclear power plant during transition period. *International Journal of Pressure Vessels and Piping*, 198, article number 104654. doi: 10.1016/j.ijpvp.2022.104654.
- [31] Lovrec, D., & Tič, V. (2014). Determination and comparison between different hydraulic and turbine oils' lifetimes. In *3<sup>rd</sup> conference "Maintenance 2014"* (pp. 153-160). Zenica: B&H.
- [32] Monge, R., González, R., Hernández, B.A., Fernández-González, A., Viescace, J.L., García A., & Hadfield, M. (2015). Ionic liquids as an additive in fully formulated wind turbine gearbox oils. *Wear*, 328-329, 50-63. doi: 10.1016/j.wear.2015.01.041.
- [33] Moosavi, S.S., Djerdir, A., Ait-Amirat, Y., & Khaburic, D.A. (2015). Demagnetization fault diagnosis in permanent magnet synchronous motors: A review of the state-of-the-art. *Journal of Magnetism and Magnetic Materials*, 391, 203-212. doi: 10.1016/j.jmmm.2015.04.062.
- [34] Narcisi, V., Quartararo, A., Moscato, I., & Santucci, A. (2023). Analysis of coolant purification strategies for tritium control in DEMO water primary coolant. *Energies*, 16(2), article number 617. doi: 10.3390/en16020617.
- [35] Permit for special water use of VP RAEP No. 53/RV/49d-20. (2020). Retrieved from <https://e-services.davr.gov.ua/>.
- [36] Pioro, I., & Duffey, R. (2019). Current status of electricity generation in the world and future of nuclear power industry. In *Managing global warming* (pp.67-114). doi: 10.1016/B978-0-12-814104-5.00003-X.
- [37] Reports on the assessment of the impact of non-radiation factors on the environment of the "Rivnenskaya NPP" SE "NAEK "Energoatom" for the years 2018-2021 (2022).
- [38] Rodiouchkina, M., Berglund, K., Mouzon, J., Forsberg, F., Ullah Shah, F., Rodushkin, I., & Larsson, R. (2018). Material characterization and influence of sliding speed and pressure on friction and wear behavior of self-lubricating bearing materials for hydropower applications. *Lubricants*, 6(2), article number 39. doi: 10.3390/lubricants6020039.
- [39] Saeed, R.M., Frick, K.L., & Shigrekar, A. (2022). Mapping thermal energy storage technologies with advanced nuclear reactors. *Energy Conversion and Management*, 267, article number 115872. doi: 10.1016/j.enconman.2022.115872.
- [40] Saidi, M.Z., Pasc, A., El Moujahid, C., Canilho, N., Badawi, M., Delgado-Sanchez, C., Celzard, A., Fierro, V., Peignier, R., Kouitat-Njiwa, R., Akram, H., & Chafik, T. (2020). Improved tribological properties, thermal and colloidal stability of poly- $\alpha$ -olefins based lubricants with hydrophobic MoS<sub>2</sub> submicron additives. *Journal of Colloid and Interface Science*, 562, 91-101. doi: 10.1016/j.jcis.2019.12.007.
- [41] Šimić, Z., Peinador Veira, M., & Banov, R. (2022). Correlation between events with different safety significance in nuclear power plants. *Nuclear Engineering and Technology*, 54(7), 2510-2518. doi: 10.1016/j.net.2022.01.034.
- [42] SOU NAEK 085:2020. (2020). Turbine oils for NPP energy equipment. Rules of operation. DP "NAEK "Enerhoatom". Retrieved from <https://www.energoatom.com.ua/app-eng/index-eng.html>.
- [43] SOU-N EE 46.501:2006. (2006). Diagnostics of oil-filled transformer equipment based on the results of chromatographic analysis of free gases taken from the gas relay and gases dissolved in insulating oil. Methodical instructions. Kyiv: Derzhspozhyvstandart of Ukraine.
- [44] Srivastava, M., Goyal, S.K., & Saraswat, A. (2020). Ester oil as an alternative to mineral transformer insulating liquid. *Materials Today: Proceedings*, 43(5), 2850-2854. doi: 10.1016/j.matpr.2021.01.066.
- [45] Tripathi, A.M., Singh, B.L.K., Singh, C.S. (2020). Dynamic reliability analysis framework for passive safety systems of Nuclear Power Plant. *Annals of Nuclear Energy*. Vol. 140. P. 107139. doi: 10.1016/j.anucene.2019.107139.
- [46] Velmurugan, V., Aathif Akmal, S.M., Paramasivam, V., & Thanikaikarasan, S. (2020). Prediction of vibration and exhaust gas emission characteristics using palm oil with nano particle diesel fuel. *Materials Today: Proceedings*, 21, 800-805. doi: 10.1016/j.matpr.2019.07.248.
- [47] Wani, S.A., Rana, A.S., Sohail, S., Rahman, O., Parveen, S., & Khan, S.A. (2021). Advances in DGA based condition monitoring of transformers: A review. *Renewable and Sustainable Energy Reviews*, 149, article number 111347. doi: 10.1016/j.rser.2021.111347.
- [48] Water Quality Standards of Fishery. (1999). Retrieved from <https://www.fao.org/faolex/results/details/en/c/LEX-FAOC135449/>.

- [49] Xiaojie, Z., Mukherjee, K., Manna, S., Das, M.K., Kim, J.K., & Sinha, T.K. (2022). Efficient management of oil waste: Chemical and physicochemical approaches. In *Advances in Oil-Water Separation* (pp. 439-467). doi: 10.1016/b978-0-323-89978-9.00027-6.
- [50] Zaitsev, S.V., Kyshnevskiy, V.A., & Shuliak, Y.D. (2015). Development of a gas chromatographic method for the determination of ionol and water in energy oils by the method of additives. *Eastern European Journal of Advanced Technologies*, 2(6), 21-28. doi: 10.15587/1729-4061.2020.217234.

## Удосконалення методів контролю енергетичної оливи агрегатів оборотного водопостачання градирень Рівненської атомної електростанції

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**Анотація.** Актуальність дослідження зумовлене тим, що на атомних електростанціях у теплообмінному обладнанні енергетичних блоків експлуатуються водні насосні агрегати з використанням енергетичних олив. Діагностичні критерії олив дозволяють виявляти дефекти у роботі технологічного обладнання. Мета роботи – підвищення надійності експлуатації оливовонаповненого енергетичного обладнання за рахунок удосконалення моніторингу фізико-хімічних властивостей енергетичної оливи Тп-30. Основна увага приділена підвищенню надійності експлуатації оливовонаповненого енергетичного обладнання за рахунок удосконалення моніторингу фізико-хімічних властивостей енергетичної оливи Тп-30. Експериментальні дослідження були проведені методами хроматографії, газової та рідинної екстракції з використанням відповідного лабораторного устаткування. При дослідженні вмісту хімічних елементів у сегментах упорного підшипника насосного агрегату градирні, основу якого становить Sn було помічено збільшення вмісту міді Cu та Sb, які перевищували норматив у середньому в 1,2 та 1,1 рази, відповідно. Більшість проаналізованих фізичних показників якості оливи (вміст води, кінематична в'язкість, температура спалаху, кислотне число) не проявляли відхилень від нормативних значень. Було відмічено лише збільшення масової частки механічних домішок на 0,0026% відносно норми при вхідному контролі оливи Тп-30. Результати експлуатаційного контролю оливи за набором фізичних показників повністю відповідали встановленим технологічним нормам. Найвищий вміст серед розчинних газів у оливі (0,56 % об.) був зафіксований для пропілену (C<sub>3</sub>H<sub>6</sub>). Рекомендовано при ідентифікації процесів деградації оливи Тп-30 використовувати відносний вміст розчинних газів до C<sub>3</sub>H<sub>6</sub>. Встановлено відсутність надходження залишків циркулюючої енергетичної оливи Тп-30 до поверхневих вод р. Стир у період експлуатаційної події. Зроблено узагальнення щодо необхідності розширення діагностичних критеріїв якості оливи Тп-30, зокрема розширення переліку її фізичних показників. У практичному аспекті отримані результати можуть бути корисні для моніторингу якості інших марок нафтових олив у системах турбінних агрегатів атомних електростанцій, що важливо з огляду безпечної експлуатації теплообмінного обладнання

**Ключові слова:** безпека атомних електростанцій, експлуатаційна подія, підшипник, розчинні гази, нафтопродукти, поверхневі води



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## Competitiveness and determinants of Indonesia's natural rubber exports in main partner countries

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**Abstract.** The main destination countries play an important role in Indonesia's natural rubber exports, as most of Indonesia's natural rubber is exported to these countries. The purpose of this study was to examine the comparative advantage and determinants of Indonesia's natural rubber exports to major partner countries. The RCA (Revealed Comparative Advantage) index is used to assess the comparative advantage, and panel data regression analysis is used to analyze the determinants of exports to the main partner countries (USA, China, Japan, India, Republic of Korea, Brazil, Canada, Germany, Belgium and Turkey). The results of this study indicate that Indonesian natural rubber has a comparative advantage in the main partner countries, which are characterized by RCA index  $>1$ . In addition, it was determined that based on panel data regression, the increase in the world price of natural rubber and export restriction policies have led to a decline in natural rubber exports from Indonesia. It is found that the population of Indonesia reduces exports, while the population of partner countries increases exports due to population growth, which will increase the consumption of natural rubber. On the other hand, the increase in Indonesia's gross domestic product (GDP) will lead to an increase in natural rubber production capacity, which will contribute to an increase in exports. It is found that the previous year's demand was also taken into account by partner countries that import Indonesian natural rubber. The results of this study can be useful for the Indonesian government and stakeholders (such as natural rubber producers and exporters) to identify strategies to improve export performance

**Keywords:** comparative advantage, export, international trade, panel data regression, RCA index



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## INTRODUCTION

International trade is key to economies around the world. International trade can boost the economy and achieve broader development goals for the countries involved, such as employment, health, food security and poverty reduction. In conventional trade theory, it is assumed that trade will encourage economic prosperity because it leads to the reallocation of capital and the countries involved tend to be specialized so that economic growth occurs.

In developing countries, trade impacts financial growth, especially in the agricultural trade. It is mainly the case in the subsistence economic period, where most of the country's GDP is generated from the agricultural sector (Sohail *et al.*, 2021; Tulush *et al.*, 2022). In Indonesia, as a developing country, the agricultural sector contributed quite a lot to GDP, amounting to 13.70% in 2020 (Badan Pusat Statistik, 2021). During the economic crisis, the agricultural sector proved strong in the face of shocks and restored the national economy (Mulyani *et al.*, 2021). Meanwhile, during the stagnation due to the Covid-19 pandemic, the agricultural sector is the most potential sector to accommodate workers who have experienced termination of work (Malahayati *et al.*, 2021; Abendin & Duan, 2021).

One of the agricultural sub-sectors that are the mainstay of Indonesia is the plantation sub-sector which has a superior commodity, namely natural rubber. The potential of Indonesian natural rubber is quite promising because Indonesia is one of the largest exporters of natural rubber in the world (Mulyani *et al.*, 2021). Natural rubber not only provides benefits to the industries involved but also contributes greatly to the country's revenue. The contribution of natural rubber also cannot be considered small because in 2020 the export value of Indonesian natural rubber reached 2.9 USD. The export value beats almost all Indonesia's agricultural commodities except palm oil.

Natural rubber is a potential commodity because it supports community activities (Rachman *et al.*, 2020). Natural rubber is a raw material in various industries, especially automotive. The rubber industry is increasingly being developed in the automotive industry to meet the growing tire demand (Saputra *et al.*, 2021). Based on the UN Comtrade report, more than 75% of Indonesia's natural rubber is exported to major trading partner countries such as; the United States, China, Japan, India, the Republic of Korea, Brazil, Canada, Germany, Belgium and Turkey. It indicates that the main trading partner countries determine the development of Indonesia's natural rubber exports. The United States, China, Japan and India are the world's largest consumers of natural rubber (Arunwarakorn *et al.*, 2019). In addition,

Japan, the United States and China are the largest automotive manufacturers in the world (Oktora & Firdani, 2019). In the Republic of Korea, the automotive industry is the main manufacturing industry (Yun *et al.*,

2018), while the German automotive industry is well-known worldwide. Although the automotive industries of Brazil, Canada, Belgium and Turkey are not as famous as other main partner countries, the production of various brands of vehicles or spare parts is in these countries.

Prasada & Dhamira (2021) said that Indonesian natural rubber has a comparative advantage in the international market. Machmud *et al.* (2022) have discussed the comparative advantages of Indonesian natural rubber in the international market. Still, there have not been many studies that focus on comparative advantages in main partner countries. Therefore, the comparative advantage of natural rubber in major trading partner countries must be studied, considering that these countries are key in Indonesia's natural rubber exports. On the other hand, the demand for Indonesian natural rubber in major trading partner countries tends to fluctuate even though, according to (Prasada & Dhamira, 2021), the world's demand for natural rubber always increases every year. Natural rubber supplier countries other than Thailand and Malaysia are starting to emerge, showing growth in natural rubber exports in Indonesia's main trading partner countries such as Vietnam, Côte d'Ivoire and the Philippines.

Thus, this study examines the comparative advantages and determinants of Indonesian natural rubber exports in main partner countries.

## LITERATUR REVIEW

Comparative advantage is key in the international economy, where comparative advantage determines trade flows (Stellian & Danna-Buitrago, 2019). Bella Balasa first introduced Revealed Comparative Advantage (RCA) in 1965. RCA revealed comparative advantages by checking trade data that realized the impact of non-price and cost factors (Saki *et al.*, 2019). Countries that work together are increasingly suitable to be partners if the value of RCA is greater (Hamid & Aslam, 2017). Usman *et al.* (2022), in their study on the competitiveness of Indonesian and Thai natural rubber exports in the international market, established that using the RCA index, Indonesia and Thailand both have comparative advantages. It is also supported by the research of Daulika *et al.* (2020), which resulted in findings that Indonesia, Thailand, Malaysia and India had a comparative advantage in natural rubber commodities.

Price is decisive in the export of natural rubber. The rise and fall of rubber prices are associated with unstable demand and supply (Arunwarakorn *et al.*, 2019). Sari *et al.* (2021), studying the determinants of Indonesian rubber exports in Japan, found that world natural rubber prices had a positive effect. Meanwhile, in the study by Hanivia & Suprehatin (2022), the world price of natural rubber positively impacts Indonesia's exports to Japan in the long-term estimate. As for the study of Purnomowati *et al.* (2015), international natural

rubber prices negatively impact the demand for Indonesian natural rubber in the United States, Japan, Singapore and the Republic of Korea. Furthermore, in other commodities, international prices show a positive and significant relationship to the volume of North Sumatra coffee exports to the United States, Japan and Malaysia (Sihombing *et al.*, 2020).

In addition to world prices, domestic prices are determinants of natural rubber exports. Rachman *et al.* (2020), in their research on the analysis of Indonesian natural rubber exports using the GLS (Generalized Least Square) method, found that the price of Indonesian natural rubber has a positive influence on Indonesia's natural rubber exports. As for the study of Mulyani *et al.* (2021), domestic rubber prices positively affect Indonesia's natural rubber exports to China. In another study, the price of natural rubber at the exporter level is also positively related to the natural rubber trade to China (Oktora & Firdani, 2019).

Another variable that is estimated to affect natural rubber exports is GDP, which is the value of a country's final goods and services. The GDP or Gross Domestic Product is often associated with a country's income. In the study (Purmiyati & Muhammad, 2020), the destination country's GDP positively affects Indonesia's natural rubber exports. Meanwhile, Abdulrahman's study (2021), which analyzed the determinants of exports in Sudan, produced findings that Sudan's GDP positively affected the country's exports. Meanwhile, in another study, the GDP of exporting and importing countries both positively influenced Pakistan's agricultural commodity exports (Atif *et al.*, 2017).

Several studies explain the effect of population on natural rubber exports (Rachman *et al.*, 2020; Purmiyati & Muhammad, 2020). Ismail *et al.* (2019) analyzed Malaysia's main commodity exports and produced findings if the world population positively affects the export of natural rubber and tin in the long run. In other commodities, the population growth of importing countries will increase rice exports, while in coffee commodities, it will reduce exports (Nguyen, 2022). As for other studies, the world population also positively impacts Indonesia's agricultural commodity exports (Sugiharti *et al.*, 2020).

One of the obstacles in international trade is the restriction of export quotas. Export restrictions are an important instrument in international trade policy in the form of direct restrictions on the number of certain goods in exports (Chen *et al.*, 2021). Hanivia & Suprehatin (2022) in their research, concluded that the export restriction policy negatively affected the volume of Indonesian natural rubber exports in Japan. As for the study of Purnomowati *et al.* (2015), the export quota restriction decreases the demand for Indonesian natural rubber in the United States, China, Japan and the Republic of Korea.

## MATERIALS AND METHODS

Source of information: This study used secondary data from the United Nations Commodity Trade Statistics Division (UN COMTRADE) with a 6-digit HS code (HS 400122). In addition, this study also uses data sourced from the World Bank, Badan Pusat Statistik (Central Bureau of Statistics), Kementerian Perdagangan Republic Indonesia (Ministry of Trade Republic Indonesia), the Food and Agriculture Organization (FAO) and the Federal Reserve Economic Data (Fred Stlouisfed). The data used in this study is within a period of 17 years (2004-2020). On the other hand, the destination countries analyzed consist of the United States, China, Japan, India, the Republic of Korea, Brazil, Canada, Belgium, Germany and Turkey, considering these countries to be the main destination countries for Indonesian natural rubber exports.

Data analysis method: RCA measurement or commonly referred to as the Balasa index, is used to assess the export potential of Indonesian natural rubber commodities in alternative destination countries, systematically formulated in Long (2021); Pehlivanoğlu *et al.* (2021) as follows:

$$RCA_{ij} = \frac{X_{ij}/X_{tj}}{W_{ij}/W_{tj}} \quad (1)$$

Where  $RCA_{ij}$  is the index of commodity  $RCA-i$  to country  $j$ .  $X_{ij}$  is the value of commodity exports to country  $j$  (USD).  $X_{tj}$  is the total export value of Indonesia to the  $j$ -country (USD).  $W_{ij}$  is the value of the world's commodity exports to the  $j$ -country (USD).  $W_{tj}$  is the total export value of world products to country  $j$  (USD).  $i$  is Indonesia's natural rubber commodity and  $j$  is the main trading partner country. When the RCA index  $>1$ ,  $i$ -commodities have a comparative and specialized advantage (Pascucci, 2018). As for if the RCA index  $<1$ ,  $i$ -commodities have a low comparative advantage and are less specialized (Pascucci, 2018; Long, 2021).

Furthermore, the determinant analysis of Indonesia's natural rubber exports in major trading partner countries was carried out using panel data regression with a natural logarithm model. The natural logarithm model was chosen because there is a difference in units in free variables (Collischon & Eberl, 2020). The function of the model refers to the research of Oktora & Firdani (2019); Rachman *et al.* (2020) presented in equation (2):

$$\begin{aligned} \ln Y_{it} = & \beta_0 + \beta_1 PRICEa_t + \\ & + \beta_2 \ln PRICEb_{it} + \beta_3 \ln GDPa_t + \\ & + \beta_4 \ln GDPb_t + \beta_5 POPa_t + \\ & + \beta_6 POPb_{it} + \beta_7 Y_{it-1} + \beta_8 D_t + \varepsilon_{it}. \end{aligned} \quad (2)$$

Where  $\beta_0$  is an intercept while  $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7, \beta_8$  are estimated parameters.  $Y$  is the export volume of Indonesian natural rubber (tons).  $PRICEa$  is the world price of natural rubber (USD/ton) and  $PRICEb$  is the price of Indonesian natural rubber (USD/ton).  $GDPa$  is Indonesia's real GDP per capita (USD), while  $GDPb$  is the real GDP per capita of trading partner countries (USD).  $POPa$

is the population of Indonesia (people) and  $POP_b$  is the population of trading partner countries (people).  $Y_{t-1}$  is the volume of natural rubber exports in the previous year (tons). At the same time,  $D$  is a dummy variable of export restriction policy (0 = no export restriction policy, 1 = there is export restriction policy).  $i$  is a major trading partner country (United States, China, Japan, India, Republic of Korea, Brazil, Canada, Belgium, Germany and Turkey).  $t$  is the year (2004, 2005, ..., 2020) and  $\varepsilon$  are error terms.

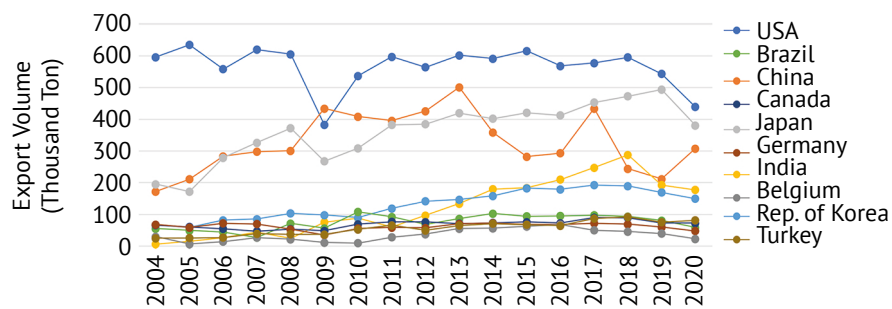
Panel data regression analysis in this study was carried out using STATA software. The coefficient of determination test ( $R^2$ ) measures the goodness of fit in the regression equation. F-test is used to simultaneously determine the independent variables' influence on the dependent variable. The t-test is used to determine the effect of independent variables on dependent variables partially.

Model selection: The data regression panel has three models: pooled OLS, fixed effect and random effect models. Therefore a chow test was conducted to choose a more suitable model for use between pooled OLS or fixed effect models (Herawati & Putra, 2018). If, in the chow test, the probability value  $<0.05$ , a more suitable

fixed effect model is used (Yuliadi, 2021). In addition, a Hausman test was also conducted to choose a model between a fixed effect or a random effect (Herawati & Putra, 2018). In the Hausman test, a better-fixed effect model is used if the probability value is  $<0.05$  (Yuliadi, 2021).

## RESULTS AND DISCUSSION

Figure 1 features the development of Indonesia's natural rubber export volume in major trading partner countries during 2004-2020. The United States is the largest importer of Indonesian natural rubber and the volume of exports to the United States is higher than other trading partner countries (except in 2009). The export volume in China and Japan shows a higher quantity than the Republic of Korea, Brazil, Canada, Germany, Belgium and Turkey. Furthermore, the export volume of natural rubber from India and the Republic of Korea showed a pace that tended to be positive. In 2018, the volume of natural rubber exports to India exceeded China's. On the other hand, Indonesia's natural rubber export volume in Brazil, Canada, Germany, Belgium and Turkey tends to be stable.

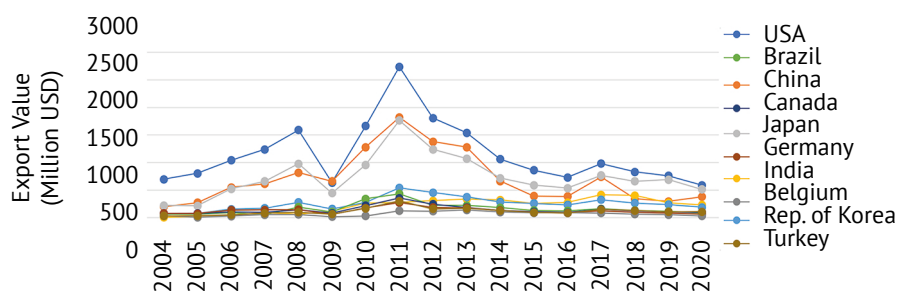


**Figure 1.** Indonesia's Natural Rubber Export Volume in Main Partner Countries during 2004-2020

**Source:** built by authors based on UN Comtrade (2021)

The development of Indonesia's natural rubber export value in the main trading partner countries is presented in Figure 2. The export value of natural rubber in the United States is higher than other trading partner countries because the demand for rubber by this country is the highest. The export value of natural rubber shows a pace with the same tendency in each of the trading partner countries. In 2008, the export value of natural rubber tended to increase, and the Food and

Agriculture Organization (FAO) reported an increase in the price of natural rubber. The following year (2009), the price of natural rubber decreased, resulting in a decrease in the value of exports in almost all trading partner countries. The export value of natural rubber peaked in 2011 due to the price of natural rubber being at the highest level. After 2011, the export value of natural rubber tended to decline even though in 2017, it experienced a slight increase due to price increase.

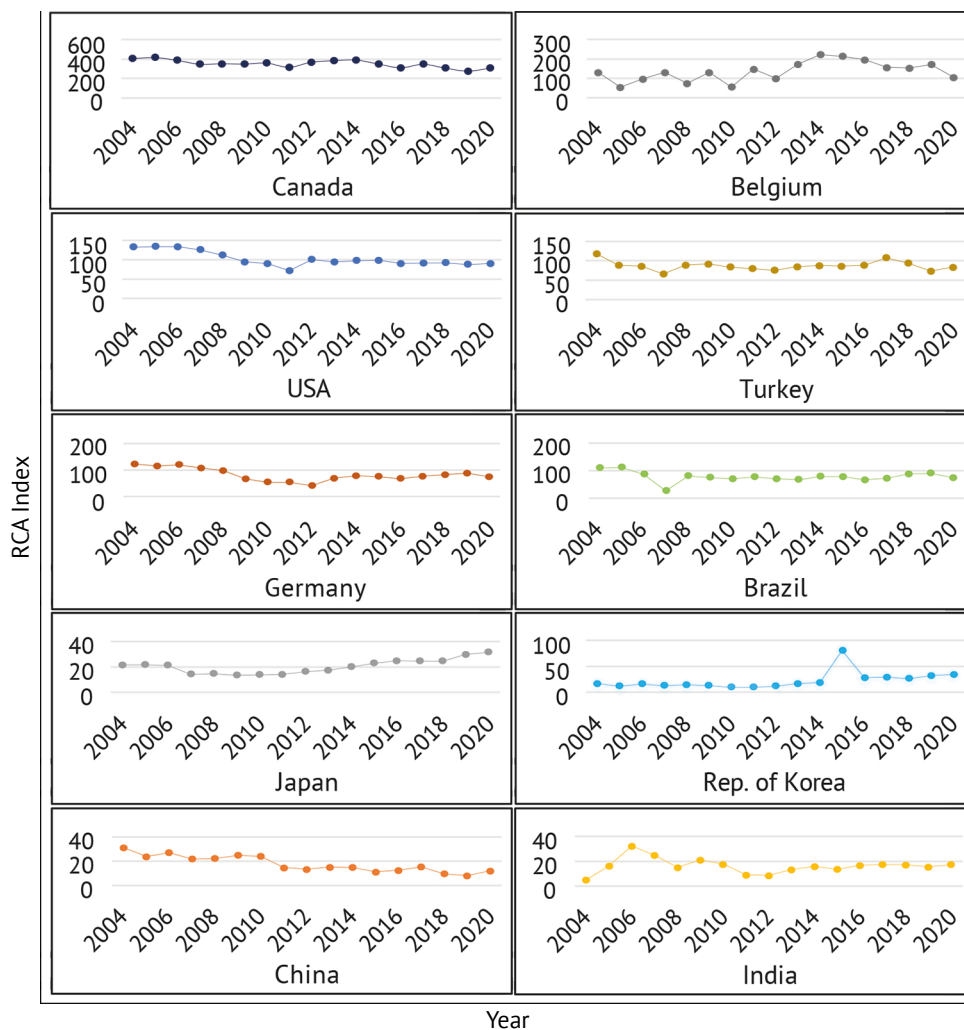


**Figure 2.** Indonesia's Natural Rubber Export Value in Main Partner Countries during 2004-2020

**Source:** built by authors based on UN Comtrade (2021)

Competitiveness is the ability of a commodity to enter foreign markets. Commodities are said to be competitive if they can survive in the market when there is a shock. Overall, the RCA index of Indonesian natural rubber commodities in major trading partner countries is  $> 1$  (shown in Fig. 3), so Indonesian natural rubber has a comparative advantage in major trading partner countries. The results of the RCA index also indicate that Indonesian natural rubber is specialized. The RCA index of Indonesia's natural rubber commodities in Belgium has fluctuated, while it has a more stable structure in other partner countries. The RCA index of Indonesia's natural rubber commodities in Canada is higher

than other trading partner countries. The RCA index in Belgium, the United States, Brazil, Germany and Turkey is larger than in China, Japan, the Republic of Korea and India. Although the value of natural rubber exports in the United States is the highest among other partner countries, the RCA index in that country is smaller than that of Canada and even Belgium. It is because the RCA index has relative properties. The rise and fall of the RCA index are not only caused by the export value of commodities in the country concerned but also influenced by the value of world natural rubber exports and also the export value of world products (natural rubber and others) both in exporting and partner countries etc.



**Figure 3.** Indonesia's natural rubber export RCA index in main partner countries during 2004-2020

**Source:** built by authors based on UN Comtrade (2021)

Based on Figure 3, the RCA Index in Brazil experienced the largest decline in 2007 when a global economic crisis caused Brazil to experience a recession (Haines *et al.*, 2020). On the other hand, the RCA Index in the Republic of Korea experienced the largest increase

and was at a peak point in 2015 due to the rise in the share of world natural rubber exports to world exports. Meanwhile, in the following year (2016), it experienced the biggest decline; that year there was a trade war in Asia Pacific.

**Table 1.** Result of panel data regression

	Pooled OLS		Fixed Effect		Random Effect	
	Intercept	Prob.	Intercept	Prob.	Intercept	Prob.
lnPRICEa	-.2843412 <sup>ns</sup>	0.251	-.4622568 <sup>**</sup>	0.035	-.2845626 <sup>ns</sup>	0.249
lnPRICEb	.2661314 <sup>ns</sup>	0.295	.3243442 <sup>ns</sup>	0.146	.2660823 <sup>ns</sup>	0.293
lnGDPa	.5047384 <sup>ns</sup>	0.214	.8955477 <sup>**</sup>	0.014	.5051322 <sup>ns</sup>	0.212
lnGDPb	.1442847 <sup>***</sup>	0.001	-.0805985 <sup>ns</sup>	0.458	.1445511 <sup>***</sup>	0.001
lnPOPa	-2.518593 <sup>ns</sup>	0.314	-4.108242 <sup>*</sup>	0.070	-2.519889 <sup>ns</sup>	0.312
lnPOPb	.2120623 <sup>***</sup>	0.000	1.972252 <sup>**</sup>	0.038	.212345 <sup>***</sup>	0.000
lnYt-1	.7310479 <sup>***</sup>	0.000	.5113546 <sup>***</sup>	0.000	.7306415 <sup>***</sup>	0.000
D (0 = no export restriction policy, 1 = there is export restriction policy)	-.0862928 <sup>ns</sup>	0.121	-.0880502 <sup>*</sup>	0.070	-.086295 <sup>ns</sup>	0.119
_cons	42.93925	0.357	43.36921	0.293	42.96	0.355
R-square	0.8143		0.7120		68.06	
Prob>F	0.0000		0.0000		0.000	

**Note:** ns insignificant; \* significant at  $\alpha = 10\%$ ; \*\* significant at  $\alpha = 5\%$ ; \*\*\* significant at  $\alpha = 1\%$

**Source:** own calculation from STATA 15

World natural rubber prices, Indonesia's per capita real GDP and Indonesia's population are positively significant in the fixed effect model. The real GDP per capita of the destination country is significant in the pooled OLS (Ordinary Least Square) model and the random effect model and has a positive influence. In addition, the population of the destination country and the volume of natural rubber exports of the previous year had a positive and significant effect on all models. The export restriction policy is only significant in the fixed effect model and has a negative impact. The price of Indonesian natural rubber is insignificant in all models.

More, world natural rubber prices, Indonesia's real GDP per capita, Indonesia's population and export quota restriction policies are not significant in the pooled OLS model and random effect model. To determine the model to be analyzed, the study was based on the results of the Chow test and the Hausman test. Chow test results are based on Table 2 showing a probability value of 0.000 ( $< 0.05$ ), making the fixed effect model more suitable. Similarly, the results of the Hausman test also showed a probability value of  $< 0.05$ , so the fixed effect model is more appropriate. Based on the results of the two tests, it was decided to use the fixed effect model in the analysis.

**Table 2.** Result of chow and hausman test

Test	N	Statistic Type	Statistic Value	Prob.
Chow	85	F	6.60	0.0000
Hauman	85	X <sup>2</sup>	79.97	0.0000

**Source:** own calculation from STATA 15

According to Piepho (2019), R-square describes the proportions of the corrected sum of squares defined by the model. The R-square value based on the fixed effect approach (Table 1) is 0.7120. These results show that 71.20% of Indonesia's natural rubber exports can be explained by the world natural rubber price (PRICEa), Indonesia's natural rubber price (PRICEb), Indonesia's per capita real GDP, Indonesia's population (POPa), the population of the destination country (POPb), the previous year's export volume ( $Y_{t-1}$ ) and the export restriction policy (D). In contrast, other variables outside the model explain the remaining 28.80%. In addition, the probability value of F based on the fixed effect model

is 0.000. If the probability value of  $F < 0.05$ , the independent variables simultaneously have a significant relationship with the dependent variable (Herawati & Putra, 2018). Based on the result, simultaneously, Indonesia's natural rubber exports are influenced by world natural rubber prices (PRICEa), Indonesian natural rubber prices (PRICEb), Indonesia's per capita real GDP, Indonesia's population (POPa), the population of the destination country (POPb), the previous year's export volume ( $Y_{t-1}$ ) and the export restriction policy (D).

The world natural rubber price with a probability of 0.035 (significant at  $\alpha = 5\%$ ) negatively influences Indonesia's natural rubber exports. These results are not

in line with the findings of (Mulyani *et al.*, 2021; Hanivia & Suprehatin, 2022). With every 1% increase in world natural rubber prices, Indonesia's exports to partner countries decreased by 0.462%. That is under demand theory, where every time there is a price increase, it will cause demand to fall. On the other hand, Indonesia's natural rubber prices have a positive but insignificant influence. Domestic rubber prices are subject to world rubber prices (Ismail *et al.*, 2019). The rise and fall of domestic rubber prices follow the movement of world rubber prices. Therefore, Indonesia's trading partners prefer to make purchasing decisions based on world prices compared to domestic prices.

Indonesia's real GDP per capita has a probability value of 0.024 (significant at  $\alpha = 5\%$ ) and positively affects natural rubber exports in partner countries. These results are in line with the findings of Atif *et al.* (2017) and Sugiharti *et al.* (2020). Every 1% increase in Indonesia's GDP will increase natural rubber exports by 1.40%. Rosyadi *et al.* (2021) stated that the larger the GDP of a country, the greater the production capacity. It has led to an increase in the number of offers so that exports increase (Abafita & Tadesse, 2021). The GDP of exporters with a negative relationship with exports indicates competition between domestic market demand and export markets (Sugiharti *et al.*, 2020). Next, the real GDP per capita of the destination country has a positive but insignificant effect. These results indicate that the income of partner countries will not affect the demand for Indonesian natural rubber. Despite changes in revenue, partner countries continue to buy Indonesian natural rubber.

Another variable is that the Indonesian population has a probability value of 0.070 and is significant at  $\alpha = 1\%$ . Every 1% growth in Indonesia's population will reduce natural rubber exports by 2.52%. The growth of the population of exporting countries has caused the level of demand for domestic goods to increase. As a result, exports will decrease due to the supply of goods that meet domestic needs. On the other hand, the population of export destination countries increases Indonesia's natural rubber exports, which is in line with the findings of Purmiyati & Muhammad (2020) and Rachman *et al.* (2020). With every population growth of 1%, Indonesia's natural rubber exports increased by 1.97%. As is the case in exporting countries, according to Purmiyati & Muhammad (2020), the larger the population of the importing country, the greater the level of need for goods. The population growth of partner countries will also increase the number of overseas consumers (Susanto & Admi, 2021). Thus, it will indirectly increase the number of exports due to the increasing demand of partner countries.

The previous year's export volume ( $Y_{t-1}$ ) was significant at  $\alpha = 1\%$  (probability value 0.000). The increase in export volume during the last year by 1% will increase Indonesia's natural rubber export by 0.51%.

These results are in line with the findings of Sugiharti *et al.* (2020). The positive relationship between  $Y_t$  (export volume in year t) and  $Y_{t-1}$  indicates a growth trend in natural rubber exports (Purnomowati *et al.*, 2015). Within each period, the gap between the actual volume and the desired number of requests will be covered (Bose *et al.*, 2019). Unmet demand in the  $t-1$  year will increase the import of the destination country in the year  $t$ . The high coefficient of variable export volumes of the previous year signifies strong relationships with partners, increased demand and concentration of certain markets (Sugiharti *et al.*, 2020).

The export restriction policy is negatively significant at  $\alpha = 10\%$  (probability value 0.070). Every increase in natural rubber export restriction by 1% will decrease the export by 0.09%. These results align with the findings of Purnomowati *et al.* (2015) and Hanivia & Suprehatin (2022). Export restrictions are a useful policy in protecting the domestic population from scarcity of basic goods needs, protecting domestic industries from shortages of raw materials and maintaining scarce resources (Chen *et al.*, 2021). The policy of export restriction directly decreases the number of offers on the world market and impacts increasing international prices (Zhai *et al.*, 2022).

Indonesian natural rubber has competitiveness in main partner countries; the United States, China, Japan, India, the Republic of Korea, Brazil, Canada, Belgium, Germany and Turkey. It indicates that Indonesia and the leading partner countries are suitable for cooperating in the field of natural rubber trade. Therefore, Indonesia needs to pay attention and focus on carrying out exports in these countries. World natural rubber prices, Indonesia's GDP, Indonesia's population, the population of partner countries, the volume of natural rubber exports in the previous year and the policy of export quotas restriction are determinants in Indonesia's natural rubber exports in major partner countries. Efforts to increase natural rubber exports in main partner countries must be carried out because these countries support the success of Indonesia's natural rubber exports.

## CONCLUSIONS

This study analyzes the comparative advantages and determinants of Indonesia's natural rubber exports in main partner countries. In general, Indonesian natural rubber has a comparative advantage in major trading partner countries, so Indonesian natural rubber is specialized. The results indicate that Indonesia and the main trading partner countries are suitable as partners. The world's natural rubber prices, Indonesia's population and export quota restriction policies have a negative effect on natural rubber exports. On the contrary, Indonesia's GDP, the population of partner countries and the volume of exports in the previous year had a positive relationship with Indonesia's natural rubber exports in main partner countries.

Based on the conclusions obtained from the results of the analysis, Indonesia needs to maintain the competitiveness of natural rubber, considering that the main partner countries are key in Indonesia's natural rubber exports. The main trading partner countries are also the most potential markets because the need for natural rubber in the country is very high, considering the automotive industry in the country. Therefore, Indonesia needs to improve the quality of Indonesian natural rubber through a more standardized production

process. On the other hand, Indonesia also needs to increase the production and productivity of natural rubber to support increased export. This research can still be developed using other methods, such as EPD (Export Product Dynamics) and CMS (Constant Market Share), in analyzing the competitiveness of natural rubber. Other variables can be included in the model to explore export determinants, such as exchange rate, price of substitution goods (synthetic rubber), consumption of natural rubber, tariff policy, inflation rate and others.

## REFERENCES

- [1] Abafita, J., & Tadesse, T. (2021). Determinants of global coffee trade: Does RTAs matter? Gravity model analysis. *Cogent Economics and Finance*, 9(1), 1-22. doi: 10.1080/23322039.2021.1892925.
- [2] Abdulrahman, B.M.A. (2021). Analysis of export determinants in Sudan by using auto regressive distributed lag model (ARDL). *Academic Journal of Interdisciplinary Studies*, 10(4), 96-105. doi: 10.36941/AJIS-2021-0101.
- [3] Abendin, S., & Duan, P. (2021). International trade and economic growth in Africa: The role of the digital economy. *Cogent Economics and Finance*, 9(1), 1-25. doi: 10.1080/23322039.2021.1911767.
- [4] Arunwarakorn, S., Suthiwartnarueput, K., & Pornchaiwiseskul, P. (2019). Forecasting equilibrium quantity and price on the world natural rubber market. *Kasetsart Journal of Social Sciences*, 40(1), 8-16. doi: 10.1016/j.kjss.2017.07.013.
- [5] Atif, R.M., Haiyun, L., & Mahmood, H. (2017). Pakistan's agricultural exports, determinants and its potential: An application of stochastic frontier gravity model. *Journal of International Trade and Economic Development*, 26(3), 257-276. doi: 10.1080/09638199.2016.1243724.
- [6] Badan Pusat Statistik. (2021). Indikator Pertanian. Retrieved from <https://www.bps.go.id/publication/2021/10/08/d87b75366a02dbdbc6df37a0/indikator-pertanian-2020.html>.
- [7] Bose, S., Naabi, A.M.R.A., Boughanmi, H., & Yousuf, J.B. (2019). Domestic ban versus border rejections: A case of oman's fish exports to the EU. *SAGE Open*, 9(1), 1-12. doi: 10.1177/2158244018823079.
- [8] Chen, T., Gong, X., Li, Q., & Xu, H. (2021). Multiseason production planning under export quotas. *Naval Research Logistics*, 68(3), 279-294. doi: 10.1002/nav.21959.
- [9] Collischon, M., & Eberl, A. (2020). Let's talk about fixed effects: Let's talk about all the good things and the bad things. *Kolner Zeitschrift Fur Soziologie Und Sozialpsychologie*, 72(2), 289-299. doi: 10.1007/s11577-020-00699-8.
- [10] Daulika, P., Peng, K.C., & Hanani, N. (2020). Analysis on export competitiveness and factors affecting of natural rubber export price in Indonesia. *Agricultural Social Economic Journal*, 20(1), 39-44. doi: 10.21776/ub.agrise.2020.020.1.6.
- [11] Food and Agriculture Organization. (2021). Retrieved from <https://www.fao.org/faostat/en/#data/PP>.
- [12] Haines, A.E.F., Ferrari-Filho, F., & Neyra, H. (2020). The consequences of the international financial crisis and the great recession in Argentina and Brazil. *Revista de Economia Politica*, 40(1), 68-85. doi: 10.1590/0101-31572020-3048.
- [13] Hamid, M.F.S., & Aslam, M. (2017). The competitiveness and complementarities of agriculture trade among ASEAN-5 Countries: An empirical analysis. *International Journal of Economics and Finance*, 9(8), 88-102. doi: 10.5539/ijef.v9n8p88.
- [14] Hanivia, S.R., & Suprehatin. (2022). The effect of agreed export tonnage scheme (AETS) policy on Indonesia's natural rubber exports to Japan. *Journal of Agricultural Socioeconomics and Business*, 5(1), 12-21. doi: 10.22219/agriecobis.v5i1.20262.
- [15] Herawati, A., & Putra, A.S. (2018). The influence of fundamental analysis on stock prices: The case of food and beverage industries. *European Research Studies Journal*, 21(3), 316-326. doi: 10.35808/ersj/1063.
- [16] Ismail, N.A., Talib, B.A., & Mokhtar, A. (2019). Export analysis of major commodities in Malaysia. *IOP Conference Series: Earth and Environmental Science*, 327(1), article number 012002. doi: 10.1088/1755-1315/327/1/012002.
- [17] Long, Y. (2021). Export competitiveness of agricultural products and agricultural sustainability in China. *Regional Sustainability*, 2(3), 203-210. doi: 10.1016/j.regsus.2021.09.001.
- [18] Machmud, M., Siregar, H., Harianto., & Susila, W.R. (2022). The rubber industry of Indonesia: Strategy for competitiveness and sustainability. *European Journal of Business and Management*, 14(3), 52-64. doi: 10.7176/ejbm/14-3-06.
- [19] Malahayati, M., Masui, T., & Anggraeni, L. (2021). An assessment of the short-term impact of COVID-19 on economics and the environment: A case study of Indonesia. *Economia*, 22(3), 291-313. doi: 10.1016/j.econ.2021.12.003.
- [20] Mulyani, M., Kusnandar, & Antriyandarti, E. (2021). Analysis of Indonesian rubber export supply for 1995-2015. *Journal of Asian Finance, Economics and Business*, 8(1), 93-102. doi: 10.13106/jafeb.2021.vol8.no1.093.

- [21] Nguyen, D.D. (2022). Determinants of Vietnam's rice and coffee exports: Using stochastic frontier gravity model. *Journal of Asian Business and Economic Studies*, 29(1), 19-34. doi: 10.1108/jabes-05-2020-0054.
- [22] Oktora, S.I., & Firdani, A.M. (2019). Natural rubber economics between China and Southeast Asia: The impact of China's economic slowdown. *Journal of Asian Finance, Economics and Business*, 6(2), 55-62. doi: 10.13106/jafeb.2019.vol6.no2.55.
- [23] Pascucci, F. (2018). The export competitiveness of Italian coffee roasting industry. *British Food Journal*, 120(7), 1529-1546. doi: 10.1108/BFJ-05-2017-0306.
- [24] Pehlivanoğlu, F., Erarslan, C., & Demir, S. (2021). Factors affecting competition in olive oil exports: Panel data analysis of selected countries. Case study. *Agricultural Economics (Czech Republic)*, 67(12), 511-518. doi: 10.17221/494/2020-AGRICECON.
- [25] Piepho, H.P. (2019). A coefficient of determination (R<sup>2</sup>) for generalized linear mixed models. *Biometrical Journal*, 61(4), 860-872. doi: 10.1002/bimj.201800270.
- [26] Prasada, I.Y., & Dhamira, A. (2021). The competitiveness of natural rubber by exporting countries in the global market. *E3S Web of Conferences*, 305(2), article number 02006. doi: 10.1051/e3sconf/202130502006.
- [27] Purmiyati, A., & Muhammad, R.Y.S. (2020). Impact of distance, exchange rate, population, and GDP on natural rubber export. *Opcion*, 36(91), 124-138.
- [28] Purnomowati, H.D., Darwanto, D.H., Widodo, S., & Hartono, S. (2015). Analisis permintaan karet alam Indonesia di pasar internasional. *Journal of Agribusiness and Rural Development Research*, 1(2), 136-148. doi: 10.18196/agr.1217.
- [29] Rachman, A.N., Darsono, & Antriandarti, E. (2020). Analysis of Indonesian natural rubber export: Generalized least square approach. *International Journal of Advanced Science and Technology*, 29(03), 12406-12413.
- [30] Rosyadi, F.H., Mulyo, J.H., Perwitasari, H., & Darwanto, D.H. (2021). Export intensity and competitiveness of Indonesia's crude palm oil to main destination countries. *Agricultural Economics (Czech Republic)*, 67(5), 189-199. doi: 10.17221/371/2020-AGRICECON.
- [31] Saki, Z., Moore, M., Kandilov, I., Rothenberg, L., & Godfrey, A.B. (2019). Revealed comparative advantage for US textiles and apparel. *Competitiveness Review*, 29(4), 462-478. doi: 10.1108/CR-03-2018-0025.
- [32] Saputra, R., Walvekar, R., Khalid, M., Mubarak, N.M., & Sillanpää, M. (2021). Current progress in waste tire rubber devulcanization. *Chemosphere*, 265, article number 129033. doi: 10.1016/j.chemosphere.2020.129033.
- [33] Sari, D.K., Supriana, T., & Rahmanta. (2021). Determinant factors of Indonesian rubber export to Japan. *IOP Conference Series: Earth and Environmental Science*, 782(2), article number 022053. doi: 10.1088/1755-1315/782/2/022053.
- [34] Sihombing, F.N., Supriana, T., & Ayu, S.F. (2020). Identifying the factors contributing to the volume of coffee export from North Sumatra to the United States, Malaysia and Japan. *Journal of Sustainable Agriculture*, 36(1), 83-96. doi: 10.20961/carakatani.v36i1.43357.
- [35] Sohail, H.M., Zatullah, M., & Li, Z. (2021). Effect of foreign direct investment on bilateral trade: Experience from Asian emerging economies. *SAGE Open*, 11(4), 1-11. doi: 10.1177/21582440211054487.
- [36] Stellian, R., & Danna-Buitrago, J. (2019). Revealed comparative advantages and regional specialization: Evidence from Colombia in the Pacific Alliance. *Journal of Applied Economics*, 22(1), 349-379. doi: 10.1080/15140326.2019.1627722.
- [37] Sugiharti, L., Purwono, R., & Esquivias, M.A. (2020). Analysis of determinants of Indonesian agricultural exports. *Entrepreneurship and Sustainability Issues*, 7(4), 2676-2695. doi: 10.9770/jesi.2020.7.4(8).
- [38] Susanto, D.A., & Admi, R. (2021). The determinants of Indonesia's coal exports demand to six Asian Countries. *Journal of Developing Economies*, 6(1), 66-78. doi: 10.20473/jde.v6i1.18916.
- [39] Tulush, L., Korchynska, O., Krushelnyskyi, M., Babicheva, O., & Pivtorak, A. (2022). Dynamics of development of production and export of agricultural products in the context of foreign trade in Australia. *Scientific Horizons*, 25(5), 125-133. doi: 10.48077/SCIHOR.25(5).2022.125-133.
- [40] United Nations Commodity Trade Statistics Division. (2021). Retrieved from <https://comtrade.un.org/data/>.
- [41] Usman, M., Rezekina, M.U., Baihaqi, A., & Srihandayani. (2022). Analysis of export competitiveness of natural rubber from Indonesia and Thailand in the international market. *Scientific Journal of Accountancy, Management and Finance*, 1(4), 220-230. doi: 10.33258/economit.v1i4.588.
- [42] Yuliadi, I. (2021). A survey of agglomeration determinants in Indonesia. *Academic Journal of Interdisciplinary Studies*, 10(1), 304-312. doi: 10.36941/ajis-2021-0026.
- [43] Yun, J.J., Jeong, E.S., Lee, Y.K., & Kim, K.H. (2018). The effect of open innovation on technology value and technology transfer: A comparative analysis of the automotive, robotics, and aviation industries of Korea. *Sustainability*, 10(7), 1-16. doi: 10.3390/su10072459.
- [44] Zhai, L., Yuan, S., & Feng, Y. (2022). The economic effects of export restrictions imposed by major grain producers. *Agricultural Economics (Czech Republic)*, 68(1), 11-19. doi: 10.17221/329/2021-AGRICECON.

## Конкуентоспроможність та детермінанти експорту натурального каучуку Індонезії в основних країнах-партнерах

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**Анотація.** Основні країни призначення відіграють важливу роль в експорті натурального каучуку з Індонезії, оскільки більша частина індонезійського каучуку експортується саме в ці країни. Метою цього дослідження було вивчення порівняльних переваг та детермінант експорту натурального каучуку Індонезії до основних країн-партнерів. Для оцінки порівняльних переваг використано індекс RCA (Revealed Comparative Advantage), а для аналізу детермінант експорту до основних країн-партнерів (США, Китай, Японія, Індія, Республіка Корея, Бразилія, Канада, Німеччина, Бельгія та Туреччина) – регресійний аналіз панельних даних. Результати даного дослідження свідчать про те, що індонезійський натуральний каучук має порівняльні переваги в основних країнах-партнерах, які характеризуються індексом  $RCA > 1$ . Крім того, визначено, що на основі регресії панельних даних зростання світової ціни на натуральний каучук та політика обмеження експорту призвели до скорочення експорту натурального каучуку з Індонезії. Виявлено, що населення Індонезії скорочує експорт, тоді як населення країн-партнерів збільшує експорт за рахунок зростання чисельності населення, що сприятиме збільшенню споживання натурального каучуку. З іншого боку, збільшення валового внутрішнього продукту (ВВП) Індонезії призведе до збільшення виробничих потужностей з виробництва натурального каучуку, що сприятиме збільшенню обсягів експорту. Виявлено, що попит попереднього року також був врахований країнами-партнерами, які імпортують індонезійський натуральний каучук. Результати цього дослідження можуть бути корисними для уряду Індонезії та зацікавлених сторін (таких як виробники та експортери натурального каучуку) для визначення стратегій покращення експортних показників

**Ключові слова:** порівняльна перевага, експорт, міжнародна торгівля, регресія панельних даних, індекс RCA



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## Export performance of Indonesian Swallow's Nest commodities in main destination countries

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**Abstract.** The trend of increasing exports of Indonesian swallow's nests and the high market potential shown by increased consumption requires Indonesia as one of the main producers of swallow's nests to be able to seize the existing market opportunities. This study aims to determine the export performance of Indonesian swiftlet nests in the main destination countries. The method used in this research is Constant Market Share. The secondary data used is time series data collected from 2011 to 2020. Based on Constant Market Share analysis, it was stated that the commodity of swallow's nest tended to be in demand in the international market compared to other types of commodities. Export quantity is sufficient to meet market demand and market requirements in export destination countries. The results show that Indonesia has been able to market the swallow's nest commodity in countries with high demand, namely China, which is indeed the largest importer of swallow's nest in the world. The swallow's nest commodity has great potential to increase exports and Indonesia is a strong competitor as an exporter in three countries, China, the United States and Vietnam. This research material has practical value for the Indonesian government to increase trade cooperation in the context of market expansion to maintain Indonesia's position as a major exporter and the need for cooperation with domestic producers through efforts to expand market access, training and production assistance, increasing innovation and technology

**Keywords:** constant market share, product composition, distribution, competitiveness, agricultural sector



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## INTRODUCTION

Divergences in the geographical conditions of a country result in those in the natural resources owned, so it has an impact on differences in the leading commodities cultivated in each country. International trade encourages opportunities for each country to carry out export and import activities by removing various existing barriers. Increased exports can provide a stimulus to domestic demand which has an impact on the growth of large industries in a country. It is important to know the performance of export activities that have been carried out by a country to find out what obstacles and opportunities exist and can then be used as an effort to expand the export market.

The agricultural sector is one sector that can survive the impact of the COVID-19 pandemic. The Central Statistics Agency recorded an increase in exports of Indonesian agricultural commodities amid the COVID-19 pandemic by 14.02% in 2020. This figure was recorded as the largest increase in the period 2011 to 2020. Meanwhile, commodities that experienced a large increase in exports during the pandemic included swallow nests, medicinal plants, aromatics and spices, tobacco, and cloves (Central Bureau of Statistics, 2021). Harapuspa and Fitriani (2018) and Ali (2017) note that swallow's nest is the result of swallow saliva, which currently has a high economic value and is therefore cultivated. Swallow's nest is a commodity from the livestock sub-sector that is starting to become a new priority in Indonesia's export goals. Chok *et al.* (2021) states that swallow's nest is rich in protein, essential amino acids, important trace elements and basic sugars necessary for human biological functions. Swallow's nest also has anti-inflammatory effects and antioxidant properties, which may serve as a new alternative treatment for neurodegenerative diseases caused by oxidative stress, such as Alzheimer's and Parkinson's diseases.

In the observation period from 2011 to 2020 (Tai *et al.*, 2020), swallow's nest still ranks with the highest export value in livestock export commodities. Indonesia is the largest exporter of swallow's nest products in the world. According to UN Comtrade (2022), the total value of world exports in 2020 is 982.2 million USD. At the same time, Indonesia accounts for 540.7 million USD, which is about 55% of the total value of world exports. The upward trend of Indonesian swallow nest exports and the high market potential shown by increasing consumption requires Indonesia, as one of the major swallow nest producers, to be able to take advantage of existing market opportunities. Kamaruddin *et al.* (2019) indicate that the high price of swallow nest and the increasingly limited resources of swallow nest collected from the wild have prompted the community to increase swallow nest production by developing swallow rearing using swallow houses.

According to the signed protocol (The Ministry of Commerce, 2012), Indonesia can directly export swallow

nests to China without transit through a third party. The export of swallow nests to China may increase from 50% to 100%. With the signed protocol, swallow nest has the opportunity to become one of Indonesia's top 10 non-oil and gas export products. The Ministry of Commerce (2012) predicts that China will benefit from lower prices in the domestic market as there are no third party fees, which will increase market demand. Challenges in the form of changes in the international environment, especially in the trading system with the liberalization of the economy, have led to increased competition, including in the "swallow's nest" market. Sukhri (2018) proved that in a free trade environment, countries with higher comparative advantage and competitive advantage will have a greater ability to exist, even to penetrate and dominate the international market. A country will benefit from international trade if it specializes in production and exports goods that it produces more productively and imports goods that the country produces relatively less or that are not productive.

Taj & Wani (2019) and Crespo & Fontoura (2018) point out that export performance reflects the specific behavior of an economy in using its resources and capabilities in the international context at a given point in time. Improving export performance is currently a priority for companies competing in the economic environment and an integral factor in the country's economic growth. Therefore, this study aims to analyze the export performance of Indonesian swallow nests in the main destination countries. The novelty of this study is to define the object of study where Indonesia is the largest producer of swallow nests in the world with increasing exports in the last few years, and in 2021, the Ministry of Trade together with the Ministry of Agriculture promotes the export of swallow nests to the main destination countries. For this reason, it is necessary to analyze Indonesia's export performance to make this swallow's nest a great Indonesian product that can contribute more to the country's foreign exchange.

## MATERIALS AND METHODS

The basic method used in this research is the descriptive analytical method which is a research method by collecting data according to the truth, then the data is compiled, processed, and analyzed to be able to provide an overview of the existing problems. Analytical descriptive research takes problems or focuses on problems as they are when the research is carried out, the research results are then processed and analyzed to conclude (Sugiyono, 2014). The data used in this study are included in the type of secondary data. The form of secondary data is used in the form of time series data or time series with the period 2011-2020. Data were obtained from the United Nations Commodity Trade Statistics Division (UN COMTRADE), the Food and Agriculture Organization (FAO), the Central Statistics Agency (BPS),

the Ministry of Trade, the International Trade Center (ITC), and several other supporting literatures.

**Data analysis method.** Constant Market Share analysis is a decomposition method that was applied for the first time in international trade flows (Simonis, 2009). The use of the CMS model is motivated by the possibility that a country's exports during a certain period experience changes to the world as standard growth (Permatasari and Rustariyuni, 2015). The CMS model explains the performance of export growth into several components, including standard growth, the effect of product composition, the effect of market distribution, and the effect of competitiveness (Kaur and Nanda, 2017). Based on the above terminology, the formulation used in the CMS analysis is described as follows.

**Standard growth.**

$$g = \frac{W(t) - W(t-1)}{W(t-1)} \quad (1)$$

$$gi = \frac{W(t)i - W(t-1)i}{W(t-1)i} \quad (2)$$

$$gij = \frac{W(t)ij - W(t-1)ij}{W(t-1)ij} \quad (3)$$

Where  $g$  = Growth in export standards of all world commodities;  $gi$  = The growth of the world's swiftlet nest commodity export standards;  $gij$  = Standard growth of swiftlet nest commodity exports to country  $j$ ;  $W(t)$  = Total export value of all world commodities in year  $t$  (US\$);  $W(t)i$  = Total export value of the world swallow nest commodity in year  $t$  (US\$);  $W(t)ij$  = The total value of the world swallow nest commodity exports to country  $j$  in year  $t$  (US\$).

The standard growth parameter shows the export growth standard of the products of countries in the world. Exports of Indonesia's competitor countries can be seen through this growth analysis. If the standard of export growth is higher, Indonesia's export performance will be better (Suhana, et al. 2016). Vice versa, if standard export growth is lower than Indonesia's export growth, importing countries show Indonesia's export performance is worse.

**Product composition effect.**

$$\frac{\sum i(gi-g)E(t-1)i}{E(t-1)i} \quad (4)$$

Where  $gi$  = Standard growth of global swiftlet nest commodity exports;  $g$  = Growth in export standards of all world commodities;  $E(t-1)i$  = The total value of a country's exports of bird's nest commodities to the world in year  $t-1$  (US\$);  $E(t-1)$  = The total value of exports of all commodities of a country to the world in year  $t-1$  (US\$).

The product composition effect indicates whether a country has concentrated on a rapidly growing commodity market. The effect parameter of this product composition can be positive or negative. The positive

parameter in the product composition explains that Indonesia is able to take advantage of the export opportunities for swallow nest commodities (Jamilah et al., 2022). If the export growth of Indonesian swallow's nest products to the importing country is higher than the growth of imports of all products by the importing country, it means that the effect of the composition of Indonesian swallow's nest products in the importing country will be positive. Likewise, if the opposite occurs, then the composition effect is negative.

**Market distribution effect.**

$$\frac{\sum i \sum j (gij - gi) E(t-1)ij}{E(t-1)} \quad (5)$$

Where  $gij$  = Standard growth of swiftlet's nest commodity exports to country  $j$ ;  $gi$  = The growth of the world's swiftlet nest commodity export standards;  $E(t-1)ij$  = The total value of exports of bird's nest commodities from a country to country  $j$  in year  $t-1$  (US\$);  $E(t-1)$  = The total value of exports of all commodities of a country to the world in year  $t-1$  (US\$).

The market distribution effect measures export performance by analyzing the gain or loss in the country's exports of concern as a result of changes in the relative size of the export market. The market distribution effect parameter can be positive or negative. The parameter is positive if the exporting country distributes its market to the center of demand growth. If the export of Indonesian swallow's nests to countries with higher import growth from Indonesia, the market distribution effect will be positive. Otherwise, the market distribution effect will be negative.

**Competitiveness effect.**

$$\frac{\sum i \sum j (E(t-1)ij - E(t-1)ij) - gij E(t-1)ij}{E(t-1)} \quad (6)$$

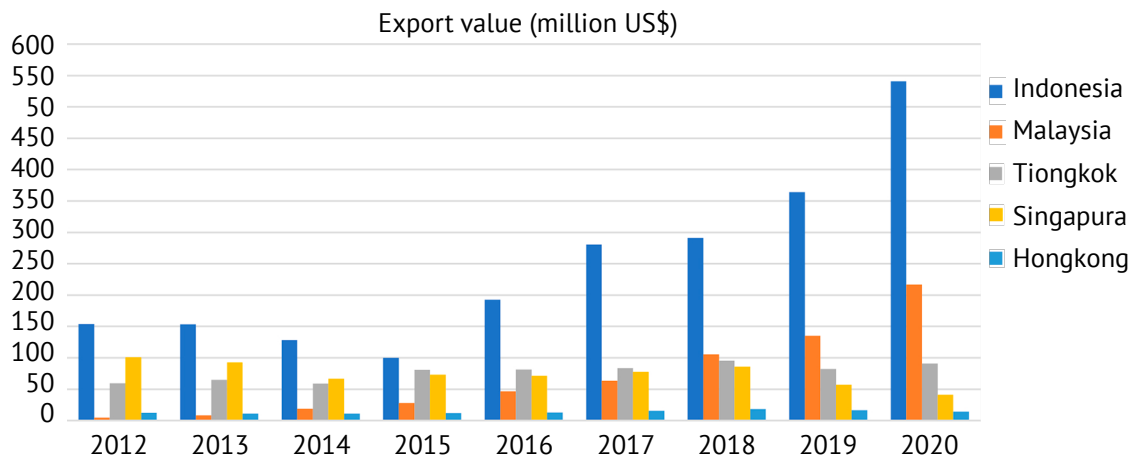
Where  $E(t)ij$  = The total value of exports of bird's nest commodities from a country to country  $j$  in year  $t$  (US\$);  $E(t-1)ij$  = The total value of exports of bird's nest commodities from a country to country  $j$  in year  $t-1$  (US\$);  $gij$  = Standard growth of swiftlet nest commodity exports to country  $j$ ;  $E(t-1)$  = The total value of exports of all commodities of a country to the world in year  $t-1$  (US\$).

The positive sign of competitiveness effect means that Indonesia's exports have increased, assuming the observed commodity contributes to the increase in exports and the country is a strong competitor. While the competitiveness effect is negative, it means that Indonesia's exports have decreased, assuming the observed commodities contributed to the decline in exports and the country is a weak competitor.

## RESULTS AND DISCUSSION

**World swallow's nest exporting countries.** The highest exporting countries for swallow's nests in the world which are in the top five based on export value are

Indonesia, Malaysia, China, Singapore and Hong Kong. These five countries have different export markets. The graphs of changes in export values for the five countries are presented below (Fig. 1).



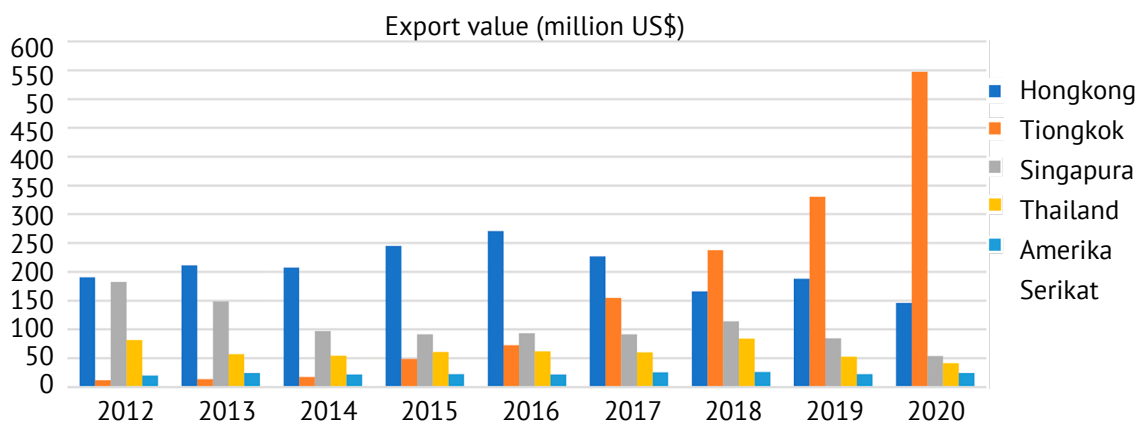
**Figure 1.** Export value of world swallow's nest exporting countries

**Source:** compiled by the authors

The graph above illustrates that the export value of Indonesian swiftlet nests in the period 2012 to 2020 still leads with a considerable difference with other exporting countries, namely Malaysia, China, Singapore and Hong Kong. Among the four other swallow nest exporting countries, only Malaysia has shown an increasing trend, although its position is still far below the export value of Indonesian swallow nests. The export value of China's swallow nests can be said to be the most constant among other countries because it is always in the range of an export value of 50-100 million

US\$. The Chinese and Indonesians both hold the same view of the business side of swallow nest farming that it is a good and lucrative business (Leonardo *et al.*, 2019).

**World swallow's nest importing countries.** The highest importing countries for swallow's nest in the world which are in the top five based on import value are Hong Kong, China, Singapore, Thailand and the United States. These five countries have different export markets (Fig. 2). The graphs of changes in import values for the five countries are presented below. Import values are presented in million US\$.



**Figure 2.** Import value of world swallow's nest importing countries

**Source:** compiled by the authors

The main importing countries of the world's swiftlet nests are China, Hong Kong, Singapore, the United States and Vietnam. Countries that have the potential to become world swallow nest importers are Thailand, Canada and Australia. In the period 2012-2017, Hong Kong was the largest importer of swallow's nests in the world, but since 2018 this position has been replaced

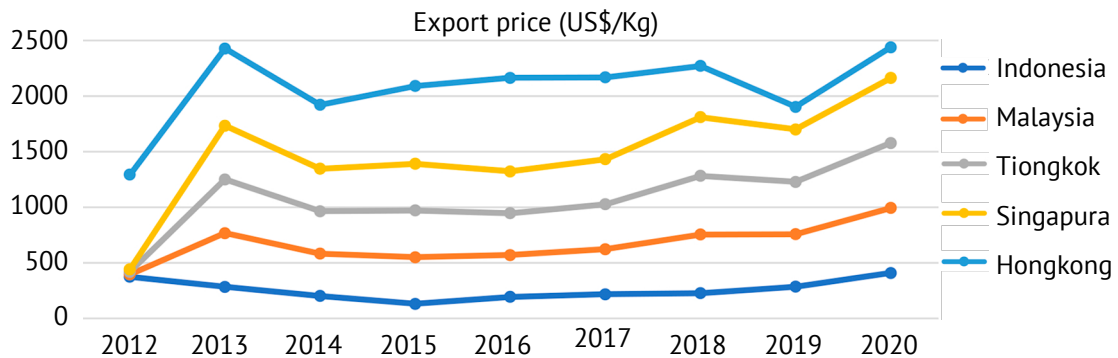
by China. The world's second largest importer of swallow's nest from 2012 to 2016 was Singapore, but since 2017 this position has been replaced by China and Hong Kong.

Swallow's nest is very popular for the people of Hong Kong and China because according to their tradition this commodity can be used as an ingredient for

longevity. This is related to the content in the swallow's nest in the form of nutrients such as carbohydrates, fats, and proteins which are very good for the regeneration of body cells (Dewi, 2020; Roh *et al.*, 2011). Generally, the people of Hong Kong and China consume swallow's nest in the form of soup. Swallow's nest soup contains much higher antioxidant activity compared with chicken and fish soup when served in the same way (Lee, 2014). Swallow's nest is also widely processed into drinks and incorporated into cosmetic mixtures as well as the main ingredients in skin care products. Traditional Chinese

medicine claims that the edible bird's nest serves as a remedy for ailments such as tuberculosis, asthma, skin problems, and stomach ailments (Golden Nest Inc, 2022; Ma and Liu, 2012; Careena *et al.*, 2018).

Indonesian Swallow's Nest Export Price. Each exporting country sells swallow's nests at different prices. This is because the exported product must undergo many processes and many costs that will affect the selling price. The graph of changes in the export price of swallow's nests by major exporting countries in the international market is presented below (Fig. 3).



**Figure 3.** Graph of changes in export price of swallow's nest in the international market, 2012-2020

**Source:** compiled by the authors

Product prices can be related to export performance. Studies show that product prices will have a negative relationship with export performance. When product prices rise, export performance will depreciate. However, if there is a decrease in product prices, export performance will increase (Tangjitmanngamkul, 2019). The export price of Indonesian swallow's nest commodities is in the lowest position when compared to its four competing countries. In this case, the amount of production has not been proportional to the demand figure or the supply and demand are not yet on a balance. So that the price of swallow's nest is always stable, never experiencing a drastic price decline. This is also influenced by the low yields, while the production and maintenance costs are so high. So that it helps raise the price of swallow nests, both raw and processed food (Risaad, 2021; Efendi *et al.*, 2022). The chart of export prices for the five main exporters of swallow's nests has almost the same trend. Hong Kong, Singapore and China have high export prices because they also import from Indonesia at lower prices and then re-export with the implementation of SPS (Sanitary and Phytosanitary), TBT (Technical Barriers to Trade), and PSI (Preshipment Inspection) which is more structured. Export prices for Indonesian swallow's nests began to increase in 2015. This was due to a reciprocal agreement between Indonesia and China which provided an opportunity for Indonesia to export directly without going through third parties, so that profits were no longer shared with countries that acted as third party in matters of trade in the swallow's nest (Ministry of Trade, 2012).

There are two options if Indonesia exports through a third party. First, selling its swallow's nest to Malaysia which has the consequence of decreasing prices because Malaysia is also one of the swallow's nest players in China. Second, sell it to Hong Kong, which applies a re-export tax fee. China is forcing Indonesia to switch exports through Hong Kong by playing up health issues which can reduce prices to become much cheaper.

The China government also devalued the currency which resulted in a two-way win for China. First, the purchase transaction of raw swallow's nest in Hong Kong requires the use of the renminbi currency so that the price paid will be much cheaper. Second, when the China government can re-export the swallow's nest it imports, both aiming to be sold in the domestic market and the international market through a reduction in this currency, taxes and tariffs from the importing country will not affect the selling price so that it has better competitiveness (Ali, 2017).

The chart shows a decline in export prices from 2012 to 2015 because at that time Indonesia was being hit by the issue of an outbreak of bird flu (H5N1), even in 2013 China had rejected swallow nests from Indonesia because they were considered to not meet standards. Indonesia always makes efforts to improve export competitiveness by carrying out a lot of inspections on the production process of swallow's nests. The production process aims to maximize the amount of output using a certain number of inputs. The government is also trying to control the quality of the swallow's nest produced so

that it can meet the requirements according to the protocol signed with China as the main importer. Production activities are not only limited to the manufacturing process, but to the process of storage, distribution, transportation, packaging and finally the marketing process (Sari and Sudiana, 2022). Packaging also affects price setting, luxurious swallow nest packaging causes the price to be more expensive than ordinary packaging. Some manufacturers invest in packaging for a reason. The purpose of packaging is not only to protect the product but also to promote it (Shukri *et al.*, 2018).

**Constant market shares analysis.** The CMS method was chosen to measure competitiveness because this CMS method can determine the most significant aspects that

affect the export growth of each product. CMS can display assessments on the composition of export products, market distribution, and competitiveness. In addition, CMS can compare national export growth relative to world average growth (Trade Analysis and Development Agency, 2013).

The export growth of swallow's nest in the period 2011 to 2020 is strongly influenced by the growth of demand in the importing country (Table 1). A positive export growth value can be obtained if the percentage value of the total increase in the world's swallow's nest exports in each period is positive or it can be said that the total export value of the world's swallow's nest in the second year must be greater than the export value of the world's swallow's nest in the first year.

**Table 1.** Swallow's nest export standard growth

Year	Global commodity export standard growth	Global swallow's nest export standard growth	Indonesian swallow's nest export standard growth
2011	0.201	0.320	0.200
2012	-0.003	-0.185	-0.175
2013	0.040	-0.006	-0.001
2014	-0.005	-0.095	-0.163
2015	-0.126	0.013	-0.219
2016	-0.028	0.311	0.921
2017	0.102	0.321	0.456
2018	0.098	0.138	0.039
2019	-0.035	0.059	0.250
2020	-0.069	0.302	0.484
Mean	0.018	0.118	0.179

**Source:** compiled by the authors

The export growth value of Indonesian swallow's nests in 2011-2020 fluctuated where the average was still above the world's average export growth of swallow's nests with an average export growth of Indonesian swallow's nests of 0.179 while the average export growth the world's swallow's nest is 0.118. So it can be said that the increase in the export value of Indonesian swallow's nests in the world market is higher than the increase in the total export value of the world's swallow's nests. On the other hand, the export growth of swiftlet nests both worldwide and in Indonesia was particularly higher than the export growth value of all world commodities. This illustrates that the bird's nest commodity is an export commodity that is highly considered in the international market.

The issue of a bird flu (H5N1) outbreak that was intense in 2012-2015 greatly affected the demand for Indonesian swallow nest exports, even in 2013 China had rejected swallow nests from Indonesia because they were deemed to not meet standards and had to re-standardize. This greatly impacted export growth in those years considering that China is one of the main export markets for Indonesia's swiftlet nest

commodities. This fact is in line with the decline in export prices which also occurred in the period 2012 to 2015. Although China has a high demand for swallow's nests, China provides a quota limit for each Indonesian swallow's nest exporter company, which is the largest swallow's nest producer in the world (Saputra *et al.*, 2022).

In addition, the negative value of Indonesia's swallow nest export growth in 2012 to 2015 was also influenced by policies issued by the government related to export duties which affected the export growth of swallow's nests in that period (Table 2). These policies include the Regulation of the Minister of Finance No. 128/PMK.011/2011 concerning the determination of export goods subject to export duties and export duty rates replacing the Regulation of the Minister of Finance No. 67/PMK.011/2010 (Ulfah *et al.*, 2019). In its development, the existence of this regulation is considered by many to be ineffective in increasing the added value and competitiveness of domestic swiftlet nests because in the future it is hoped that Indonesia will not only export raw swiftlet nests, but also its derivative products that have added value.

**Table 2.** World swallow's nest export growth in main destination countries, 2011-2020

Year	World swallow's nest export growth in destination countries				
	Hong Kong	China	Singapore	USA	Vietnam
2011	0.215	0.490	0.164	-0.122	-0.837
2012	-0.103	-0.726	-0.295	0.210	8.630
2013	0.245	0.089	-0.141	0.049	3.309
2014	-0.033	0.724	-0.352	-0.042	0.508
2015	-0.245	1.290	-0.432	0.080	-0.129
2016	1.132	0.772	-0.069	0.206	0.290
2017	0.120	1.108	-0.390	0.116	0.971
2018	-0.313	0.474	1.109	0.062	0.669
2019	0.040	0.450	0.264	-0.201	-0.550
2020	0.468	0.697	-0.411	0.315	-0.829
Mean	0.153	0.537	-0.055	0.067	1.203

**Source:** compiled by the authors

Based on the results of the analysis, it can be seen that the export growth of the world's swallow's nests in the main destination countries in the period 2011-2020 is very volatile (Table 3). This is influenced by the policies and demands of the importing country. Among the five main export destinations for swallow's nests, China has the most stable export growth value and only once was negative in 2012. Meanwhile, Vietnam is the main destination country with the highest

average export growth with a value of 1,203. Finicelli *et al.* (2012) examined the evolution of emerging market economies at disaggregated level and found out that among the emerging economies, China has a strong export growth, increasing its market shares across sectors and destinations due to its competitiveness, while industrial countries benefited from specialization in fast-growing sectors (high-tech) or destinations (Asia).

**Table 3.** Export growth of Indonesian swallow's nest in main destination countries, 2011-2020

Year	Export growth of Indonesian swallow's nest in main destination countries				
	Hong Kong	China	Singapore	USA	Vietnam
2011	0.261	1.610	0.098	0.114	-1.000
2012	0.086	-0.964	-0.271	-0.017	0.000
2013	0.145	-0.673	-0.159	0.115	1159.828
2014	-0.026	-1.000	-0.384	-0.086	0.898
2015	-0.343	0.000	-0.479	0.011	-0.131
2016	1.710	1.175	-0.115	0.309	0.102
2017	0.127	1.882	-0.550	0.268	1.948
2018	-0.333	0.366	1.448	-0.037	0.345
2019	-0.021	0.559	0.520	0.012	-0.585
2020	-0.082	0.902	-0.402	0.241	-0.886
Mean	0.152	0.386	-0.029	0.093	116.052

**Source:** compiled by the authors

The table above illustrates the growth value of Indonesian swallow nest exports in the main destination countries where the value is also very volatile (Table 4). There is a very striking difference in value for the destination country of Vietnam in 2013 where the value of export growth reached 1159,828. This is because in 2011 Indonesia did not export to Vietnam at all, but

then in 2012 was only able to export with a small nominal as the beginning of entering a new market and then in 2013 was able to export with a fairly high nominal of more than 1000 times compared to the previous year, so of course Vietnam has the highest average growth as an export destination country with swallow nest commodities from Indonesia. The increasing growth of

swallow's nest exports indicates that Indonesia is still able to take advantage of the world's export growth of

swallow's nests so that it is considered a strong competitor by its competitor countries (Ulfah *et al.*, 2019).

**Table 4.** Effects of Indonesian swallow's nest product composition, 2011-2020

Year	Product composition effect
2011	0.00012
2012	-0.00017
2013	-0.00004
2014	-0.00008
2015	0.00010
2016	0.00023
2017	0.00029
2018	0.00007
2019	0.00015
2020	0.00081
Mean	0.00015

**Source:** compiled by the authors

The effect of product composition measures the change in exports as a result of changes in the composition of Indonesian swallow nest export products in total imports in the importing country. The effect of product composition is positive in 2011, and from 2015 to 2020, it can be said that Indonesia's exports are distributed to all types of goods whose demand grows relatively faster in importing countries. The average value of the composition effect of swallow nest products for the period 2011 to 2020 based on CMS analysis is positive at 0.00015, indicating that swallow nest commodities tend to be in demand in the international market compared to other types of commodities and the export value tends to increase compared to the total exports of a country. Based on these results, it can also be concluded that the export quantity

of swallow's nests is sufficient to meet market demands and market requirements in the export destination countries (Sa'idy, 2013).

The positive effect of product composition can increase exports of Indonesian swallow nests (Table 5). This is in line with the main point of the theory of comparative advantage, that specialization in producing a certain product that has an advantage will encourage the country to export that product. Thus, specialization in a product will provide benefits and advantages for countries that carry out international trade (Ramadhani and Santoso, 2019). The positive effect of product composition can also mean that Indonesia specializes in exported products, in this case the exported swallow's nest can be accepted by the people of the importing country (Simangunsong and Wulandari, 2016).

**Table 5.** Market distribution effect of Indonesian swallow's nest commodity in main destination countries, 2011-2020

Year	Market distribution effect				
	Hong Kong	China	Singapore	USA	Vietnam
2011	-0.00003	0.00001	-0.00009	-0.00002	0.00000
2012	0.00002	-0.00003	-0.00006	0.00002	0.00000
2013	0.00008	0.00000	-0.00006	0.00000	0.00000
2014	0.00002	0.00000	-0.00009	0.00000	0.00001
2015	-0.00010	0.00000	-0.00010	0.00000	-0.00001
2016	0.00024	0.00005	-0.00005	-0.00001	0.00000
2017	-0.00016	0.00019	-0.00009	-0.00001	0.00003
2018	-0.00035	0.00020	0.00005	-0.00001	0.00006
2019	-0.00001	0.00030	0.00002	-0.00002	-0.00009
2020	0.00009	0.00052	-0.00013	0.00000	-0.00007
Mean	-0.000020	0.000124	-0.000060	-0.000005	-0.000007

**Source:** compiled by the authors

A positive distribution effect value illustrates that a country has marketed certain commodities in countries that have high demand for these commodities. Meanwhile, if the value of the distribution effect is negative, then a country is considered not to have marketed the commodity to countries with high demand (Fitriana *et al.*, 2014). The average distribution effect of the Indonesian swallow's nest market in the period 2011 to 2020 is only positive for China's destination countries. This is because Indonesia is the largest exporter in China for swallow nest commodities. Based on these results, Indonesia is deemed to have been able to market swallow

nest commodities in a country that has a high demand for this commodity, namely China (Sa'idy, 2013).

The market distribution effect also illustrates Indonesia's ability to increase swallow nest exports in markets that are always growing or in markets that are stagnant. The majority of the average market distribution effect values for Indonesian swallow nest commodities in the main destination countries are negative (Table 6). So that it can be interpreted that Indonesia does not concentrate its exports in markets that are experiencing fast growth but is only concentrated in more stagnant areas (Satryana and Karmini, 2016).

**Table 6.** Competitiveness effect of Indonesian swallow's nest commodities in main destination countries, 2011-2020

Year	Competitiveness effect				
	Hong Kong	China	Singapore	USA	Vietnam
2011	0.00001	0.00003	-0.00004	0.00001	0.00000
2012	0.00005	-0.00001	0.00001	-0.00001	0.00000
2013	-0.00003	0.00000	-0.00001	0.00000	0.00002
2014	0.00000	0.00000	-0.00001	0.00000	0.00001
2015	-0.00004	0.00009	-0.00001	0.00000	0.00000
2016	0.00017	0.00004	-0.00001	0.00001	-0.00001
2017	0.00001	0.00019	-0.00002	0.00001	0.00004
2018	-0.00002	-0.00007	0.00002	-0.00001	-0.00004
2019	-0.00003	0.00008	0.00003	0.00002	-0.00001
2020	-0.00028	0.00027	0.00000	-0.00001	0.00000
Mean	-0.000016	0.000062	-0.000004	0.000002	0.000001

**Source:** compiled by the authors

China, the United States, and Vietnam have an average value of the competitiveness effect that is positive. This means that swallow's nest commodities have great potential to increase exports and Indonesia is a strong competitor as an exporter in the three countries. A positive competitive effect can indicate a decrease in the price of an Indonesian commodity, namely swallow's nest, against world prices (from other exporting countries) for the same commodity. This could mean that the price of Indonesian swallow's nest fell, while the world price of swallow's nest remained or in other words the rate of increase in world prices was higher than the rate of increase in Indonesia's exports.

This competitiveness effect can be influenced by changes in price factors and non-price factors (such as improving quality, product development, improving marketing systems, changing consumer preferences and tastes, increasing exporters' ability to meet export demand quickly, and so on) (Dyadkova & Momchilov, 2014). The average competitive effect of Indonesian swallow's nest commodities in China, the United States, and Vietnam is positive, so it can be said that exports in these three countries occur because of superior quality or better prices, while the average effect of competitiveness

in Hong Kong and Singapore have negative values, so that it can indicate that the competitiveness of swallow's nests is weak when compared from the aspect of quality and price (Aji *et al.*, 2017). This negative value reflects a failure to maintain market share associated with an increase in relative prices (Kellman *et al.*, 2003). This is relevant to research from Katepan *et al.* (2012) which identified the factors affecting okra exports using the Porter's Diamond model. This study identified 84 factors that could affect okra exports from Thailand to Japan. One of the most powerful factors is the price of the product itself. This study shows that product price can be an important factor that makes buyers make decisions.

Export performance can be said to be successful when the export activities carried out are able to take advantage of existing opportunities and are able to overcome threats and obstacles properly. Indonesia already holds a great opportunity in dominating the export market for swallow's nests, this is due to the potential of supporting resources and the price offered is still far ahead compared to other exporters. The obstacle that is still felt by Indonesia in the export of swallow's nests is the lack of standardization applied by Indonesia, which is a major consideration for importing countries.

Standardization is a very important aspect because it relates to consumer safety and health. Against the backdrop of the rapid development of the swiftlet nest industry, relevant departments in many countries have taken active measures. This is in line with the statement of Ya'acob *et al.* (2021) in his research which describes that Malaysia issued a national standard MS 2334:2011 "Edible Bird Nest (EBN) Specification" in 2011 (Department of Standards Malaysia, 2011) and Thailand issued a national standard TAS 6705-2014 "Bird's Nest" in 2014 (National Bureau of Agricultural Commodity and Food Standards, 2014). Indonesia does not have a specific national standard for swallow's nests, Indonesia only has documents regarding procedures for good manufacturing practices of edible bird nests and animal quarantine measures for importing or exporting bird nests into or outside the territory of the Republic of Indonesia. This obstacle can be a threat to Indonesia in developing its potential swallow nest market. According to Wellner & Lakotta (2020), business threats can limit an industry's earning potential. High returns in business attract new companies with new capabilities and increased capacity that are competing for market share, putting pressure on prices and costs. General variables that become the main obstacles for swallow nest exporters are government policies, economies of scale and capital.

The potential possessed by the Indonesian swallow's nest can be optimally utilized as an effort to maintain its superior position as the largest exporter by increasing the competitiveness of the swallow's nest in the form of increasing production accompanied by improving product quality and food safety, while still paying attention to production cost efficiency. Indonesian producers of swallow's nests need to improve hygiene and make the best use of land so they can continue to produce export quality swallow's nests that meet the requirements for importing products from each importing country so that Indonesia is able to export as much as possible without going through other countries as a third party. The Indonesian government needs to increase trade

cooperation with other countries than the main importers of swallow's nests in the hope of market expansion in order to maintain Indonesia's position as the main exporter of swallow's nest needs in the world. The government also needs to increase cooperation with swallow's nest producers by expanding market access, training and production assistance, increasing innovation and technology, as well as promoting efforts to export markets.

## CONCLUSIONS

The average value of the composition effect of the swallow's nest commodity for the period 2011 to 2020 based on Constant Market Share analysis is positive at 0.00015, indicating that the swallow's nest commodity tends to be in demand in the international market compared to other types of commodities and the quantity of exports is sufficient to meet market demand (market demand) and market requirements (market requirements) in the export destination country.

The average value of the distribution effect of the Indonesian swallow's nest market in the period 2011 to 2020 is only positive for the destination country of China, this means that Indonesia has been able to market the swallow's nest commodity in countries that have high demand for this commodity, namely China which is indeed the largest importer of swallow's nests in the world. China, the United States, and Vietnam have an average value of the competitiveness effect that is positive. This means that the swallow's nest commodity has great potential for increasing exports and Indonesia is a strong competitor as an exporter in these three countries.

There is a need to increase trade cooperation with other countries than importers to expand markets and increase cooperation with domestic producers through efforts to expand market access, assist production, increase innovation and technology. For further research, it is expected to be able to analyze what factors affect the export of swallow's nests to the global market so that the results obtained are more comprehensive.

## REFERENCES

- [1] Aji, R.V., Ishak, Z., & Mukhlis. (2017). Comparative analysis of cocoa bean export competitiveness between Indonesia, Ivory Coast and Ghana: RCA and CMS approaches. *Jurnal Ekonomi Pembangunan*, 15(2), 69-84. doi: 10.29259/jep.v15i2.8832.
- [2] Ali, H. (2017). Non-tariff barrier Tiongkok terhadap perdagangan sarang burung walet 2012-2015. *Jurnal Analisis Hubungan Internasional*, 6(1), 278-284.
- [3] Careena, S., Sani, D., Tan, S.N., Lim, C.W., Hassan, S., Norhafizah, M., Kirby, B.P., Ideris, A., Stanslas, J., Basri, H.B., & Lim, C.T.S. (2018). Effect of edible bird's nest extract on lipopolysaccharide-induced impairment of learning and memory in wistar rats. *Evidence-Based Complementary and Alternative Medicine*, 2018, article number 9318789. doi: 10.1155/2018/9318789.
- [4] Central Bureau of Statistics. (2021). *Analysis of export commodities 2013-2020 for the agricultural, industrial and mining sectors*. Jakarta: BPS.
- [5] Chok, K.C., Ng, M.G., Ng, K.Y., Koh, R.Y., Tiong, Y.L., & Chye, S.M. (2021). Edible bird's nest: recent updates and industry insights based on laboratory findings. *Frontiers in Pharmacology*, 12(1), article number 746656. doi: 10.3389/fphar.2021.746656.

- [6] Crespo, N., & Fontoura, M.P. (2018). *What determines the export performance? a comparative analysis at the world level*. Lisbon: School of Economics and Management.
- [7] Department of Standards Malaysia. (2011). *MS2334:2011: Edible-Bird Nest (EBN) specification*. Cyberjaya: Department of Standards Malaysia
- [8] Dewi, M.E. (2020). Benefits of edible bird nest consumption. *Jurnal Kedokteran Ibnu Nafis*, 8(2), 26-34.
- [9] Dyadkova, M., & Momchilov, G. (2014). *Constant market shares analysis beyond the intensive margin of external trade*. Bulgaria: Bulgarian National Bank.
- [10] Efendi, E., Sitompul, D.R.H., Sinurat, S.H., Ruben, R., Situmorang, A., Ziegel, D.J., Rahmad, J., & Indra, E. (2022). *Implementation of greedy algorithm for profit and cost analysis of swallow's nest processing dirty to finished products*. *INFOKUM*, 10(02), 849-858.
- [11] Ulfah, M., Ismono, R.H., & Murniati, K. (2019). The export performance of indonesia's palm oil in international market. *Jurnal Manajemen & Agribisnis*, 16(2), 140-150. doi: 10.17358/jma.16.2.140.
- [12] Finicelli, A., Sbracia, M., & Zhagini, A. (2012). A disaggregated analysis of the export performance of some industrial and emerging countries. *International Economics and Economic Policy Heidelberg*, 8(1), 23-24. doi: 10.1007/s10368-010-0174-8.
- [13] Fitriana, N., Tarumun, S., & Tety, E.E. (2014). Competitiveness analysis of indonesian cocoa beans in the international market. *Jurnal Online Mahasiswa*, 1(2), 2-12.
- [14] Golden Nest Inc. (2022). Bird's nest benefits: Nutrition facts of edible bird's nest. Retrieved from <https://goldennest.com/blogs/news>.
- [15] Harapuspa, A., & Fitriani, D. (2018). Analysis of factors affecting bird's nest exports in indonesia. *Jurnal Fokus Manajemen Bisnis*, 8(2), 150-162. doi: 10.12928/fokus.v8i2.1587.
- [16] Jamilah, J., Zahara, H., Kembaren, E.T., Budi, S., & Nurmala, N. (2022). Market share analysis and export performance of Indonesian crude palm oil in the EU market. *International Journal of Energy Economics and Policy*, 12(2), 218-225. doi: 10.32479/ijee.v12i2.12690.
- [17] Kamaruddin, R., Ismail, E., & Ahmad, S.A. (2019). *Key factors for the sustainable production of swiftlet birds' nest industry in Malaysia: A case study in Northern Peninsular Malaysia*. *Supply Chain Management*, 33(1), 724-733.
- [18] Katepan, P., Makhora, T., & Mankeb, P. (2012). *Factors affecting success for exporting Thai okra (Abelmoschus esculentus L. Moench) in the world market*. *King Mongkut's Agricultural Journal*, 30(3), 1- 12.
- [19] Kaur, A., & Nanda, P. (2017). *Competitiveness of India's manufactured exports: A constant market share analysis*. *Indian Journal of Economic & Business*, 2(2), 267-280.
- [20] Kellman, M., Roxo, T., & Shachmurove, Y. (2003). *South Africa's international competitiveness: A product level analysis*. *PIER Working Paper Archive 03-020*. University of Pennsylvania: Department of Economics.
- [21] Lee, K.S. (2014). *Effects of particle size and double boiling time on the antioxidant activities of bird nest soup (Collocalia fuciphaga)*. (Doctoral thesis, Universiti Kebangsaan Malaysia, Selangor, Malaysia).
- [22] Leonardo, C., Efferin, S., & Darmasetiawan, N.K. (2019). *An exploration of the cultural beliefs of the Indonesian and Chinese people in relation to the business of swallow farming*. *Calyptra*, 7(2). Retrieved from <https://journal.ubaya.ac.id/index.php/jimus/article/view/3420>.
- [23] Ma, F., & Liu, D. (2012). Sketch of the edible bird's nest and its important bioactivities. *Food Research International*, 48(2), 559-567. doi: 10.1016/j.foodres.2012.06.001.
- [24] *Ministry of Trade of the Republic of Indonesia*. (2012). *Export news xxii: 6. edible products of animal origin, Nesoi*. Jakarta: Ministry of Trade.
- [25] *National Bureau of Agricultural Commodity and Food Standards*. (2014). *TAS 6705-2014: bird's nest*. Bangkok: National Bureau of Agricultural Commodity and Food Standards.
- [26] Permatasari, I.G.A.I., & Rustariyuni, S.D. (2015). *Analysis of Indonesian cocoa bean export competitiveness in the ASEAN region 2003-2012*. *E-Jurnal Ekonomi Pembangunan Universitas Udayana*, 4(7), 855-870.
- [27] Ramadhani, T.N., & Santoso, R.P. (2019). Competitiveness analyses of Indonesian and Malaysian palm oil exports. *Economic Journal of Emerging Markets*, 11(1), 46-58. doi: 10.20885/ejem.vol11.iss1.art5.
- [28] Risaad, M., Syafari, R., Sompaa, A.T., Budhi, S., & Yunani, A. (2021). Community empowerment strategy in management of swallow's nest cultivation to increase regional original income in Kotabaru District. *International Journal of Politic, Public Policy and Environmental Issues*, 1(2), 70-79. doi: 10.53622/ij3pei.v1i02.23.
- [29] Roh, K.B., Lee, J., Kim, Y.S., Park, J., Kim J.H., Lee, J., & Park, D. (2011). Mechanisms of edible bird's nest extract-induced proliferation of human adipose-derived stem cells. *Evidence-Based Complementary and Alternative Medicine*, 2012, article number 797520. doi: 10.1155/2012/797520.
- [30] Sa'idy, I.B. (2013). Decomposition of growth in exports of textiles and textile products to the USA. *Journal of Economics and Policy*, 6(1), 10-16.

- [31] Saputra, D., Asihatka, P.F., & Sutanto, E.P. (2022). *Analysis of swallow nest export strategies from Indonesia to China with export restriction regulations*. In *Proceedings of the international conference on industrial engineering and operations management* (pp. 2658-2665). Istanbul: Istanbul Technical University.
- [32] Sari, P.D.J., & Sudiana, I.K. (2022). Analysis of competitiveness and factors affecting the export of Indonesian swallow's nests in the Hong Kong market. *E-Jurnal Ekonomi Pembangunan Universitas Udayana*, 11(1), 325.
- [33] Satryana, M.H., & Karmini, N.L. (2016). *Analysis of the export competitiveness of Indonesian tea to the ASEAN market for the period 2004-2013*. *E-Jurnal Ekonomi Pembangunan Universitas Udayana*, 5(5), 598-611.
- [34] Simangunsong, B.C.H., & Wulandari, R.A. (2016). Competitiveness analysis of Indonesia's pulp and paper products in a global market. *Jurnal Ilmu Teknologi Kayu Tropis*, 14(1), 88-98. doi: 10.51850/jitkt.v14i1.399.
- [35] Simonis, D. (2009). *Belgium export performance, a constant market share analysis*. Working paper 2-00, economic analysis and freedom. Brussels: Federal Planning Bureau.
- [36] Sugiyono. (2014). *Quantitative, qualitative and R&D research methods*. Bandung: Alfabeta.
- [37] Suhana, N., Kusumastanto, T., Adrianto, L., & Fahrudin, A. (2016). *Tuna industries competitiveness in the international market*. *AACL Bioflux*, 9(6), 1251-1258.
- [38] Sukhri, N.N.H.M., Nawati, N.M., Abdullah, A.M., & Man, N. (2018). *Consumer's perception on the quality of controversial contents in edible bird's nest products*. *Pertanika Journal of Scholarly Research Reviews*, 4(1), 1-9.
- [39] Tai, S.K., Hamzah, Z., Ng, Q.H., & Tan, C.S. (2020). Surface morphology study on unclean, commercial and bromelain treated edible bird nest (ebn) using scanning electron microscope. *IOP Conference Series: Materials Science and Engineering*, 932(012013), 1-3. doi: 10.1088/1757-899X/932/1/012013.
- [40] Taj, Z., & Wani, N.U.H. (2019). Evaluation of Afghanistan export performance: A constant-market-share analysis approach. *Kardan Journal of Economics and Management Sciences*, 2(2), 18-19. doi: 10.31841/KJEMS.2021.55.
- [41] Tangjitmanngamkul, J. (2019). A comparative analysis of Thai bird's nest export to Chinese Market. *European Journal of Business and Management*, 11(13), 70-71. doi: 10.7176/EJBM.
- [42] Trade Analysis and Development Agency. (2013). *Potpourri of coffee commodity info*. Jakarta: Ministry of Trade of the Republic of Indonesia.
- [43] UN COMTRADE. (2022). *United nations commodity trade statistics database*. Retrieved from <https://comtrade.un.org/data/>.
- [44] Wellner, S., & Lakotta, J. (2020). Porter's five forces in the German railway industry. *Journal of Rail Transport Planning & Management*, 14, article number 100181. doi: 10.1016/j.jrtpm.2020.100181.

## Показники експорту індонезійських товарів «Ластівчине гніздо» до основних країн призначення

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**Анотація.** Тенденція до збільшення експорту індонезійських ластівчиних гнізд і високий ринковий потенціал, який демонструє збільшення споживання, вимагають від Індонезії як одного з основних виробників ластівчиних гнізд можливості скористатися наявними ринковими можливостями. Це дослідження має на меті визначити показники експорту гнізд індонезійського стрижа в основні країни призначення. У цьому дослідженні використовується метод постійної частки ринку. Використані вторинні дані – це дані часових рядів, зібрані з 2011 по 2020 рік. На основі аналізу постійної частки ринку було зазначено, що товар ластівчиного гнізда, як правило, користується попитом на міжнародному ринку порівняно з іншими видами товарів. Обсяг експорту є достатнім для задоволення ринкового попиту та вимог ринку в країнах призначення експорту. Результати показують, що Індонезія змогла продати товар із ластівчиного гнізда в країни з високим попитом, а саме в Тіонгкок, який справді є найбільшим імпортером ластівчиного гнізда у світі. Товар «ластівчине гніздо» має великий потенціал для збільшення експорту, і Індонезія є сильним конкурентом як експортер у трьох країнах: Китаї, США та В'єтнамі. Цей дослідницький матеріал має практичну цінність для уряду Індонезії, щоб збільшити торговельне співробітництво в контексті розширення ринку, щоб зберегти позицію Індонезії як великого експортера та потребу у співпраці з вітчизняними виробниками шляхом зусиль щодо розширення доступу на ринок, навчання та допомоги у виробництві, збільшення інновацій і технології

**Ключові слова:** постійна частка ринку, склад продукту, розподіл, конкурентоспроможність, аграрний сектор

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## Analysis the capacity of grain export potential in Ukraine, possible reasons for the decrease and development trends

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**Abstract.** The research presents an analysis of grain production and export capacity in Ukraine from 2010-2021. The major general factors that have recently affected the country's macroeconomic indicators and determined their potential for the decline have been destroyed and damaged infrastructure, a high level of military threat to crops, and massive internal and external migration of working-age people and businesses. Therefore, analysis of the availability and regularity of changes in the production reserve of these crops for domestic farm use and external consumers defines the relevance of the issue under study. The purpose of the study is to analyse the main indicators of grain crop production in Ukraine and to identify the factors that significantly influence their export potential. Using technical statistical methods, models have been developed to demonstrate possible fluctuations in the number of grain exports, considering the possible development of the country's economy. Using regression methods, the main factors influencing the export potential of grains were identified. These factors have been demonstrated to include, in particular, gross harvest volumes, availability and quantities of mineral and organic fertilisers, purchasing prices for produce, etc. A sustained long-term trend in grain exports over the past 10 years is demonstrated, but it has been established that Ukraine's significant export potential could change significantly. It could affect the economies of Ukraine's grain-importing countries. It is suggested that the adverse impact of the possible causes of Ukraine's declining export potential should be reduced through further development of technologies for growing, storing and transporting grain crops. The applied value of the results is to reduce uncertainty in the agricultural market for agro-industrial and foreign trade institutions by accounting for the impact of major grain production and export indicators

**Keywords:** exports of grain, economic analysis, grain yields, cultivated area, wheat cultivation



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## INTRODUCTION

The share of grain exports from Ukraine to other countries is very significant. With the beginning of the full-scale Russian invasion of Ukraine, the opportunity to export grain crops abroad has significantly decreased, but Ukrainian grain is still supplied. As of the end of November 2022, Ukraine exported 16,239 thousand tons of grain and legumes (Ministry of Agrarian Policy..., 2022). Compared the volume of grain exports with last year, it can be seen that with the beginning of the full-scale war, it decreased by more than 7 thousand tons. According to Ukrainian Grain Association statistics (UGA, 2022), corn (11,051,295 tons) was exported the most since March 2022, while wheat exports took the second place by volume (6,251,277 tons). The above statistics show the urgency of solving logistical and economic problems with the delivery of Ukrainian grain around the world, because otherwise importing countries may face a significant increase in prices or, in the worst case, starvation.

The search for a solution to the problem of exporting goods during crisis periods has been studied by scientists in the economic and agrarian spheres for a long time. For example, researchers C. Betrán and M. Huberman (2022) studied the influence of internal and external factors on the formation of political decisions in Spain in the interwar period. The study covers the period of the Great Depression (1929-1930), during which tariffs were the basis of the political approach to support the economy. The Spanish government was faced with the need for bilateral negotiations to open new markets for goods. As can be seen from the results of the articles, the saving step for the Spanish economy was cooperation with Great Britain and Italy, which agreed to accept Spanish goods in exchange for Spain's access to their market. The study shows that for difficult economic features, and it is necessary to have external partners, it is possible to prevent the recovery of the country's economy.

The role of grain exports in the events of the Great Famine in China was studied by H. Kasahara and B. Li (2020). In the course of the study, the scientists quantified the various causes that could have led to such mass mortality among the Chinese population from 1955 to 1963. Scientists have come to the conclusion that the increase in the volume of grain exports was directly proportional to the increase in the death rate of the Chinese. It is peculiar that death rates were higher in areas with fewer members of the Chinese Communist Party. Using the example of China, it can be seen that the lack of development of agricultural enterprises, an increase in the number of imported goods, and a parallel increase in the amount of exported grain can lead to a demographic catastrophe. Therefore, for Ukraine, reducing the export of grain in the post-war period can be quite a rational decision to avoid similar situations.

Other researchers such as Gutierrez *et al.* (2022), raised the issue of regulating the feed (cereal) market after the COVID-19 crisis. Cereal crops are consumed

not only by humans but also by animals. This suggests an increase in the need for each of the states to import and export grain crops. The authors used a global vector auto regression model to estimate the shock to oil, exports, and stocks of wheat, corn, and barley for exporting countries. The results of the analysis indicate that grain prices remained stable in early 2020 thanks to the oil market. However, restrictions on grain exports, which could be observed at the beginning of 2020, may still lead to an increase in prices in importing countries. Given this forecast, reducing the volume of grain exported from Ukraine to other countries would be able to maintain a stable price policy in this food segment, but such actions may lead to the beginning of a shortage of grain crops at the national level. That is why the issue of export after the end of the war is so urgent.

Canada has a very large agricultural potential, but even such an economically stable state faced a crisis that was called the Great Canadian Grain Logistics Crisis. The events of the agricultural sector in 2013-2014 in Canada were studied by P.J.A.M. Rimmer and C. Comtois (2018). The researchers study the "politics" of Canada's grain supply chain, which includes producers, grain companies, rail companies, port operators and export buyers. P.J.A.M. Rimmer and C. Comtois (2018) suggest that Canadian grain exports have been in decline due to ineffective changes in the supply chain, particularly in the Asia-Pacific region. Researchers Brown *et al.* (2020) drew attention to the possibility of Canadian farms switching from low-value wheat to high-value canola. Such changes were associated with the abolition of export subsidies in the country in 1995. The authors of the study come to the conclusion that the adaptation of farms to new political and economic conditions can be carried out heterogeneously, but each farm must have an individual approach.

The purpose of the study is to identify factors that significantly affect the level of production and export potential of grain crops in Ukraine. It should consider the general economic situation in the country, investigate possible reasons for significant fluctuations in production, and identify potential scenarios for the development of Ukrainian grain exports. For this purpose, the following objectives have been set: to analyse statistical data from official sources on the main features of grain crop production and exports; to identify the main trends in grain production and to identify the main factors affecting this area of the economy; to establish a proper forecast of fluctuations in the capacity of Ukraine's grain export potential and to estimate the possible consequences.

## MATERIALS AND METHODS

To estimate the production capacity and export potential of grain crops, the use of official statistical methods to determine this integral indicator has been suggested.

During the preliminary analysis, the main groups of indicators that comprehensively describe the export potential of the country's agro-industrial complex were identified. The export potential of grain crops was estimated in the following sequence: to define a system of indicators to estimate the grain export potential; to determine the significance of individual indicators in the system for grain export volumes; to define the influence of the most influential indicators on the level of grain crops export potential; to calculate the forecast of grain export volumes for the medium term; to develop recommendations for agro-industrial and foreign trade institutions by considering their impact on the main indicators of grain crop production and exports according to the results of the forecast.

The main input data for the analysis of grain production indicators are derived from sources (State Statistics Service of Ukraine, 2022; Ukraine 2022, 2022) and for the years 2010-2021. To obtain an estimate of the prospects in the export potential, there is a necessity to forecast grain export volumes based on the series of dynamics of grain production volumes in Ukraine, the cultivated areas used for this purpose, the amount of mineral and organic fertilisers used, purchasing prices, etc. In the process of selecting a method for forecasting the capacity of grain export potential, it is considered that the forecast result must fulfil the requirements of applicability to the studied dynamic series and the objective significance of the obtained estimates (Hunk *et al.*, 2003). Considering this, it is suggested to use adaptive models of nonlinear type, which is described in (Ingle *et al.*, 2021; Silva *et al.*, 2019). These methods are seasonal and reflect modern approaches to forecasting complex time series, such as production and export volumes of grain crops. The trend adaptive model for forecasting the level of the indicator  $S_t$  will be called the analytical function of the type:

$$\begin{cases} S_t = f(t, G) \\ F(G) = S_t - f(t - 1, G) \end{cases} \quad (1)$$

where:  $t$  – time unit given in the considered case, years;  $G$  – vector of parameters significantly influencing the levels of the forecast indicator.

The function  $F(G)$  allows the deviation of the actual and modelled values of  $S_t$  over time to be estimated and the dependence of the parameters at which the model has the highest possible accuracy to be clarified. In general, the function  $f(t, G)$  can be represented in analytical form, or by a complex neural network, etc. To establish these models, the least-squares method of error estimation is applied in most cases. The forecasting of grain export volumes has been suggested using the Holt-Winters exponential triple-smoothing (ETS) time-series forecasting method (Holt, 2004; Winters, 1960). Compared to simple and double exponential smoothing, the Holt-Winters triple exponential

smoothing model considers trend and seasonality factors (Holt, 2004; Winters, 1960). The selection of this model is based on the fact that it has performed extremely well for data with a pronounced seasonal component. It is assumed that the seasonal component of grain production and export levels is additive based on a predetermined annual period of constant periodic fluctuations from the mathematical expectation. With additive seasonality, the level of indicator  $S_t$  at time  $t$  is calculated as a recurrent relationship as:

$$S_t = \alpha(X_t - C_t - R) + (1 - \alpha)(S_{t-1} + B_{t-1}) \quad (2)$$

where:  $X_t$  is the levels of the original time series in period  $t$ ;  $S_{t-1}$  is the seasonally deprived, smoothed value in the previous period  $t-1$ ;  $B_{t-1}$  is the trend component of the series;  $C_t$  is the seasonal component of the series;  $R$  is the season length in periods;  $\alpha$  is the level smoothing factor,  $\alpha \in (0, 1)$ , which is selected based on the minimum accumulated error in expression (1).

Using the smoothing coefficient  $\alpha$ , the influence weight of the current value of  $X_t$  and the smoothed previous value of  $S_{t-1}$  of the level of grain exports is distributed. In calculating the smoothed value, the following feature is considered: if the corresponding smoothing coefficient is closer to 1, the values of the current and the nearest previous values of grain export levels are considered more. To identify the main trends in grain production and exports, regression methods have been proposed. The selection is based on the fact that, despite their relative simplicity, these methods provide effective results even when a large number of factors are involved. The multiple regression equation for capacity and export volumes of grain crops  $S_t$  can be represented as:

$$S_t = f(\beta, W) + \varepsilon, \quad (3)$$

where:  $W = (W_1, W_2, \dots, W_p, \dots, W_m)$  – vector of factors influencing the one under study;  $\beta$  – weight vector of coefficients to be determined;  $\varepsilon$  – random error (or deviation).

In explicit form, the linear multiple regression equation has the form:

$$S_t = \beta_0 + \beta_1 W_1 + \beta_2 W_2 + \dots + \beta_m W_m + \varepsilon, \quad (4)$$

where:  $\beta_0$  – free regression term, determining the value of  $S_t$ , in the case when all factors  $W_p$  and  $\in [1 \dots m]$ , are 0;  $\beta_1 \dots \beta_m$  – regression coefficients.

The estimation of the regression coefficients  $\beta_i$  is proposed to be performed using the least-squares method, as it is quite common and efficient as it provides a minimum of the mathematical expectation of the random deviation  $\varepsilon_t$ . To solve the problem of identifying the main factors influencing grain production and exports, it is suggested to estimate the value of the paired correlation coefficient:

$$R_m = \frac{\sum_i (W_i - \bar{W})(S_t - \bar{S}_t)}{\sqrt{\sum_i (W_i - \bar{W})^2 \sum_i (S_t - \bar{S}_t)^2}}, \quad (5)$$

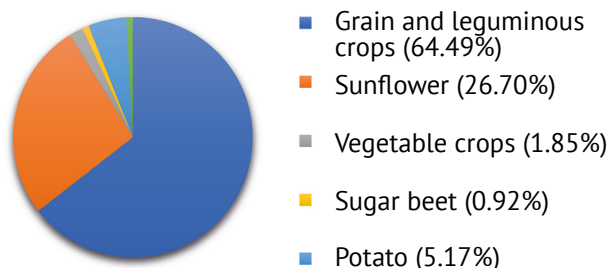
where:  $\bar{W}$   $\bar{S}_t$  – is the mathematical expectation of the corresponding values  $W_i$  and  $S_t$  at time  $i$ .

The quality of the obtained regression model is suggested by identifying the hypothesis of equality of zero coefficient of determination of data by Fisher's F-criterion using well-known methods (Lomotko *et al.*, 2019; Silva *et al.*, 2019).

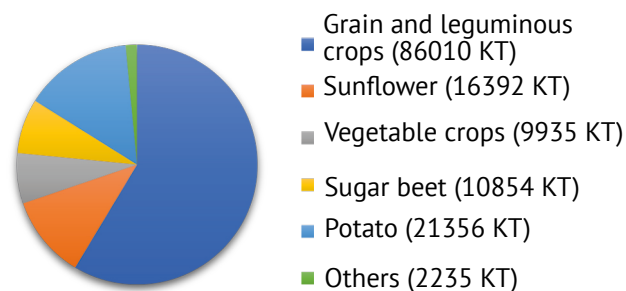
## RESULTS AND DISCUSSION

The production and export of grain and leguminous crops occupy a major place in the income structure of the national economy. Grain production is the activity of agricultural producers, which is specifically designed to grow grain to meet the domestic demands of Ukraine for seed, grain for food, fodder and technical purposes, to improve its quality, to maintain and develop the export potential of grain crops market, and is associated with the food security of Ukraine through the development of grain economy (Law of Ukraine No. 37-IV, 2002). The situation in the Ukrainian economy and agro-industrial complex is defined by the high level of military threat to agriculture and crops, massive damage to the infrastructure necessary for proper functioning and other adverse consequences. It presents new challenges to all economic subjects. Therefore, the analysis of the availability and patterns of changes in the reserve of grain crop production for domestic usage of the farm and external consumers determines the relevance of the question under study.

The agricultural industry occupies one of the main positions in terms of volume and financial performance among all economic activities in the country. A significant role in agricultural production is dedicated to the cultivation of grain crops. Grain and its products have multiple uses: food, fodder and technical. The leading crop for the national economy in terms of production and cultivated area belongs to grains (Fig. 1). As it can be seen, cereals and leguminous crops dominate in the structure of cultivated area – 64.49% of the total Ukrainian crop production, which according to (State Statistics Service of Ukraine, 2022) in 2021, amounted to 24804 thousand hectares. By production volumes (Figure 2) wheat and maize are in the lead, respectively 38.7% and 47.1%, followed by 11.4% of barley in the total production of grains and leguminous crops in 2021. It demonstrates the significance of studying the availability of these crops for domestic use in Ukraine and for external consumers who import grain from Ukraine.



**Figure 1.** Structure of cultivated area in Ukraine (2021), %  
**Source:** State Statistics Service of Ukraine (2022)



**Figure 2.** Production volumes of grains and leguminous crops in Ukraine (2021), KT

**Source:** State Statistics Service of Ukraine (2022)

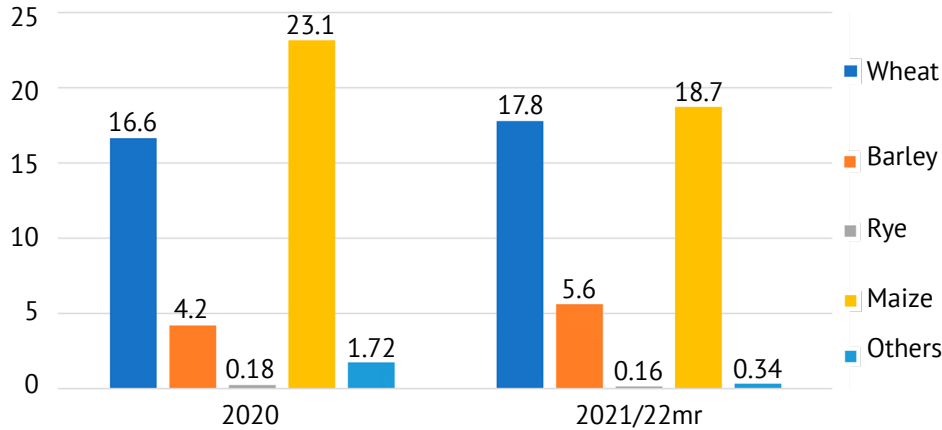
**Note:** KT – thousand tonnes

Currently, the government has been obliged to classify crops as critical goods for import under martial law. The criteria for this decision are defined in (Resolution of the Cabinet of Ministers of Ukraine No. 153, 2022) and reflect the fact that grain is a food commodity, the lack of which can result in a humanitarian and food crisis, and it is part of the production cycle of critical food commodities. The influence of this fact is considered in establishing the purposes of the study (Ukraine 2022, 2022). The study of trends in the grains market is connected to an analysis of the level of total grain yield in the country: according to (FAOSTAT: Ukraine, 2022), it has almost doubled, from 2.77 t/ha in 1992 to 5.38 t/ha in 2021, according to the data. Researchers argue that it has significantly affected the structure and priorities of the national economy and confirms a significant export potential (Kyzym *et al.*, 2014; Klymenko *et al.*, 2013). According to data (Kyrylenko *et al.*, 2017) Ukraine aspires to join the world's leading economic alliances, which requires the development of strong, extensive international economic relations and the conclusion of appropriate foreign economic agreements. Up to 70% of Ukraine's agricultural production is exported through transnational corporations, which unfortunately does not guarantee continued investment in the industry and provides little stability in the agribusiness complex (Nakonechna & Yakubovska, 2018).

At the beginning of 2022, there is a tendency for Ukrainian grain exports to decrease and export prices to increase from \$200-250 to \$400-450/t in world markets (Grain: World Markets and Trade, 2022). It contributes to the termination of existing and lack of commercial interest in new contracts for the supply of grain products to the European Union (EU) and other countries (Garbelini *et al.*, 2022). Compounding the trend is the forced transportation of crops by rail through congested land border crossings, which has resulted in longer delivery times and more complicated grain logistics (Lomotko *et al.*, 2019). To reduce the level of uncertainty in the grain market, a necessity emerged to forecast trends and developments in the market. Regrettably, the analysis of most of the reviewed studies demonstrates insufficient consideration of current

trends in the agricultural industry. Therefore, the obstacles to the conclusion of long-term contracts due to martial law and the situation of the Ukrainian economy, against the background of the rapid integration into the EU, cannot ensure stability in the production and

export volumes of grain crops. Ukraine has exported 45.8 million tonnes of grain in 2020 and 42.6 million tonnes in 2021-2022 marketing year (mr) (as of February 21, 2022), as presented in Figure 3 (State Statistics Service of Ukraine, 2022).



**Figure 3.** Structure of grain and leguminous crops exports in Ukraine

**Source:** State Statistics Service of Ukraine (2022)

The gross harvest and yield of the crop vary according to natural-geographical and anthropogenic factors (Nakonechna & Yakubovska, 2018; Vasylykivska & Malakhovska, 2019). Natural factors include the availability of cultivated areas, natural soil fertility, climatic conditions and photosynthetic activity. Technogenic

factors refer to the level of modern technology used to provide plants with moisture, the required amount of mineral and organic matter (Guo *et al.*, 2022). The main input data for the analysis of grain production indicators are considered for 2010-2021 and are presented in Table 1.

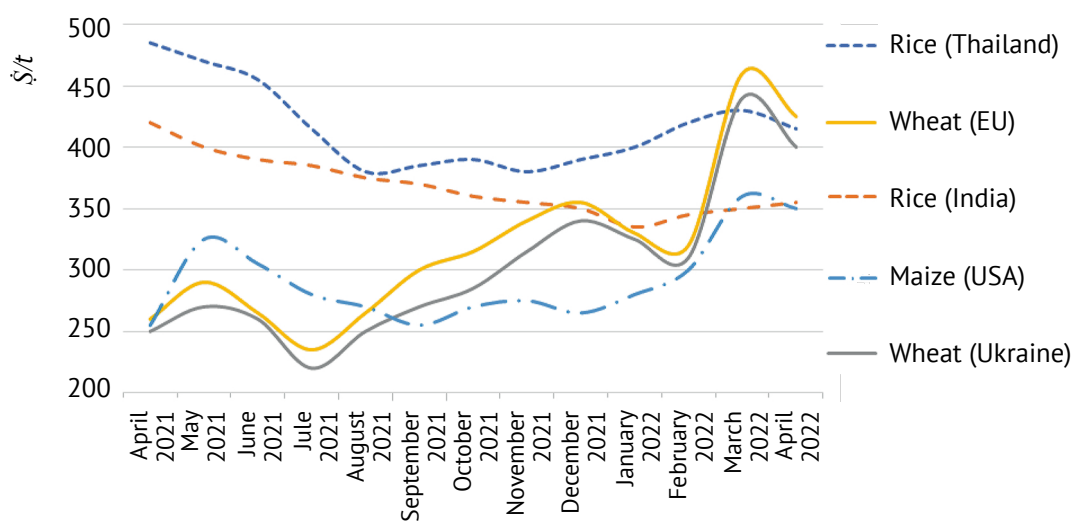
**Table 1.** Main indicators of Ukraine's agro-industrial complex for the production of grain and leguminous crops in all categories of farms

Year	Cultivated area of grain and leguminous crops, thousand ha	Production volume (gross harvest) of grain and leguminous crops, thousand tonnes	Grain export, thousand tonnes	Mineral fertiliser application for grain and leguminous crops (excluding maize) thousand tonnes	Organic fertiliser application for grain and leguminous crops (excluding maize) thousand tonnes	Average prices of agricultural grain products, UAH/t
	$W_1$	$W_2$	$S_1$	$W_3$	$W_4$	$W_5$
2010	15090	39271	12180	185.3	2939.5	1120.9
2011	15724	56747	23230	261.8	2916.8	1374.2
2012	15449	46216	22190	340.6	2825.3	1547.1
2013	16210	63051	32520	439.6	2620	1299.8
2014	14801	63859	35600	404.7	2253.4	1801.4
2015	14739	60126	38620	342.3	2332.5	2912.1
2016	14401	66088	44990	410.7	2025.4	3414.0
2017	14624	61917	40270	478.8	1873.9	3771.6
2018	14839	70057	50090	482.5	2316.6	4315.0
2019	15318	75143	55090	528.0	2368.5	3867.5
2020	15392	64933	45810	659.9	2060.7	4794.1
2021	15995	86010	50800	630.5	1875.7	6296.1

**Source:** based on data from (State Statistics Service of Ukraine, 2022; FAOSTAT: Ukraine, 2022)

The publications (Kyrylenko *et al.*, 2017; Nakonechna & Yakubovska, 2018) consider exports to be an essential factor for economic growth and the integration of the state into international relations with EU countries and the world economy, i.e., exports are already acquiring the features of potential. Thus, exports of agro-industrial products ensure Ukraine's ability to attain the general economic purposes of European integration and the ability to solve the problems of grain and leguminous products supply not only for a particular country but to contribute to the solution of the world food problem in general. Since the early 2022, EU grain markets have been significantly affected by the situation in the Ukrainian economy and the nearly

completely discontinuation of Ukrainian grain exports compared to previous years (Table 1). As Ukraine is a major exporter of wheat and maize, the result has been a sudden shift in demand to suppliers from outside Europe and a 2-3x increase in grain export prices. The trend is an attempt to start transporting crops by rail rather than by sea, which has caused sharp fluctuations in quotations on world markets. For example, quotations for maize exports declined slightly due to the level of harvests in South America (Grain: World Markets and Trade, 2022). In comparison, there is stability in the rice market, whose producers are in relatively calmer economic conditions outside Europe, which contrasts with the volatility of wheat and maize (Fig. 4).



**Figure 4.** The dynamics of quotations on the world crop market

**Source:** Grain: World Markets and Trade (2022)

Ukraine's grain export potential correlates with global grain market trends. The data analysis presented in (Nakonechna & Yakubovska, 2018; Melnyk, 2017) indicates that world grain production in the short and long term can generally fulfil the demand for grain products, even if the world population continues to increase by 80 million people each year. Under these conditions, it is forecasted that the growth in grain crop production will be mostly due to its development in those countries where there are suitable conditions for it. Therefore, the conditions of the Ukrainian agricultural market should be attributed precisely to promising regions with strong grain crop producers. A negative trend that could constrain further increases in global grain production is the limited amount of land available for grain cultivation. It is explained by the high level of urbanisation and the

necessity to preserve forests, further involvement of unused fertile lands in the conditions of limited water resources for agricultural purposes. The Ukrainian grain and legume market is significantly affected by this, as most grain seeds are exported at prices that are established on international stock exchanges. However, the latter level is influenced by the global trend in grain production and consumption, as tracked by relevant indicators of global price fluctuations and quotations on the world crop market (FAOSTAT: Ukraine, 2022). To reduce the level of uncertainty in the grain market, a necessity emerged to forecast trends and developments in the market.

The forecasting of the export capacity of crops was performed using the Holt-Winters exponential triple-smoothing method using formulas (2) and (3) with a 95% confidence interval, the result is presented in Figure 5.

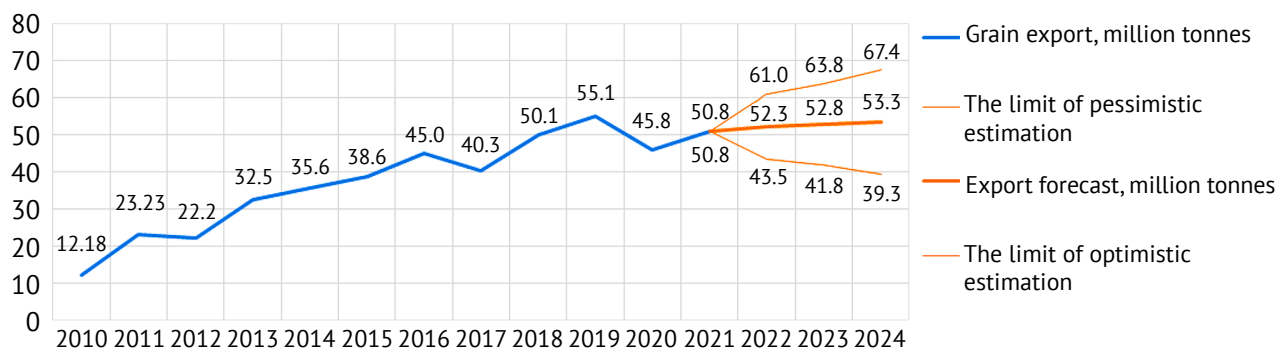


Figure 5. Forecast of grain export potential dynamics

Source: authors' research

Thus, if the current trend in grain export volumes continues, the slight increase to 52.3 million tonnes in 2022 and 52.8 million tonnes in 2023 is more realistic. However, the situation in the Ukrainian economy allows asserting that the pessimistic scenario – 43.5 million tons in 2022 and 41.8 million tons in 2023, or a reduction of grain export by 18% – is a more realistic forecast. The accuracy of the forecast was estimated at 84%, which is a rather high value for the forecasting method applied. In contrast to the proposed approach, studies (Ingle *et al.*, 2022; Silva *et al.*, 2019) are based on ARIMA (autoregressive integrated moving average) models of an integrated autoregressive moving average model for the time-series analysis. They are used to forecast demand for grain, flour, food products. The authors demonstrate that their model is sufficiently reliable and can be used for demand forecasting, both for the industry in general, for individual farms, retail outlets, supply chains and transport, and inventory management purposes. But the Holt-Winters model used is well-established in agricultural and food production research due to its prevalence and relative simplicity of construction, and, as calculations have demonstrated, sufficient predictive validity (Lomotko *et al.*, 2019).

Forecasting the demand for resources such as food, grain, and water is one of the key objectives of most companies and economies in general (Klymenko, 2013). Resource consumption varies according to several factors, including periodicity over time and accidental occurrence. That is why resource demand forecasting is performed using models, the results of which have been analysed in detail in (Hunk *et al.*, 2003; Ingle *et al.*, 2021; Sirohi *et al.*, 2021). The forecast data obtained by the authors from such models are used for managing, controlling and adjusting the existing production and supply of the resource, and for designing the elements of the required infrastructure for this purpose. However, it may be observed that there is no universal method for forecasting and modelling crop production and exports. For this reason, the authors (Hunk *et al.*, 2003; Holt, 2004; Winters, 1960) proposed a solution in which the dynamics of the process under study are determined

by trend analysis and a random factor. The implementation of such prediction models has demonstrated a good correspondence with empirical and predictive data and a relatively accurate reflection of the fluctuations of the research process over time. Therefore, the results obtained in the study in this research using the Holt-Winters method demonstrate this as a good tool for forecasts in agricultural production.

The search for the main factors influencing grain exports was performed using formulas (3) and (4) using the least squares method, the following regression equation was obtained (regression equation estimation):

$$S_t = 108107.6223 - 12.4083W_1 + 0.8576W_2 + 60.9059W_3 + 16.0424W_4 + 0.08657W_5 \quad (6)$$

The regression coefficients have the following interpretation:

Constant estimates the aggregate impact of factors other than those considered in the model (6) on the volume of grain exports  $S_t$ , which would amount to 108107.62 thousand tonnes. Coefficient  $\beta_1$  indicates that with an increase in the cultivated area of grains and leguminous plants per 1 thousand ha the volume of grain export decreases by 12.4083 thousand tonnes. It is explained by the specific features of grain cultivation technology under extensive farming conditions and by the fact that the expansion of the cultivated area is generally performed for domestic consumption. This influence naturally has some limits, the establishment of which is beyond the scope of this study. Coefficient  $\beta_2$  demonstrates that with an increase in the gross harvest of grains and leguminous crops by 1 thousand tonnes, the volume of grain exports increases by 0.8576 thousand tonnes. It is explained by the desire of agricultural companies to export grain residues (if any).

Coefficient  $\beta_3$  indicates that with an increase in mineral fertiliser application under crops of grains and leguminous crops by 1 thousand tonnes, the volume of grain export increases by 60.9059 thousand tonnes. It can be explained by the natural causes of the impact of mineral fertilisers on the level of yield. Evidently, the positive impact has some limits, the establishment of which is beyond the scope of this study (Nakonechna &

Yakubovska, 2018). Coefficient  $\beta_4$  demonstrates that with an increase in organic fertiliser application under grains and leguminous crops by 1 thousand tonnes, the volume of grain export increases by 16.0424 thousand tonnes. It can be explained by the natural causes of the effect of organic fertilisers on yield levels, by analogy from the previous factor. Coefficient  $\beta_5$  indicates that with an increase in the average price of agricultural grain products by 1 UAH/t, the volume of grain exports increases by 86.57 t. It is explained by the desire of agricultural companies to export grain residues at the most attractive price.

The list of factors influencing the volume of grain exports is not exhaustive and can be expanded by considering additional factors (Grain: World Markets and Trade, 2022; Vasylykivska & Malakhovska, 2019), and model (6) will result in an enriched and more refined one. The correlation coefficient is known to reflect the degree of connection between two indicators. If the coefficient is close to 0, it indicates the absence of a connection between the variables. To find the degree of influence of the main factors on grain exports, the following results were obtained for the raw data in Table 1 using formula (6): coefficient  $R_1 = -0.137$  indicates a low level of influence of the cultivated area of grains and leguminous crops on the volume of grain exports; coefficient  $R_2 = 0.904$  demonstrates a very strong level of influence of the gross grain harvest on grain export volumes; coefficient  $R_3 = 0.840$  indicates a strong influence of the amount of fertiliser applied to grain and leguminous crops on grain export volumes; coefficient  $R_4 = 0.798$  indicates a strong influence of the amount of organic fertiliser applied to grain and leguminous crops on grain export volumes; coefficient  $R_5 = 0.839$  indicates a strong level of influence of the average price of agricultural grain products on the volume of grain exports.

A qualitative evaluation of the resulting model (6) was performed by testing the hypothesis of nullity of the coefficient of determination of the data by Fisher's F-criterion. The Fisher's F-criterion for the model is 42.751, the critical value for 5 degrees of freedom is 4.39. Since  $42.751 > 4.39$ , the influence of the factors can be considered statistically significant and the regression equation (6) is statistically reliable. According to experts (How much grain does Ukraine export, 2022), the cultivated area of grains in Ukraine has recently decreased by 10-12%. Most experts are inclined to believe that the decline in the main indicators of grain and fertiliser production will be in the range of 10-15%. Based on this, the resulting regression model (6) was applied to predict the export potential of grain crops. Grain exports in 2022 are estimated at 47.7 million tonnes and in 2023 at 42.8 million tonnes, assuming current trends remain unchanged. It corresponds to the pessimistic scenario in the previous forecast model, with the discrepancy between the results not exceeding 9%. Considering this, it can be assumed that the models obtained are of sufficiently high quality and appropriate.

Notably, changes in the amount of cultivated area, in the quality of the crop due to the evolution of production technology and fluctuations in world procurement prices have a significant impact on the export potential of the state. Meanwhile, an analysis of the resulting impact of the factors concludes that seasonal demand for grain products requires compensation. It can be used at specific times of the year in the domestic market, but agribusinesses have the option of exporting to foreign markets at different times of the year. Selling the excess production volume of grain products to exports, if the proposed forecast model is applied, would facilitate the ability to sell their products in the foreign market without giving large discounts to foreign buyers or not lead to the elimination of excess production of agro-industrial products. At the present stage of Ukraine's economic transformation, the issue of adapting foreign trade to EU requirements arises. A significant factor influencing the Ukrainian agricultural sector is the pre-crisis excess of its production potential over domestic market demand (Nakonechna & Yakubovska, 2018). It has established a vector for national export policy development, but requires a complex process of transition to international quality standards in the areas of agricultural products themselves, customs regulations and transport technologies (Esfahani et al., 2019; Council Directive 92/106/EEC, 1992).

Unfortunately, Ukrainian exporters of grain and leguminous crops, compared to all major trade competitors, have no efficient system of insurance, crediting and export guarantees, which cannot fully ensure the promotion of their agricultural exports. Based on the forecast models obtained, it is possible to propose actions to improve the normative regulation of export relations in the market of agro-industrial products by strengthening measures to protect the interests of Ukrainian grain producers in anti-dumping, special protective or countervailing measures against agricultural goods of Ukrainian origin. Recent events in Ukraine have proved the necessity to increase the effectiveness of work on preventing price discrimination of Ukrainian grain products on foreign markets, establishing an updated contractual and legal framework with partner countries to protect the interests of Ukrainian producers of agro-industrial products on foreign markets and improving the efficiency of information and advisory support and export development of grain crops. Summarising the data of the above sources and (Vasylykivska & Malakhovska, 2018; Melnyk, 2017) it is possible to estimate the export potential of grains as the ability of the national economy to produce competitive agricultural products and to sell them on international markets under conditions of continuous growth of efficiency of natural and land resources use, development of the scientific and technical potential of the agro-industrial complex, providing grain producers with foreign exchange and financial and credit support, and service and transport

infrastructure, subject to the establishment of a system of economic security for the country in general. It requires agribusinesses to support constant growth in yields and the efficiency of the applied agro-technologies, which is why the development of the economy in the period up to February 2022 observed a natural alternation of growth and decline in grain production in the absence of a long-term imbalance in the country's export potential for these products.

When assessing the place of the Ukrainian grain producer in the global market, note the EU export forecast for 2021/22, which has been reduced to 34.0 million. The main reason for this is a slowdown in supplies from Ukraine, and two EU members (Bulgaria and Hungary) have given priority to maintaining their reserves to combat high world grain prices (Grain: World Markets and Trade, 2022). Bulgaria and Hungary, which together account for 8% of EU wheat exports, are expected to export less wheat by the end of the trading year as their governments imposed restrictions on grain export volumes. Wheat exports from the EU are highly concentrated, with the five largest wheat exporters to the EU (France, Germany, Romania, Poland and Lithuania) accounting for 80% of total wheat exports. Thus, it is particularly notable that a significant part of the export deficit is the result of slower growth in France, Lithuania and Poland. Under such conditions, it is not easy for Ukrainian agribusinesses to establish their place in the global economic complex, especially since the world markets of major grain producers have already been established. On the other hand, Ukrainian grain exports are mainly a raw material source in the world market for the production of finished grain products, which, as a consequence, the country has to import from abroad. Experts (Grain: World Markets and Trade, 2022) estimate that EU exports will accelerate in the last quarter of 2022 as buyers shift away from supplies from Ukraine. To reach the reduced forecast of 34.0 million tonnes, exports from the EU must average 3.5 million tonnes per month. Demand for crops in Egypt, Turkey, Jordan, Nigeria and other markets in Africa is expected to increase, ending the trading year in line with the revised forecast.

In November 2021, Forbes selected the 13 largest agricultural companies in Ukraine (by annual revenue in 2020) (Ministry of Agrarian Policy and Food of Ukraine, 2022). The total revenue of 13 agricultural companies is UAH 342 billion (14.9%) out of the hundred largest private companies in Ukraine – UAH 2.3 trillion. The most efficient agricultural companies include "Kernel" (UAH 118.7 billion), "MHP" (UAH 51.5 billion), "Nibulon" (UAH 25.8 billion). The 13 largest agricultural companies employ 67,800 people. Considering the forecasts, the question arises regarding not only the financial but the social aspect of the consequences of adverse trends in the grain market. Studies (Nakonechna & Yakubovska, 2018) demonstrate that agricultural production faces the risk of severe water shortages and nitrogen fertiliser

efficiency, which could be another factor significantly influencing the performance of agricultural companies. In (Garbelini *et al.*, 2022) notes that the permanent use of intensive cultivation areas can worsen soil yields, profit margins for agribusinesses and environmental sustainability. Thus, the authors (Sirohi *et al.*, 2021; Guliyev *et al.*, 2021) conducted research on the level of grain yield and profitability of agricultural systems with various levels of plant diversity. It is proposed to do this by predicting yield volumes and automating particular processes. The disadvantage of such systems is their design cost. The proposed set of measures requires budgetary and extra-budgetary funding and foreign investment, the amount of which should be determined based on existing international practices, and an assessment of the national economy and the existing structure of grain exports. Thus, for these purposes, the selection of an efficient formal forecasting method will enhance the functionality of agribusiness operations and have the expected effect of reducing uncertainty in the grain market.

## CONCLUSIONS

The demand for grain crops products on both world and Ukrainian markets has a steady upward trend due to objective (natural influence on grain crop fertility, modern farming technologies, application of the latest fertilisers) and subjective reasons (changing consumption culture of the population, a trend towards the consumption of ecologically clean products). Statistical data analysis of the main features of crop production and exports in Ukraine demonstrates that the country's potential is, regrettably, unstable. Although the trend of grain exports in 2010-2021 is centred on growth, with a maximum of 50.8 million tons in 2021, the forecast obtained in this research demonstrates that the export potential of grains is expected to decrease. EU exports are expected to accelerate in the last quarter of 2022, as buyers unfortunately shift away from supplies from Ukraine. To reach the reduced forecast of 34.0 million tons, exports from the EU must average 3.5 million tons per month. That forecast estimate of grain supply to Egypt, Turkey, Jordan, Nigeria and some other countries demonstrates an increasing trend in demand.

The Holt-Winters exponential triple-smoothing method was selected as the methodological apparatus for forecasting economic processes in the grain market, and regression methods were proposed for identifying the main trends and the degree of influence of factors on grain exports. The influence of the main factors on a country's export potential has been defined, in particular, the amount of cultivated land, the amount of mineral and organic fertilisers applied, grain purchasing prices, etc. The resulting models demonstrated sufficient statistical reliability, and the discrepancy between the results obtained by the various methods did not exceed 9%. Assuming that the current trend in the volume of Ukrainian

grain exports continues, it is established that a slight increase to 52.3 million tons in 2022 and 52.8 million tons in 2023 is the most probable. At the same time, the proposed forecast models reflect current economic trends, which allows asserting the reality of pessimistic expectations for grain exports with its reduction by 18% to 43.5 million tonnes in 2022 and 41.8 million tonnes in 2023. The reliability of the forecast is estimated at 84%, which demonstrates the quality of the applied forecasting method. The way to reduce the possibility of a decline in the export potential of crops is to expand

strong and extensive international economic connections and to conclude appropriate long-term foreign trade agreements for agro-industrial and foreign trade institutions. Thus, in the terms of the agreements, the predicted results obtained and the level of influence of the main factors investigated in the research should be considered. Taking into account the current state of Ukrainian crop production and its export, conducting further research to identify ways to avoid an economic imbalance in the grain market of Ukraine in the next 5-10 years was justified from a scientific point of view.

## REFERENCES

- [1] Betrán, C., & Huberman, M. (2022). Against the grain: Spanish trade policy in the interwar years. *Journal of Economic History*, 82(1), 42-86. doi: 10.1017/S0022050721000474.
- [2] Brown, W.M., Ferguson, S.M., & Viju-Miljusevic, C. (2020). Farm size, technology adoption and agricultural trade reform: Evidence from Canada. *Journal of Agricultural Economics*, 71(3), 676-697. doi: 10.1111/1477-9552.12372.
- [3] Council Directive 92/106/EEC "On the Establishment of Common Rules for Certain Types of Combined Transport of Goods between Member States". (1992, December). Retrieved from <http://data.europa.eu/eli/dir/1992/106/oj>.
- [4] Esfahani, A.A.K., Mirdamadi, S.M., Hosseini, S.J.F., & Lashgarara, F. (2019). Overseas cultivation: The complimentary approach for developing food security. *Bulgarian Journal of Agricultural Science*, 25(1), 26-35.
- [5] FAOSTAT: Ukraine. (2022). Retrieved from <https://www.fao.org/faostat/ru/#country/230>.
- [6] Garbelini, L.G., Debiasi, H., Junior, A.A.B., Franchini, J.C., Coelho, A.E., & Telles, T.S. (2022). Diversified crop rotations increase the yield and economic efficiency of grain production systems. *European Journal of Agronomy*, 137, article number 126528. doi: 10.1016/j.eja.2022.126528.
- [7] Grain: World Markets and Trade. (2022). Retrieved from <https://apps.fas.usda.gov/psdonline/circulars/grain.pdf>.
- [8] Guliyev, E., Atashov, B., & Alekperov, E. (2021). *Cooperative movement: Evolution, current state and development trends*. Baku: Kooperasiya.
- [9] Guo, J., Fan, J., Xiang, Y., Zhang, F., Yan, Sh., Zhang, X., Zheng, J., Li, Yu., Tang, Z., & Li, Zh. (2022). Coupling effects of irrigation amount and nitrogen fertilizer type on grain yield, water productivity and nitrogen use efficiency of drip-irrigated maize. *Agricultural Water Management*, 261, article number 107389. doi: 10.1016/j.agwat.2021.107389.
- [10] Gutierrez, L., Pierre, G., & Sabbagh, M. (2022). Agricultural grain markets in the COVID-19 crisis, insights from a GVAR model. *Sustainability (Switzerland)*, 14(16), article number 9855. doi: 10.3390/su14169855.
- [11] Holt, C.C. (2004). Forecasting seasonals and trends by exponential weighted moving averages. *International Journal of Forecasting*, 20(1), 5-10. doi: 10.1016/j.ijforecast.2003.09.015.
- [12] How much grain does Ukraine export? (2022). Retrieved from <https://cutt.ly/8VHy3KT>.
- [13] Hunk, D.E., Wichern, D.W., & Rights, A.D. (2003). *Business Forecasting*. Moscow: Williams Publishing House.
- [14] Ingle, C., Bakliwal, D., Jain, J., Singh, P., Kale, P., & Chhajed, V. (2021). Demand forecasting: Literature review on various methodologies. In *12<sup>th</sup> International conference on computing communication and networking technologies* (pp. 1-7). Piscataway: IEEE. doi: 10.1109/ICCCNT51525.2021.9580139.
- [15] Kasahara, H., & Li, B. (2020). Grain exports and the causes of china's great famine, 1959-1961: County-level evidence. *Journal of Development Economics*, 146, article number 102513. doi: 10.1016/j.jdeveco.2020.102513.
- [16] Klymenko, I.V., Kharazishvili, Yu.M., Sharov, O.M., & Us, I.V. (2013). *Ukraine in integration processes in the post-Soviet space: Modelling alternatives*. Kyiv: National Institute of Strategic Studies.
- [17] Kyrylenko, I.H., Ivchenko, V.Ye., & Demyanchuk, V.V. (2017). Food security of Ukraine in the light of modern trends in the world economy. *Economy APK*, 8, 5-14.
- [18] Kyzym, M.O., Matyushenko, I.Yu., Shpilevskyy, V.V., Haustova, V.E., Dorovskyi, O.V., Antonenko, S.V., Berenda, S.V., Oliynyk, A.D., Yaroshenko, I.V., Semigulina, I.B., Kostenko, D.M., Makhanyova, Yu.M., Moiseyenko, Yu.M., & Buntov, I.Yu. (2014). *Assessment of the consequences of Ukraine's membership in the World Trade Organization*. Kharkiv: INZHEK.
- [19] Law of Ukraine No. 37-IV "On Grain and the Grain Market in Ukraine". (2002, July). Retrieved from <https://zakon.rada.gov.ua/laws/show/37-15>.
- [20] Lomotko, D., Arsenenko, D., Kovalova, O., & Ischuka, O. (2019). Methods of infrastructure management for optimization of grain transport organization. *Procedia Computer Science*, 149, 500-507. doi: 10.1016/j.procs.2019.01.168.
- [21] Melnyk, O.H. (2017). Export potential of the enterprise: The essence and methodological basis of the analysis. *Economic Problems*, 1, 226-231.
- [22] Ministry of Agrarian Policy and Food of Ukraine. (2022). *Export of grain, legumes and flour from Ukraine*. Retrieved from <https://minagro.gov.ua/investoram/monitoring-stanu-apk/eksport-z-ukrayini-zernovih-zernobobovih-ta-boroshna>.

- [23] Ministry of Agrarian Policy and Food of Ukraine. (2022). Retrieved from <https://minagro.gov.ua/>.
- [24] Nakonechna, K.V., & Yakubovska, Ya.V. (2018). *Export of agricultural products of Ukraine under the conditions of functioning of the free trade zone with the EU*. Retrieved from [http://www.economy.nayka.com.ua/pdf/12\\_2018/98.pdf](http://www.economy.nayka.com.ua/pdf/12_2018/98.pdf).
- [25] Resolution of the Cabinet of Ministers of Ukraine No. 153 "On Certain Issues Regarding Ensuring the Implementation of Imports". (2022, February). Retrieved from <https://zakon.rada.gov.ua/laws/show/153-2022-%D0%BF>.
- [26] Rimmer, P.J.A.M., & Comtois, C. (2018). The great canadian grain logistics crisis of 2013-14 and its aftermath. *Journal of International Logistics and Trade*, 16(2), 47-63. doi: 10.24006/JILT.2018.16.2.57.
- [27] Silva, J.C., Figueiredo, M.C., & Braga, A.C. (2019). Demand forecasting: A case study in the food industry. In S. Misra, O. Gervasi, B. Murgante, E. Stankova, V. Korkhov, C. Torre, A.M.A.C. Rocha, D. Taniar, B.O. Apduhan, & E. Tarantino (Eds.), *Computational science and its applications* (pp. 50-63). Cham: Springer.
- [28] Sirohi, R., Pandey, J.P., Tarafdar, A., Sharma, P., Sharma, P., & Sindhu, R. (2021). Tailoring a hybrid intelligent model to predict fermentable sugar production from enzyme-catalyzed hydrolysis of damaged wheat grains. *Food Bioscience*, 43, article number 101299. doi: 10.1016/j.fbio.2021.101299.
- [29] State Statistics Service of Ukraine. (2022). Retrieved from <http://www.ukrstat.gov.ua/>.
- [30] Ukraine 2022: How not to lose your chance to become a strong state: The Ukrainian Institute of the Future. (2022). Retrieved from <https://uifuture.org/publications/ukrayina-2022-yak-ne-vtratyty-svij-shans-staty-sylnoyu-derzhavoyu/>.
- [31] Ukrainian Grain Association. (2022). *The state of foreign trade in agricultural products*. Retrieved from <https://uga.ua/eksportni-pokazniki/#undefined>.
- [32] Vasytkovska, K.V., & Malakhovska, V.O. (2019). Analysis of the export potential of cereals in Ukraine. *Central Ukrainian Scientific Bulletin: Economic Sciences*, 3(36), 313-320. doi: 10.32515/2663-1636.2019.3(36).313-320.
- [33] Winters, P.R. (1960). Forecasting sales by exponentially weighted moving averages. *Management Science*, 6, 324-342.

## Аналіз потужностей експортного потенціалу зернових культур України, можливих причин занепаду та напрямів розвитку

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**Анотація.** У статті представлено аналіз виробництва та обсягів експорту зерна в Україні у 2010–2021 роках. Основними загальними факторами, що останнім часом вплинули на макроекономічні показники країни та визначили можливість їх занепаду, стали знищення та пошкодження інфраструктура, високий рівень військової загрози для посівних площ, масова внутрішня та зовнішня міграція працездатного населення та бізнесу. Тому аналіз наявності та закономірностей змін резерву виробництва цих культур для внутрішньодержавного використання господарства та для зовнішніх споживачів визначає актуальність досліджуваного питання. Метою дослідження є аналіз основних показників виробництва зернових культур в Україні та виявлення чинників, що суттєво впливають на їх експортний потенціал. За допомогою використання формальних статистичних методів розроблено моделі, що відбивають можливі коливання обсягів експорту зерна з урахуванням можливого розвитку ситуації в економіці країни. Використання регресійних методів дозволило встановити основні фактори, що впливають на експортний потенціал зернових. Доведено, що до цих факторів, зокрема можливо віднести валові обсяги збору врожаю, наявність та кількість мінеральних та органічних добрив, закупівельні ціни на продукцію тощо. Показано стійку тривалу тенденцію до збільшення обсягів експорту зернових протягом 10 останніх років, але встановлено, що значний експортний потенціал України може суттєво змінитися. Це може вплинути на стан економік країн-імпортерів українського зерна. Пропонується зменшити негативний вплив можливих причин занепаду експортного потенціалу України шляхом подальшого розвитку технологій вирощування, зберігання та транспортування зернових культур. Практична цінність отриманих результатів полягає у зменшенні невизначеності на ринку сільськогосподарської продукції для агропромислових та зовнішньоторговельних установ шляхом врахування ними впливу основних показників виробництва та експорту зернових культур

**Ключові слова:** експорт зерна, економічний аналіз, врожайність зернових культур, посівна площа, вирощування пшениці

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## Increasing the competitiveness level with the help of management reporting at the agricultural sector enterprises

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**Abstract.** In modern realities, enterprises are the main entity of the economy performance. However, their role has changed over time, which also led to changes in the principles of accounting, which in general increased its importance for achieving the company's best financial performance. Thus, it remains relevant to consider the modern features of accounting in enterprises. In this work, the analysis is carried out in the Republic of Tajikistan, which is explained both by the economic features of the country's development and by its socialist past and relatively short history within the capitalist mechanism of the state. In addition, the analysis is mainly focused on the agricultural sector due to its significant role in the country's strategic and economic development plans. The purpose of the work was to assess the current state of management reporting methods in Tajikistan. The main method used in writing of the article was the analysis, taking into account the number of considered sources, used to form conclusions, modeling, graphic and statistical methods. The work described the main features of management reporting for agricultural enterprises in the Republic of Tajikistan. The analysis of the structure and main forms that exist for reporting by the agricultural sector companies showed their low efficiency. This is due to the volume of provided data, which is not enough for the effective functioning of the agricultural sector. It was proved that by introducing some changes in the methods accounting (management) reporting and improving the data quality in it, it was possible to increase the level of enterprises competitiveness. Therefore, the work presented such forms of their reporting that could solve some existing problems. The work provided new knowledge of the principles of financial reporting, as well as analyzed the peculiarities of its preparation in the country, therefore its results can be used practically by the specialists in the respective field

**Keywords:** agricultural management, level of competitiveness, accounting reporting, entrepreneurship, economy of Tajikistan



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## INTRODUCTION

Accounting plays a huge role in the enterprise functioning: this generally accepted set of rules allows not only for effectively taking into account income and costs, but also for planning a future development strategy; monitor current activities (Al-Khasawneh *et al.*, 2014; Jostan & Alimbudiono, 2020), making it an important part of maintaining a company's competitiveness (Jaf *et al.*, 2020). Accounting methods introduced in a country play a significant role in the formation of a company's operation principles, hence the effectiveness of its functioning (Gao, 2022). The reason for this is that a qualitative information analysis about the companies' activities helps managers to draw conclusions for the formation of a future development strategy (Oyewo & Ajibolade, 2019). The accounting report also plays an important role in the economy development of states as a whole, because it allows assessing the degree of enterprises development for subsequent decisions in macroeconomic policy and monitoring their activities (Randriamiarana, 2015).

This work examines the level of management and accounting reporting of agricultural enterprises of the Republic of Tajikistan. In general, this industry is of great importance for the country development due to its economic and strategic components. In the first case, the reason is the high sector share in the economic development of the country, and in the second case the universal role of developing one's own agriculture in the event of various global shocks and crises (Alpatova *et al.*, 2021). Therefore, it is still relevant to consider the features of accounting reporting to improve the companies' welfare in the agricultural sector in the Republic of Tajikistan.

A significant number of scientists have been engaged in the consideration of this and related topics. Works that studied the interaction features between management and accounting reporting and the competitiveness level of enterprises became important for conducting this research. This, in particular, was the article by A.Y. Othman (2020), which analyzed the role of management accounting practices in terms of achieving competitive advantages by a company using the empirical example of Iraq. In the study, the author conducts a qualitative statistical analysis of the selected variables and generates recommendations for companies in accounting to achieve better results. S.J. Braim (2020) worked on the same issue in the research on the role of management accounting in the company's decision-making process. They point to the interaction between the quality of reporting with the financial performance of companies, which confirms the importance of quality reporting in enterprises. New competition methods among enterprises were studied by V. O'Connell *et al.* (2020), pointing to the role of such phenomenon as competitive intelligence, which allows better building of future development strategy using data on the competing enterprises development. Works in which scientists

studied the interaction of the information availability and quality when submitting reporting with the level of subsequent financial performance of companies, have also become important: among them, A.P. Monteiro *et al.* (2020) should be noted.

Thus, the purpose of the work is to analyze and assess the present state of management reporting methods in the Republic of Tajikistan. The object of the study is the methods of accounting for enterprises by themselves. The novelty of the article lies in a detailed analysis of the forms and rules of accounting in the country, especially for companies in the agricultural sector. In addition, it provides an opportunity to find new problems in the industry functioning (in terms of reporting), which is especially relevant, because not many scientists pay attention to them when studying the functioning features of the agro-industrial complex in Tajikistan.

## MATERIALS AND METHODS

It should be noted that this work analyses, first of all, how management reporting affects the increase in the companies' competitiveness in the market. However, the article mentions accounting reporting more than once: the reason for this is that management reporting is an integral part of accounting. This is described in more detail below in the work in the diagram. Thus, within the article, these two concepts can be considered synonymous.

The main information sources in the article were the existing regulatory legal acts of the Republic of Tajikistan, which made it possible to assess and describe the modern principles of accounting reporting in the country. Among them, there are the Album of forms of primary accounting documentation and reporting for enterprises and associations (approved by the Ministry of Finance of the Republic of Tajikistan) (2013), from which the templates existing in the country for keeping records of agricultural enterprises activities were taken, as well as the Order of the Ministry of Finance of the Republic of Tajikistan No. 124 "On Approval of the Instructions on the Procedure for Filling in Forms of Quarterly and Annual Financial Statements by Business Entities" (2001). In addition, works of other scientists were important for the analysis of different views on the management reporting role in the company functioning.

When conducting the research, a significant number of scientific methods were used, however, analysis should be recognized as the most common one among them due to the big amount of literature processed for holding the study. With the help of induction, disparate data on accounting reporting methods among enterprises of the Republic of Tajikistan were processed, and thus it was possible to draw conclusions about the general methodology for its maintenance. Modeling played an important role, with the help of which the conditions for the enterprises functioning were formed and conclusions were drawn about what reporting standards

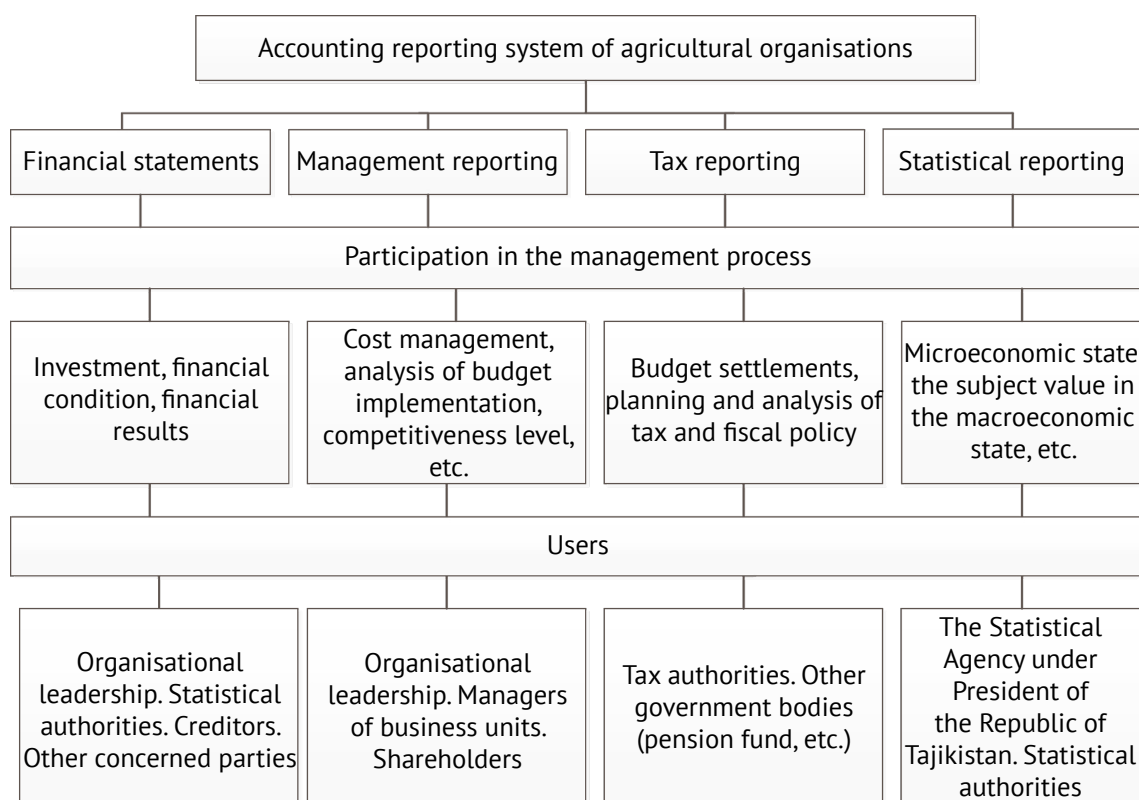
should be for the most effective management of the company. Thus, abstraction was crucial, and with its use, the influence of external factors on the enterprises activities was measured in order to form conclusions. Although statistical study methods are practically not used, they are also relevant for this study. Among them, graphical method should be distinguished, which made it possible to demonstrate disparate data particles within one design, thus simplifying their perception and the formation of main conclusions.

The whole work can be divided into several stages. At the first stage, the structure and essence of the accounting reporting system for agricultural and its features are described and forms for its submission are shown. The second part of the study presents the existing and recommended reporting forms in the agriculture field, both to increase the efficiency of enterprises and their financial performance, and the level of competitiveness in general. The article also includes discussion, review and re-evaluation of the obtained results based on the work of other scientists.

### RESULTS

The current state of the market economy significantly depends on the achieved level of competitive environment

based on the information support of the management system. As it is known, the main role in the information support system through reporting is assigned to the accounting and analytical system, which often depends on proper development and improvement (Gandour, 2021). Its development as an information source for making managerial decisions in agriculture should take into account all the specific features, considering also the technological and organizational structure of production and management. The main economic information source in the accounting and analytical system is accounting, which summarizes all information into a single reporting system that serves to make appropriate managerial decisions for management, potential buyers and suppliers, investors and other persons (Bergonia, 2021). The system of accounting and reporting in agricultural enterprises that exists today does not fully meet the management requirements through and by the method of presenting economic and facilities data, which are excessively detailed. Also, the reporting compliance is affected by such factor as insufficient efficiency in compiling and presenting the necessary information that affects the effectiveness of made decisions. Accounting systems types and their participation in management systems is shown in Figure 1.



**Figure 1.** Types of accounting reporting and their participation in the management system of an agricultural enterprise  
**Source:** prepared by the author based on the special literature study (Barfiyev, 2019)

As it can be seen from Figure 1, the main mechanism of influence on managerial decisions of an economic entity management is organized reporting, which is formed on the indicators system. Management reporting being internal reporting in a structural and composite aspect depends on the main user of this reporting form. In this regard, to make appropriate managerial decisions in a competitive environment, it is necessary to promptly and adequately respond to the changes dynamics in the external and internal environment, and for this the accounting and analytical system, covering the system of planning, accounting, analysis and control, should have adaptability and flexibility. An important document characterizing the financial and economic activities of an agricultural enterprise, as well as other organizations, is the financial statements, which consist of the approved Order of the Ministry of Finance of the Republic of Tajikistan No. 124 "On Approval of the Instructions on the Procedure for Filling in Forms of Quarterly and Annual Financial Statements by Business Entities" (2001). The standard financial statements composition of an agricultural enterprise, as well as other management forms, covers such forms as: balance sheet (statement of financial position), statement of financial and economic activities results (profit and loss statement), cash flow statement, statement of owners' equity (Vavrek *et al.*, 2021).

The methodological basis for the preparation and presentation of financial statements by both an agricultural enterprise and other economic entities of a market economy is regulated by the relevant regulatory legal acts, as well as national financial reporting standards (NFRS) for organizations that do not have a public interest and International Financial Reporting Standards (IFRS) for enterprises and organizations of public interest. In terms of compiling these types of reporting, as well as in those of the availability of a regulatory methodology in modern conditions, almost all economic entities compile and submit financial statements, including agricultural ones, in addition to dehqan (farm) enterprises, which can submit accounting reporting in a simplified system. The modern economy puts its principles before the managerial personnel and, with the improvement of methodological and practical aspects causes specialists to carry out, in addition to maintaining mandatory accounting (financial) accounting, maintaining management (internal) accounting, the main product of which is management reporting aimed at providing information to the management system of an economic entity. Considering the problems of organizing and maintaining management accounting in different economy sectors, the main emphasis is made primarily on the organization industry specifics. Such a statement can also be attributed to the preferences and requirements of users, which are often managers and management of an economic entity.

In the managing system of the economic activity of agrarian formations and their competitiveness, the

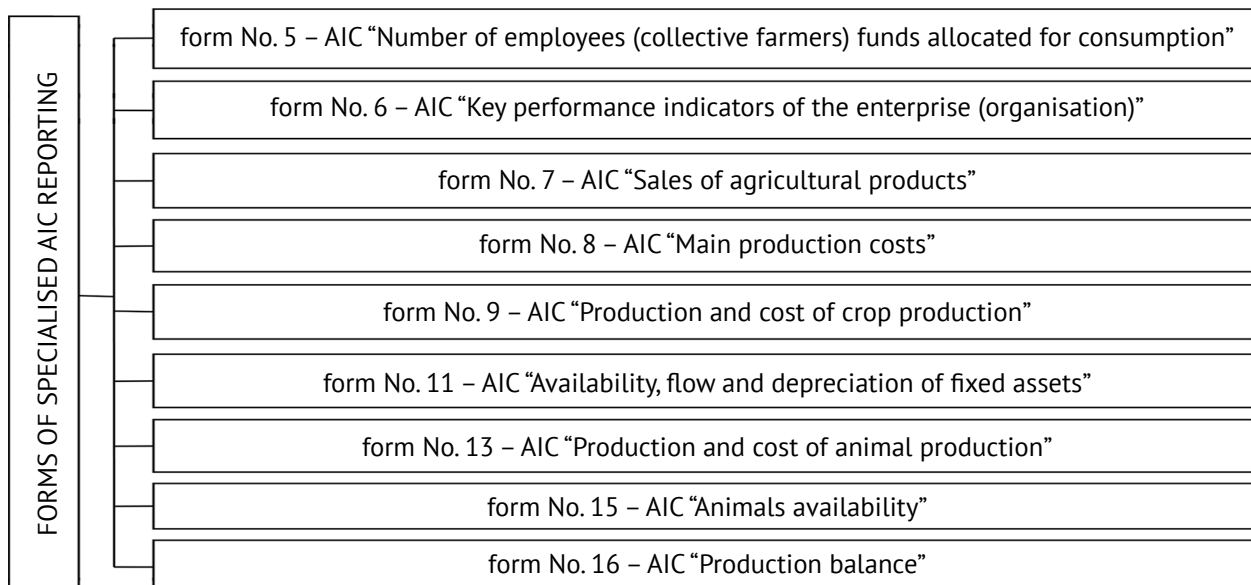
indicators that are properly adapted to the relevant management purposes become more important. It should be noted that when managing competitiveness, at some time, financial purposes fall to the background compared with capturing the sales market and increasing consumer demand for the products presented to them (Alsoboa, 2015). However, in making this statement, it should be remembered that excessive market capturing can lead to a significant level of financial loss for the farmer, that is, loss (O'Hara & Oldfield, 1986). Therefore, to move financial indicators to a secondary plan, the management of an entity should at least ensure the achievement of the breakeven point, and it in turn, will ensure the successful functioning of the farmer in a strategic aspect (Barfiyev, 2019). Achievement of set tasks is ensured on the basis of the use of reliable and comprehensive information from management reporting. Reporting aimed at managing competitiveness should characterize not only the achieved results of the financial, economic and production activities of an economic entity, but also to some extent reflect the forecast of ongoing measures aimed at ensuring the growth of the competitiveness level. Considering this statement from the point of view of a terminological concept, the suggested management report can be classified as a "report with references to the future", that is, it is a report that to some extent covers forecast, current and past indicators.

To argue that agricultural enterprises do not properly maintain an accounting and reporting system is not entirely fair, because in addition to the general forms of financial reporting, they also submit additional forms that reflecting industry characteristics reveal certain specific features of the agricultural business. These forms belong to the specialized AIC reporting forms and consist of nine separate forms (Fig. 2), each of which reflects certain information about the entity's activities. They are approved by Order of the Ministry of Finance of the Republic of Tajikistan No. 124 "On Approval of the Instructions on the Procedure for Filling in Forms of Quarterly and Annual Financial Statements by Business Entities" (2001).

The forms of specialized reporting shown in Figure 2 are submitted by agricultural enterprises to their higher branch departments, in this case, this is the Ministry of Agriculture of the Republic of Tajikistan. Compilation of these specialized reporting forms allows the management of an economic entity use the indicators reflected in them. Each of the forms presented in Figure 2 plays an important role in the preparation of the general enterprise reporting, because it displays a separate component of its activities. Containing certain information, they provide management personnel with a certain opportunity to make appropriate managerial decisions. Considering the process of making of managerial decisions in terms of certain procedures, they are in contact with economic and financial analysis, which serves as the main information source (a kind of basis)

for making managerial decisions. The textbooks given by specialists it is assumed the use of IFRS as the basis for managing or, most likely, improving the financial condition of an economic entity, and for agricultural enterprises, first of all, it is the use of IFRS 41 "Agriculture" aimed at assessing and reporting biological assets. With

taking these standards as the basis for the preparation of financial statements, and in the future, in the management of competitiveness for the conditions of the Republic of Tajikistan, difficulties will arise, and they will require appropriate clarifications, amendments and additional forms of financial and economic reporting.



**Figure 2.** Specialized reporting forms for AIC enterprises

**Source:** prepared by the author based on the Album of forms of primary accounting documentation and reporting for enterprises and associations (approved by the Ministry of Finance of the Republic of Tajikistan) (2013)

Taking advantage of the management accounting definition aimed at implementing the development strategy of an agricultural enterprise, as well as its contribution to the management system, it can be noted that the end result is the development and presentation of various forms of management reporting, which is based on adapting the value chain to meet the needs of its users. Based on this, it can be noted that internal management reporting is aimed at the management system, and to meet its needs it is necessary to develop the most optimal management reports that contribute the management system to manage competitiveness. The concept of management reporting development refers to the form of management reporting preparation, which may include articles, the indicators of which play a key role in making managerial decisions. To manage the enterprise competitiveness in the developed management reporting, it is necessary to take into account the possibility of collecting, systematizing and reflecting financial and non-financial information. Considering the direction of the strategic functioning and development of an agricultural enterprise, management reporting can only be effective and efficient if it provides the possibility of implementing analytical procedures, or providing comparative indicators of the achieved results. To ensure the analytical process in the structure of management reporting connected with ensuring the

management of competition and competitiveness of an agricultural enterprise, it is necessary to include planned indicators of the possibility and prospects for development, and for comparability with other sector subjects, the actual indicators of the enterprise position in the industry, etc.

The formation complexity of management reporting of an agricultural enterprise is based on its diversity, the conditions and rules for the formation of management information, and, as noted above, on the target focus of this reporting' users, as well as on the possibility and development of the information that makes up the reporting indicators. Management reporting is determined by many parameters, but its main task is to form such reporting package that would reflect the business structure and meet the information requirements of management. It is connected with the enterprise activities, forms a kind of unique product which is the result of management accounting, and contains its own specific features. Despite the lack of uniform regulatory requirements in the preparation of management reports and those fragmentations, their data can be systematized together in accordance with a system of certain regulatory rules. The most optimal form of management reporting aimed at accounting for the manufacturing products costs which is reflected in the following Table 1 are analyzed below.

**Table 1.** Form for main production cost

Cost elements	Total for main production	Planned indicators		Total for main production	Actual indicators	
		Including for production			Including for production	
		crop production	animal production		crop production	animal production
Labor costs with contributions to social insurance and social security						
Material costs included in the production cost (including: seeds and planting material)						
Feed						
Mineral fertilizers						
Petroleum products						
Electrical energy						
Fuel						
Spare parts						
Payment for services and work performed by third parties and other material costs						
Depreciation of fixed assets						
Insurance payments						
Other costs						
Total cost for main production						

**Source:** prepared by the author based on the Album of forms of primary accounting documentation and reporting for enterprises and associations (approved by the Ministry of Finance of the Republic of Tajikistan) (2013)

The form presented in Table 1 as a form of management reporting connected with the production costs of the main production of agricultural products cannot fully disclose the costs, and the presented table summarizes the costs by types (sub-areas) of agricultural production. However, agricultural production covers the crop and animal production areas, managers are required to make appropriate management decisions for each production

area separately, and sometimes for certain types of products (Lal, 2020). The management of the agricultural products competitiveness requires the development of such management reporting form that would reflect in detail the cost value and the output products quantity, considering the presented report preparation connected the production and production cost of both the crop and animal production industries, which is shown in Tables 2 and 3.

**Table 2.** Production and cost for crop production

Crop	Line code	Actual cultivation area, ha	Total costs, somoni	Including					
				Labor payments with accruals	Seeds and planting material	Fertilizers	Fuels and lubricants	Management expenses	Depreciation

**Source:** prepared by the author based on the Album of forms of primary accounting documentation and reporting for enterprises and associations (approved by the Ministry of Finance of the Republic of Tajikistan) (2013)

**Table 3.** Production and cost for animal production

Animal types	Line code	Average livestock, heads	Total costs, somoni	Including				
				Labour payments with accruals	Feed	Fuels and lubricants	Management expenses	Depreciation

**Source:** prepared by the author based on the Album of forms of primary accounting documentation and reporting for enterprises and associations (approved by the Ministry of Finance of the Republic of Tajikistan) (2013)

The forms of management reporting presented in Tables 2 and 3 are quite sufficient to manage the competitiveness level in terms of value. They reflect the output products, both in quantitative and value terms. But it should be noted that the system for managing the production process and sales of products in any economy sector requires, first of all, efficiency. Any managerial decisions should be made very promptly and clearly, because in a competitive environment every minute is worth its weight in gold for an enterprise, and timely information provided to the management system becomes the basis for making appropriate managerial decisions.

## DISCUSSION

In general, the way in which a company's reporting is formed can greatly influence its competitiveness level. Thus, A.Y. Othman *et al.* (2020) in their work on management accounting practices write that standards are often unable to keep up with the changing pace in business practices. This reduces the indication of both the report itself and hinders enterprises in conducting their activities. Thus, the company's reporting standards should be universal, variable and changeable, which will allow the business constantly adapting to new business realities. It will also reduce the need for permanent changes to reporting standards. Their research shows that in the studied enterprises, accountants play a significant role in a strategy development to increase the competitiveness of enterprises, and the statistical study of the scientist indicates an existing positive correlation of the statistical impact of management accounting on achieving competitive advantage. Other scientists confirm this idea. In particular, S.J. Braim (2020) writes that management accounting variables are positively correlated with each other, which means that improving one of the management accounting variables will lead to improvement in others. In addition, scientists note the existing correlation between management accounting variables (information collection, information processing, management accounting reports quality and information transfer) and decision making, which, however, strongly depends on the company's ability to collect reliable information and process it. All this information confirms the concept that the role of accounting and reliable information in it is very high to increase the level of the company's competitiveness.

Interesting thoughts are reflected by V. O'Connell *et al.* (2020), as they note the importance of another aspect of management, namely competitive intelligence. This becomes especially relevant in countries with developed capital markets, where companies that enter the market are forced to make their reporting available to absolutely everyone. In their opinion, the daily activities of a modern financial reporting service require the collection, synthesis and analysis of huge data amounts from both internal and external sources. Thus, high-quality reporting can increase not only the level of competitiveness of an individual enterprise, but also improve the competitive environment in the entire market

as a whole, because managers will have all available information about the development of competitors' enterprises and thus change their own development strategy. It should be noted that the role of management and accounting reporting in the process of company management is primarily that it allows assessing the available financial information about the enterprise state, which provides for making quality decisions: in turn, incorrect development of the principles for filing and reporting can distort information, and therefore harm the company in the long run, given the likely erroneous decisions made by its managers in the future.

In general, analyzing the indicators system of each form of specialized AIC reporting noted in the work, it can be noted that they are more suitable for management reporting. Each form contains the information that is necessary for a more rational analysis and management of the economic entity's activity. But it should be noted that in relation to the management of costs and results of a specific industry, they are sufficient, but in relation to the competitiveness level, the question arises about the information quality stated in the reports. As stated by M.J. Imhof *et al.* (2018), this results in some companies adopting stronger policies to protect confidential information from competitors. A.P. Monteiro *et al.* (2020) generally agree with this in their work, in which they consider the impact of information systems and non-financial information on business performance. Some disadvantages of the reporting system in Tajikistan that were noticed in the work should be noted: it can be said that in the financial and management reporting systems aimed at agricultural enterprises that were mentioned previously, information (article) reflecting the state of affairs connected with using biological assets. In connection with the role of this assets type for business conducting in agriculture, it is concluded that for a better data representation in reporting, these articles should be added in their subsequent revisions.

Considering the abovementioned forms of specialized reports of enterprises in the sphere of agricultural production, as the basis for preparation, in a generalized form, the results of management accounting, management reporting for the purposes of competitiveness management, individual groups of indicators can be combined into a single management report, which will possibly characterize the following main objects of management accounting. By reading the work of E. Marfolla (2016), the following objects of management accounting can be distinguished: indicators on the main resources state of the enterprise (labor, material, current and non-current); on the capital state of an economic entity (own and borrowed); on the state and results of economic processes performed by an economic entity, including income and expenses; on the results of activities of such main aspects of the flow of funds of the enterprise such as: current; financial and investment activities. The grouping of the constituent indicators of management reporting allows determining the main data connected with the management system of the

agricultural producer competitiveness, which is primarily based on the cost indicators connected with the production of a particular type of product. It should be noted that other scientists in their works state other methods of improving operation of enterprises with the reporting. In particular, V.V. Galautdinova (2019) writes about the role of introducing of management reporting automation, because, in her opinion, this allows for variably planning of business decisions for a sufficiently long horizon period, as well as reduce the costs of an enterprise in the long term, with which is hard to disagree.

In general, scientists note the significant problems that exist in the economy of Tajikistan connected with the insufficient level of its competitiveness: P.K. Azimov and A.V. Babkin (2011) emphasis on it in their research, where they indicate that the country is only at the beginning of the path for building a competitive economy. Scientists state to significant prospects for increasing the competitiveness of the country's economy, in particular through development assistance to small and medium-sized enterprises. However, in Tajik economic thought, little attention is paid to the problems of accounting and management reporting in the country, more describing the possibilities of supporting enterprises with the help of government intervention or increasing their innovation level, which is a negative indicator and suggests that the topic needs further detailed review.

## CONCLUSIONS

The work described how the accounting reporting system in the Republic of Tajikistan operates for companies in the agricultural sector. In addition, it was shown what main forms of filling this reporting existed in the country

and what their features were. By analyzing these forms and the reporting structure in general, it was shown that such structure had its own disadvantages, which did not allow achieving a sufficiently high level of enterprises competitiveness in the agricultural sector in Tajikistan. In particular, they are not detailed enough for agricultural companies, as they do not have separate sections for considering the types of crops and animals available at the enterprises. Therefore, in the article, other reporting options were suggested for companies in the agricultural sector, which would better provide information to managers due to the greater abundance of data in them and not much greater complexity of their submission.

It was established that by improving the reporting level, it was indeed possible to improve the enterprises competitiveness level, which was very important for Tajikistan, given the long country's Soviet legacy and only emerging entrepreneurship institution. Particular attention is paid to the role of information to increase the competitiveness level of any enterprise, because managers should have a sufficient amount of reliable data to make informed decisions for the enterprise development. This is the role of high-quality submission of accounting, namely management, reporting. However, it is also important to pay attention to the needs of managers and take into account their reporting requirements. This makes the reporting process particularly complex and time-consuming, but important for increasing the competitiveness of all enterprises and the economy as a whole. Promising for future study is the development of possible methods for improving accounting records in Tajikistan to increase the efficiency of the country's enterprises.

## REFERENCES

- [1] Album of forms of primary accounting documentation and reporting for enterprises and associations (approved by the Ministry of Finance of the Republic of Tajikistan). (2013). Retrieved from <http://minfin.tj/>.
- [2] Al-Khasawneh, R.O., Oqool, M., & Bshayreh, M. (2014). The Importance of the accounting information and the role of the scientific accounting research in developing the economic development service in the developing countries (Case Study Jordan). *Research in Applied Economic*, 6(1), 240-257. doi: 10.5296/rae.v6i1.4699.
- [3] Alpatova, E., Zenkina, I., Fedosova, O., Lykova, O., & Krivetskaya, T. (2021). Strategy for the development of agricultural enterprises. *E3S Web of Conferences*, 285(51), article number 01018. doi: 10.1051/e3sconf/202128501018.
- [4] Alsoboa, S. (2015). Practices of competitor accounting and its influence on the competitive advantages: An empirical study in Jordanian manufacturing companies. *Global Journal of Management and Business Research: D Accounting and Auditing*, 15(3), 13-23.
- [5] Azimov, P.K., & Babkin, A.V. (2011). Analysis of the competitiveness of the economy of the Republic of Tajikistan in the world market. *π-Economy*, 2(119), 210-218.
- [6] Barfiyev, K.Kh. (2019). *Competitiveness of agricultural production and its accounting and analytical foundations: Theory, methodology, organization based on the materials of the Republic of Tajikistan*. Bishkek: Kyrgyz National University named after J. Balasagyn.
- [7] Bergonia, N.A. (2021). The role of accounting information systems in a business. *Ascendens Asia Journal of Multidisciplinary Research Conference Proceedings*, 4(1), 1-52.
- [8] Braim, S.J. (2020). *The role of management accounting in the decision-making process*. Nicosia: Near East University Graduate School of Social Science.
- [9] Galautdinova, V.V. (2019). Automation of management reporting. *Eurasian Union of Scientists*, 4(61), 12-14.
- [10] Gandour, D. (2021). Analytical review of the current and future directions of management accounting and control systems. *European Journal of Accounting, Auditing and Finance Research*, 9(3), 42-73. doi: 10.2139/ssrn.3819654.
- [11] Gao, J. (2022). Analysis of enterprise financial accounting information management from the perspective of big data. *International Journal of Science and Research*, 11(5), 1272-1276. doi: 10.21275/SR22514203358.
- [12] Imhof, M.J., Seavey, S.E., & Watanabe, O.V. (2018). Competition, proprietary costs of financial reporting, and financial statement comparability. *Journal of Accounting, Auditing & Finance*, 37(1), 114-142. doi: 10.1177/0148558X18814599.

- [13] Jaf, R.A., Sabr, S., & Nader, K.A. (2020). *Impact of management accounting techniques on achieve competitive advantage*. *Research Journal of Finance and Accounting*, 6(4), 84-98.
- [14] Jostan, M.N., & Alimbudiono, R.S. (2020). The role of accounting studies in student lifestyle and financial behavior. *Management and Entpreneursip: Trends and Development*, 3(13), 16-23. doi: 10.26661/2522-1566/2020-3/13-02.
- [15] Lal, R. (2020). Integrating animal husbandry with crops and trees. *Frontiers in Sustainable Food Systems*, 4, article number 113. doi: 10.3389/fsufs.2020.00113.
- [16] Marfolla, E. (2016). Tax aggressiveness in family firms and the non-linear entrenchment effect. *Journal of Family Business Strategy*, 7(3), 178-184. doi: 10.1016/j.jfbs.2016.08.003.
- [17] Monteiro, A.P., Vale, J., Leite, E., Lis, M., & Kurowska-Pysz, J. (2020). The impact of information systems and non-financial information on company success. *International Journal of Accounting Information Systems*, 45, article number 100557. doi: 10.1016/j.accinf.2022.100557.
- [18] O'Connell, V., AbuGhazaleh, N., & Whelan, G. (2020). Financial reporting as a source of innovation-relevant competitive intelligence. *Journal of Open Innovation: Technology, Market and Complexity*, 7(117), 1-13. doi: 10.3390/joitmc7020117.
- [19] O'Hara, M., & Oldfield, G.S. (1986). The microeconomics of market making. *The Journal of Financial and Quantitative Analysis*, 21(4), 361-376. doi: 10.2307/2330686.
- [20] Order of the Ministry of Finance of the Republic of Tajikistan No. 124 "On Approval of the Instructions on the Procedure for Filling in Forms of Quarterly and Annual Financial Statements by Business Entities". (2001, August). Retrieved from [https://continent-online.com/Document/?doc\\_id=30568619](https://continent-online.com/Document/?doc_id=30568619).
- [21] Othman, A.Y. (2020). The role of management accounting practices in achieving competitive advantage. *International Journal of Humanities and Social Science*, 11, 437-450. doi: 10.33193/IJoHSS.11.24.
- [22] Oyewo, B., & Ajibolade, S. (2019). Does the use of strategic management accounting techniques creates and sustains competitive advantage? Some empirical evidence. *Annals of Spiru Haret University. Economic Series*, 19(2), 61-92. doi: 10.26458/1923.
- [23] Randriamiarana, J. (2015). The role of accounting in economic development: Case of IFRS adoption in Western Africa. *Recherches en Sciences de Gestion*, 110, 61-88. doi: 10.3917/resg.110.0061.
- [24] Vavrek, R., Vozarova, I.K., & Kotulic, R. (2021). Evaluating the financial health of agricultural enterprises in the conditions of the Slovak Republic using bankruptcy models. *Agriculture*, 11(3), article number 242. doi: 10.3390/agriculture11030242.

## Підвищення рівня конкурентоспроможності за допомогою управлінської звітності на підприємствах аграрного сектору

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**Анотація.** У сучасних реаліях підприємства є основним суб'єктом функціонування економіки. Проте з часом їх роль змінилася, що призвело до змін у принципах ведення бухгалтерського обліку, які в цілому підвищили його значення для досягнення найкращих фінансових результатів діяльності підприємства. Отже, залишається актуальним розгляд сучасних особливостей ведення бухгалтерського обліку на підприємствах. У даній роботі аналіз проводиться на прикладі Республіки Таджикистан, що пояснюється як економічними особливостями розвитку країни, так і її соціалістичним минулим і відносно недовгою історією в рамках капіталістичного механізму держави. Крім того, аналіз в основному зосереджений на аграрному секторі через його значну роль у стратегічних та економічних планах розвитку країни. Метою роботи було оцінити поточний стан методів управлінської звітності в Таджикистані. Основним методом, використаним при написанні статті, був аналіз, з урахуванням кількості розглянутих джерел, використаних для формування висновків, моделювання, графічний та статистичний методи. У роботі описано основні особливості управлінської звітності для сільськогосподарських підприємств в Республіці Таджикистан. Аналіз структури та основних форм, що існують для звітності підприємств аграрного сектору, показав їх низьку ефективність. Це пов'язано з обсягом наданих даних, який є недостатнім для ефективного функціонування аграрного сектору. Доведено, що за рахунок внесення певних змін у методику складання бухгалтерської (управлінської) звітності та підвищення якості даних у ній можна підвищити рівень конкурентоспроможності підприємств. Тому в роботі запропоновано такі форми їх звітності, які могли б вирішити деякі існуючі проблеми. Робота надала нові знання про принципи фінансової звітності, а також проаналізувала особливості її складання в країні, тому її результати можуть бути використані на практиці фахівцями у відповідній галузі

**Ключові слова:** управління сільським господарством, рівень конкурентоспроможності, бухгалтерська звітність, підприємництво, економіка Таджикистану



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## Directions and recommendations for enterprises to overcome crises using anticipatory teams

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**Abstract.** Anticipatory management plays an important role in the quality functioning and development of the enterprise, which determines the relevance of the study of the selected problem. The purpose of the article is to substantiate the importance of anticipatory management in the management of agricultural enterprises through the introduction of anticipatory teams into the organizational structure, which was caused by the destabilization of the external and internal environment in the conditions of the Russian-Ukrainian war. During the research, general scientific and special methods were used: analysis and synthesis, abstract-logical. The types of crisis situations that may occur on the enterprise have been studied. The main factor of the onset of the crisis in agricultural enterprises of Ukraine has been determined. Special attention is paid to the consequences of Russian military aggression. An analysis of the main performance indicators of agricultural enterprises was carried out. The share of Ukrainian companies that have anticipative teams was determined. The urgency of forming anticipatory teams in agricultural enterprises is indicated, which is a necessary means of forecasting and overcoming all possible crises. The basic structure of the company's anticipatory team has been formed. It was established that solving the current crisis problems requires the involvement of specialists both at the state level and consultants from international organizations. It is recommended to create anticipatory teams at the level of agricultural enterprises, which will provide an opportunity for producers to quickly respond to crisis situations; it will be appropriate to implement the recommendations developed by the anticipatory team of donors. Thus, this study brings new knowledge about the specifics of the functioning of anticipatory teams and has practical value for Ukrainian agricultural enterprises in overcoming the consequences of crisis situations, including the Russian-Ukrainian war

**Keywords:** anticipatory management, crisis situations, war, crisis teams, agricultural enterprises



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## INTRODUCTION

In recent years, the agricultural economy is becoming more and more popular among several other areas of the economy, starting another round of qualitatively new cyclical development. The reaction of various state and international institutions, professional communities of investors, and the population confirm the trend of increased interest in this industry. Therefore, agricultural enterprises and agro-industrial formations in modern conditions must develop state-of-the-art intellectualized and computerized systems of anticipatory management, which can be an effective tool on the way to achieving complex, short- and long-term goals of economic development.

Among scientists, there is still no consensus on the definition of the concepts of "anticipatory management" and "anticipatory team" and their significant influence on the effective management of the enterprise (Kistion, 2019). Thus, V. Morozov & Sova (2020) consider anticipatory management as a type of anti-crisis management, which covers the financial activities of the enterprise and is aimed at the prevention and prevention of crisis phenomena, as well as the use of chances of operating conditions. In contrast, Poberezhets and Klymenko (2019) consider it as management, which is aimed at forming a complex of management decisions regarding the effective and rational functioning of the enterprise under the conditions of external and internal threats.

However, there are studies that show that the development of anticipatory management has a significant impact on the further development of the enterprise. In the works of Scott Graffin *et al.* (2011), V. Miroshnichenko and N. Tanklevska (2019), special attention is focused on the need for effective management of financial potential, due to several problems of anticipatory management. Thus, these tasks represent the basis for managing the financial potential of the enterprise. Scientists also considered conceptual approaches to managing the financial potential of an enterprise based on anticipatory management. The work of these authors carries not only the theoretical validity of the importance of anticipatory management but also practical value, which consists in the application of the proposed conceptual approaches to the management of financial potential based on anticipatory management in practical activities, which will allow for quick detection, response and prevention of crisis situations. Therefore, today, the formation of anticipatory teams is a significant advantage for every enterprise that wants to maximize its own profit and occupy a leading position in the market, which is constantly undergoing changes.

A significant number of scientists are engaged in the study of this topic and related issues. B. Kaminska (2018)

in her works analysed the features of anti-spacious management on the potential of enterprises and recognized the special importance of its further research and development. V. Komunyar (2022) was engaged in modelling anticipatory trade at agricultural enterprises. He highly appreciated the role of anticipatory management in modern agriculture, but he paid little attention to the theoretical basis of this concept. After all, its complete understanding makes it possible to fully apply its capabilities in practice. Therefore, the theoretical principles of anticipatory management are reflected in the works of: J. Derbyshire (2017), R. Poli (2017), V. Rogov (2018), S. Melnyk (2020), I. Petruk (2021), V. Yanchuk (2018), Thakral & Tô (2021) and others. In their works, scientists tried to reveal the concept of "anticipatory management" in more detail and characterize its significance for socio-economic development. It is also worth noting the works of Z. Harbar and V. Horynska (2021), in which researchers pay attention to the formation of the anticipatory management mechanism at agricultural enterprises. As for ways to ensure the economic stability of agricultural enterprises using anticipatory management, this opinion is revealed in the works of O. Butkova (2020).

Olaniran *et al.* (2020) highlighted the importance of the process of identifying weak signals that affect the enterprise. As a result, the structure of the crisis communication centre using the model of anticipatory management was proposed. This structure will be able to play a role in determining the most necessary resources for anticipatory management.

Furlanetto & Poli (2018) demonstrate the difference between uncertainties and risks. After all, risks allow for calculating probabilities, when uncertainties do not have such an opportunity. Therefore, by distinguishing these concepts, enterprises will be able to build a correct strategy for preventing the emergence of crisis situations. In turn Kerem (2017), T.T. Binh (2022), Gasca & Schindel (2022), Glaister & Gold (2022) in their works explore the importance of feedback between management and employees from the perspective of anticipatory management. These scientific works provide an understanding of the importance of the contribution of team supervision. That is, the strengthening of the culture of responsibility, the involvement of other employees in the development and implementation of anticipatory management, reporting mechanisms and their effective interaction change the landscape of surveillance and monitoring, which will significantly strengthen preventive stimulation and expectations of the quality of surveillance and monitoring functions in the future. In contrast to the above, T. Merritt (2002)

focused attention not on the concept of “anticipatory management”, but revealed the concept of a “road map” of anticipatory management, which can become indispensable in every enterprise. Its development and implementation are no less important than the formation of an anticipatory team. Thus, by having a clear and understandable action plan, employees who are involved in the anticipatory team will be able to understand their goals and step-by-step actions.

In their research, these scientists tried to develop various methodological approaches to the development and implementation of anti-discharge management in the activities of enterprises. The authors' conclusions are indeed very important for the formation of anticipatory management at enterprises, but little attention has been paid to the concept of an “anticipatory team”, which is the component responsible for managing crisis situations.

Therefore, based on the above, the purpose of this study is to justify the importance of anticipatory management implementation in the management of agricultural enterprises through the introduction of anticipatory teams, which was caused by the destabilization of the external and internal environment in the conditions of the Russian-Ukrainian war. To achieve this purpose, the following tasks were set: definition of the concept of “anticipatory team”; consider and analyse the main indicators of the activity of the agrarian industry; determine the main crisis situations from the beginning of a full-scale invasion; to propose basic proposals for eliminating crisis situations.

### THE IMPORTANCE AND IMPACT OF ANTICIPATORY MANAGEMENT

The crisis is considered to be the events, most of which the enterprise can foresee, having an anticipatory team of specialists. The anticipatory team (AT) is a group of specialists who direct their actions on minimizing or completely eliminating risks in the company's activities. A coordinated anticipatory management team allows the enterprise solving the following tasks: to ensure the maximum contribution of managers and various specialists of the company to Association for Computing Machinery (ACM); to support the readiness of people in the company to make efforts and even sacrifice their own interests to solve the problems of the crisis; to accumulate additional resources for diagnosis and identification of organizational weaknesses and their elimination; to ensure the development of documents, templates, booklets, procedural formats and other materials necessary for effective communication with the media and stakeholders that will be

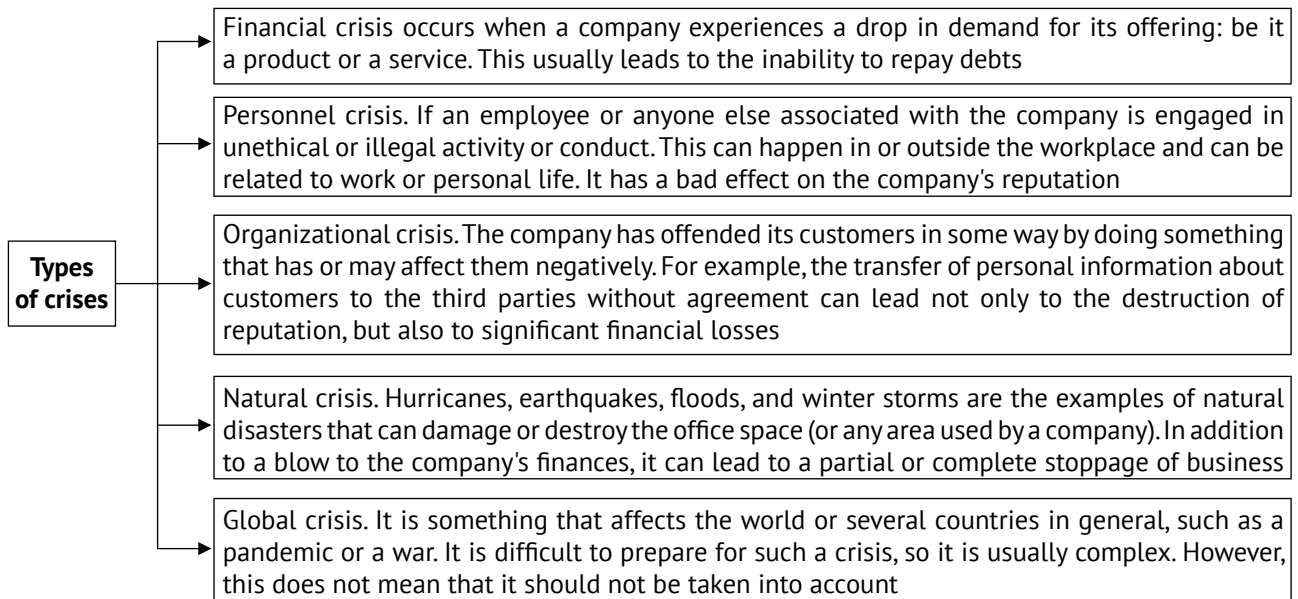
needed during a crisis; to attract consultants and organize training for managers and specialists concerning behaviour during a crisis.

Miller's “Transforming the Future: Anticipation in the 21<sup>st</sup> Century” (2018), which explores and defines the theory and practice of forecasting around the world, fully conveys the true importance and impact of anticipatory management in today's world. The author uses the concept of “Literacy of the Future” as a tool for defining anticipatory systems. This is an important element because the future is not a constant value and over time every field, from social sciences to everyday life, undergoes changes, which in turn affects the financial success of enterprises. Thus, R. Miller fully discloses the concept of anticipatory management but does not give recommendations regarding anticipatory teams, on which this type of management should be built. After all, a full understanding by entrepreneurs of the importance of anticipatory management is only one of the components of securing leading positions in the market. Knowledge of the essence, meaning, functions and main composition of anticipatory teams is the basis that enterprises must possess.

Also, it is worth noting that scientists such as N. Podluzhna *et al.* (2020) and Pavlovski (2017) provided a detailed description of the effectiveness of anticipatory management, which should be integrated into all areas of corporate management. According to these scientists, the formation of a complex of anticipatory measures will ensure a more rational and less expensive management. Thus, based on the research of the above-mentioned scientists, it will be useful to study and analyse in more detail the meaning and impact of anticipatory teams on the activities of enterprises, which are a component of these measures.

### TYPES AND FACTORS OF CRISES

Analysing the types of crises, one should not forget about the force majeure circumstances that cannot always be predicted: for example, natural disasters, emergencies, war etc. (Fig. 1). The military aggression against Ukraine is classified as a “force majeure situation”, but its consequences can be predicted if the company has qualified specialists and uses anticipatory management, according to O.V. Kovalenko (2014). This statement is supported by the fact that the prerequisites for a full-scale Russian-Ukrainian war date back to 2014, and the most critical signals regarding the possible start of a full-scale war were observed in the autumn of 2022. Based on this, the company's anticipatory team should minimize losses from the occurrence of such a crisis.

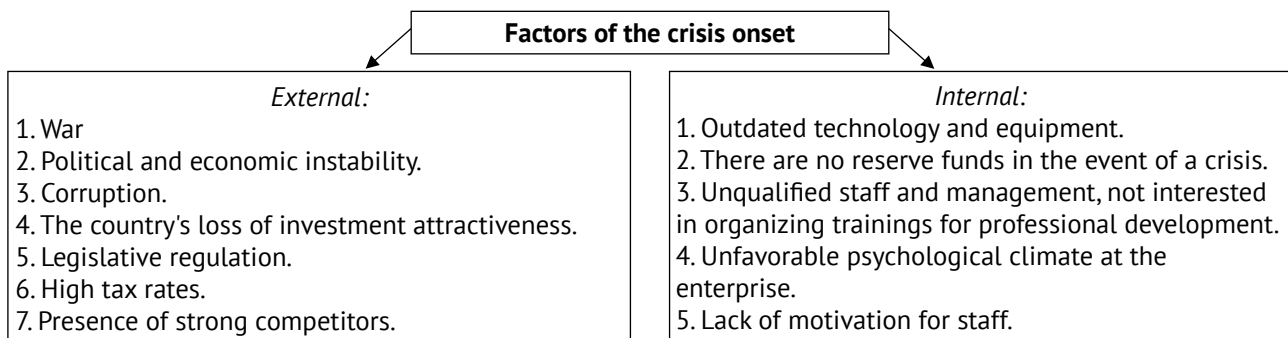


**Figure 1.** Types of crises that can probably happen to the company

**Source:** compiled by the authors based on data from Bakertilly (2022)

Considering the factors of the onset of the crisis in the activity of the enterprise plays an important role in effective and successful functioning. Therefore, the analysis of these factors in wartime and peacetime is an important component. If examine the crisis

phenomena which the company may face daily in peacetime, then when having the AT and adaptive management, the business entity has all the opportunities to occupy a leading position in the market of the relevant industry (Fig. 2).



**Figure 2.** The main factors of the crisis onset in the agricultural enterprises of Ukraine

**Source:** compiled by the authors based on own development

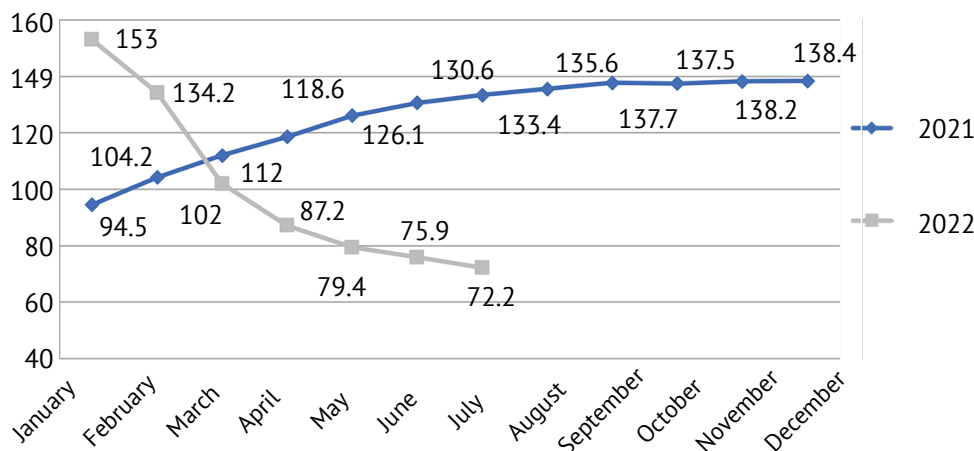
If management can control and eliminate internal factors as arise and thus avoid a crisis, then when it comes to external factors, in this case, the company can only adapt to them, with the aim of causing negative crisis consequences. That is why the use of anticipatory teams at enterprises is of such great importance because their main task is to prevent possible external and internal factors of the onset of a crisis. Timely detection of a crisis is the key to the successful functioning of the enterprise.

## ANALYSIS OF AGRICULTURAL INDICATORS

Before starting the research and a detailed analysis of the use of anticipatory teams in agricultural enterprises, it will be useful to consider the main indices of the activity of the agricultural sector of Ukraine, which determines its competitiveness. Namely, indicators of cultivated areas, rates of growth (decrease) of exports and imports, and volumes of production of agricultural crops, which will give a general understanding of the situation.

According to the Figure 3, there is a clear tendency to decrease the export of agricultural products by 34% in the first half of 2022 compared to the first half of 2021. This situation has had a negative impact on the incomes of the

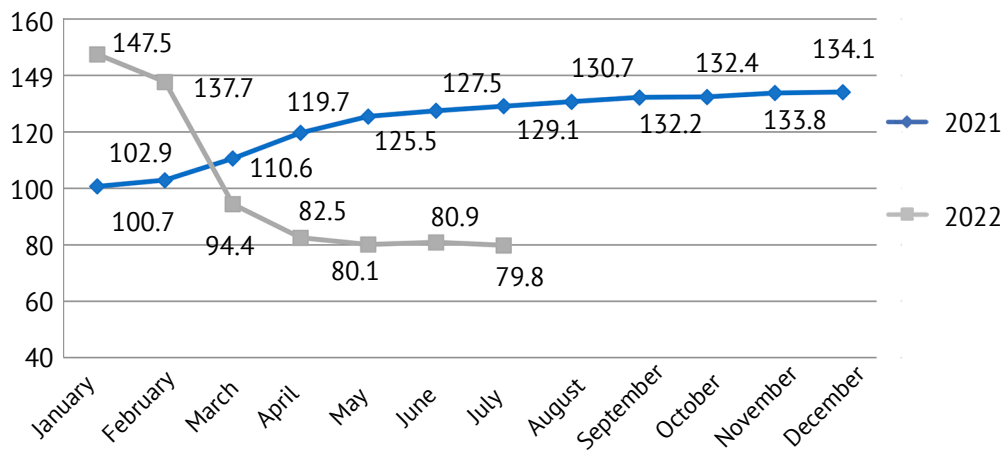
world population, as the prices of food products have increased significantly. Also, the decrease in the rate of export of agricultural products leads to a food crisis, which in turn causes other negative consequences for the world society.



**Figure 3.** Rates of growth (decrease) in the export of goods (in % compared to the corresponding period of the previous year)  
**Source:** compiled by the authors based on data State Statistics Service of Ukraine (2022)

The volume of import was 80.9%, and the deficit that arose in the country was tried to be compensated by substitute goods. The export-import coverage ratio is 0.90 (0.96 in the first half of 2021). This decrease in the import of goods during the period

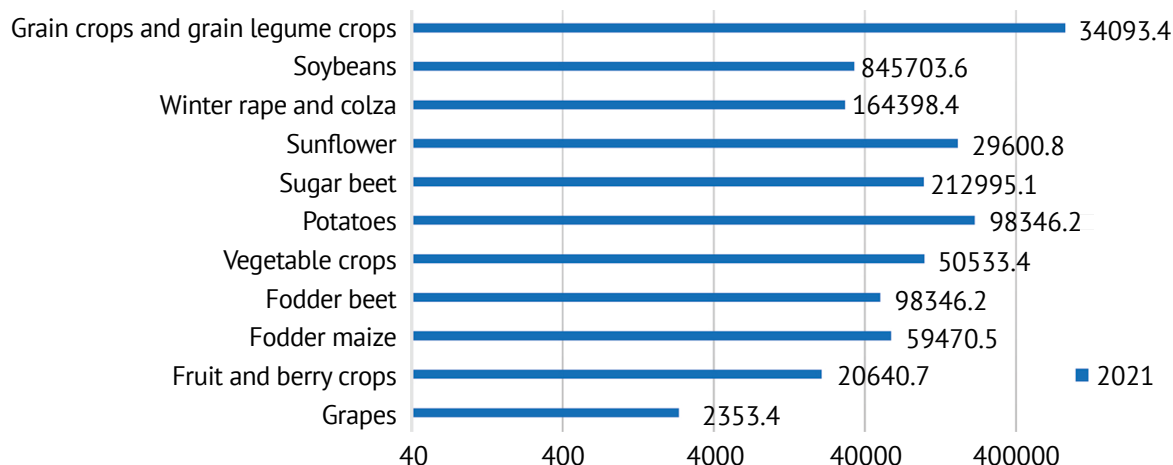
of hostilities is reflected in the shortage of certain goods, although efforts are being made to compensate with substitute goods. However, import is one of the components of the effective and smooth functioning of the market.



**Figure 4.** Rates of growth (decrease) in the import of goods (in % compared to the corresponding period of the previous year)  
**Source:** compiled by the authors based on data from State Statistics Service of Ukraine (2022)

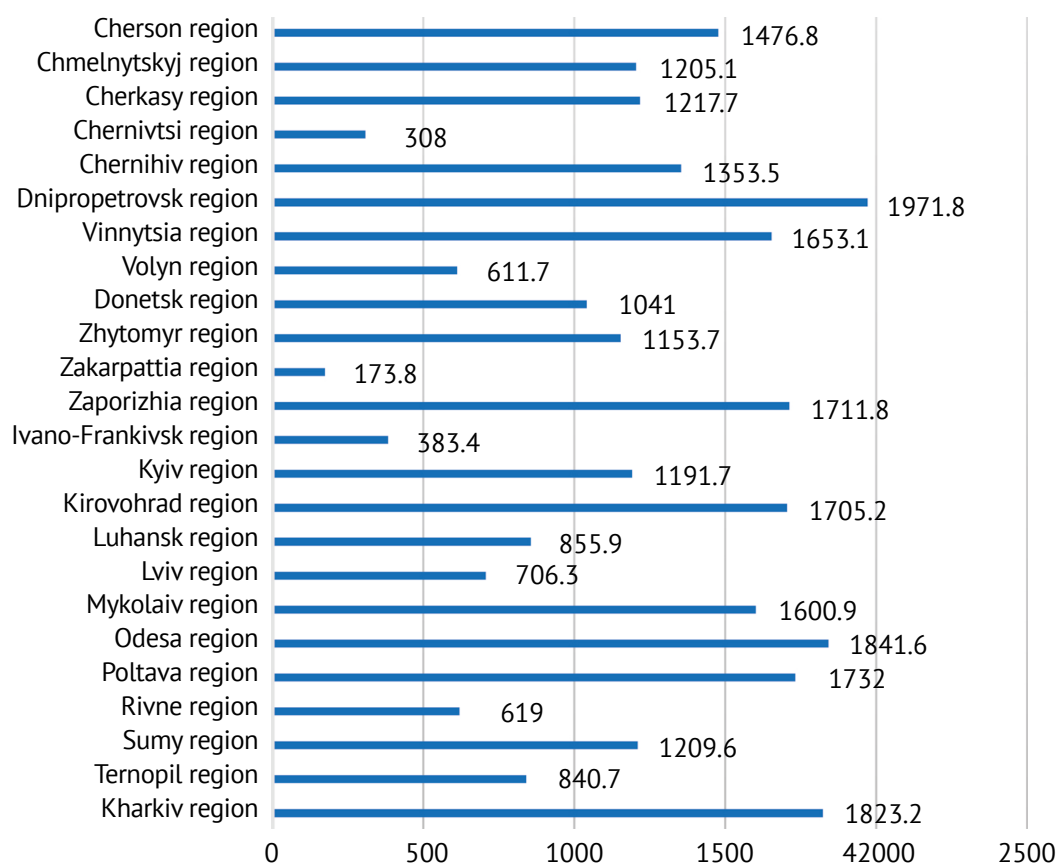
According to the statistical data, the sown areas in 2022 amounted to 28,387.5 thousand hectares. In the first half of 2022, the occupiers controlled approximately 22% of Ukraine's agricultural land. Thus, according to approximate data, now there are 22,142.25

thousand hectares left for the use of Ukrainian farmers. Before the full-scale war, Ukraine supplied 46% of world oil exports, 9% of wheat exports, 17% of barley exports, and 12% of corn exports on world markets (see Figs. 5-6).



**Figure 5.** Production volumes of agricultural crops in 2021, thousand dt\*

**Source:** compiled by the authors based on data from State Statistics Service of Ukraine (2022)



**Figure 6.** Sown areas of agricultural crops in 2022 (by region), thousand ha\*

**Source:** compiled by the authors based on data from State Statistics Service of Ukraine (2022)

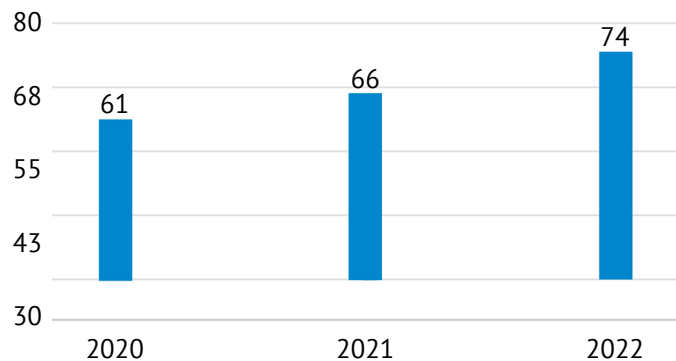
At the same time, the experts predict that the harvest in 2022 will be much smaller than in 2021, but larger than expected, considering the military aggression. In particular, the forecast for a sufficient wheat harvest is at a level of 19 million tons. In general, the harvest of grain and oilseed crops in Ukraine in 2022 is expected a level of 65-70 million tons, which, under a positive scenario, will be about 70% of the 2020-2021 index.

According to the forecasts of the Ministry of Agrarian Policy and Food of Ukraine, there may not be enough warehouses to store the harvest in autumn, which poses another challenge to the farmers. It cannot also be eliminated within the specified time limit. Thus, studying the production indices of agricultural enterprises in 2022, it is definite that the negative forecasts of experts are confirmed, which will directly affect the

profitability of producers and indirectly on consumers due to the increase in the cost of food products (Ovcharuk, 2022). Therefore, according to the obtained data, it can be concluded that the year 2022 became a challenge for every farmer because many crisis situations arose that had to be dealt with in the short term. It becomes obvious that the issue of forming anticipatory teams in agricultural enterprises is not just relevant, but a necessary means of forecasting and overcoming all possible crises.

### ANALYSIS OF THE SHARE OF COMPANIES WITH ANTICIPATORY TEAMS

With the beginning of the full-scale Russian-Ukrainian war, Ukrainian agricultural enterprises faced a number of problems for which they were not prepared. According to statistics provided by the EY company, by the beginning of 2022, only 74% of enterprises had the anticipatory teams. Other manufacturers are on the verge of bankruptcy. The increase in the share of enterprises that began to form such teams' dates back to 2020, when the world faced the COVID-19 (Fig. 7).



**Figure 7.** The share of Ukrainian companies that have anticipatory teams, %

**Source:** compiled by the authors based on data from LIGA360 (2022)

One can assume that the tendency of increase of this percentage will continue in the future. The end of active phase of war, although it will stop the growth of crisis, but will not get rid of them completely; it may take decades to restore economic stability. Thus, enterprises should already adapt activities to the new conditions of existence using anticipatory teams.

### THE ESSENCE OF ANTICIPATORY TEAMS

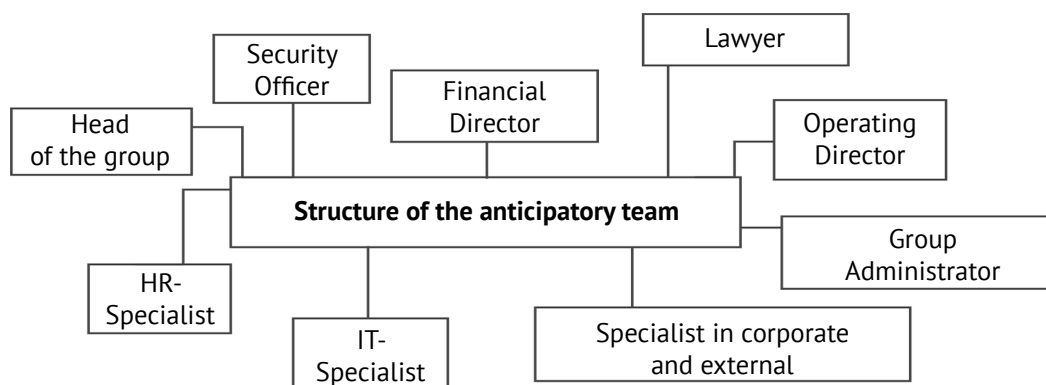
As stated above, most scientists in their writings single out the very concept of “anticipatory management” forgetting about its main component – the team. Therefore, in contrast to this, in the scientific works of D. Burrus (2018), it is proposed to consider the very concept of an “anticipatory team”. The similarity of opinions makes it possible to rely on the works of the specified scientist in this study. It is worth noting that the main idea of the scientist's works, which is supplemented in each subsequent work, is “An organization that involves waiting: can turn changes into an opportunity and an advantage”. That is, according to the scientist's opinion, the enterprise should become anticipatory, in which the strategy of the transition of the organization from reactive to anticipatory thinking is proposed, so that changes create opportunities and progress, not chaos, and without understanding the concept of “anticipatory team” it is impossible to do this.

For corporations or large companies with many branches, it makes sense to create a permanent

anticipatory team. Medium-sized companies can combine some positions into one or delegate responsibilities to one or more employees. A small business should think through a plan of action in case of crises and make a list of the third-party specialists to whom they can turn. The scientists distinguish three types of anticipatory management teams (Hliebova, 2015).

Regional teams are the regional emergency management groups that monitor local needs in a crisis. If the company has an extensive business with the offices in different cities or regions, this team will manage to overcome the consequences of the crisis that affect the region. This type of team is usually consisting of people who already live and work in the region. Emergency response team is the team that works with the crisis there where it happened. If it is in another city or country, they go there. This team includes field workers, assigned workers and local officials. Business support teams manage the impact of the crisis on the business as a whole. This team often consists of employees, who ensure that all management plans are implemented to resolve the crisis. Business support teams can include employees from several different locations and offices (Elexa *et al.*, 2019).

To understand what kind of specialists are needed in the anticipatory management, the structure of the main team of anticipatory headquarters should be considered (Fig. 8).



**Figure 8.** The structure of the main team of the Anticipatory Headquarters

**Source:** compiled by the authors based on data from A. Dudareva (2019)

In the Figure 8, the basic structure for forming an anticipatory team is shown. The agricultural enterprises can use this structure as a model for the further formation of ATs at the enterprises, with its further improvement, if necessary. When forming the structure of the headquarters of the anticipatory management team, took into account the three stages of the crisis and the tasks that will be performed by the employees of the AT (Butkova & Kravchenko, 2021):

1. A period of stability – crisis prevention: monitoring the state of the enterprise, forecasting potential risks and developing preventive measures;

2. The period of crisis aggravation – countermeasures: detailed diagnosis of the situation, development of an anti-crisis plan, distribution of responsibilities between responsible persons and monitoring of compliance with the plan;

3. “Aftermath” or crisis completion – “correction of mistakes”: analysis of the crisis impact on the company’s activities, assessment of the effectiveness of the anti-crisis team, “learning lessons” for countering crises in the future.

The functions of the anticipatory team, depending on its composition, can be as follows (Dovhan, 2013):

ensuring the financial stability of the company during a crisis situation; implementing solutions aimed at supporting employees affected during the crisis, relocating employees; communicating with the employees, partners, and media; assessing physical damage at objects; solving issues related to insurance reimbursements; ensuring uninterrupted operation of the company’s IT infrastructure; cooperating with local and national law enforcement agencies; assessing of risks, the legality of anti-crisis plans and their legal consequences.

### RESEARCHING NEW CHALLENGES AND FINDING SOLUTIONS

The war in Ukraine causes an extremely difficult crisis situation for the economy of the country and the world as a whole, at the same time, the existence of other crisis factors also determines the need for the creation of anticipatory teams. First of all, this is due to the fact that the micro- and macro-environment are not a constant, but a space that daily undergoes changes and influences, to which it is necessary to be ready or react quickly if the business entity wants to remain competitive in the future. Therefore, agricultural enterprises are currently facing a considerable number of problems in their activities (Fig. 9).

#### Crisis situations since the beginning of a full-scale invasion

1. Elimination of the VAT refund mechanism from the export of products.
2. Lack of a stable logistics corridor.
3. Rising energy prices.
4. Occupation of a part of agricultural land. Lack of stability of the land market.
5. Land tax in the occupied territories.
6. Absence of regulations regarding the mobilization of equipment.
7. Shortage of employees, due to the active mobilization of workers of technical specialties from the agrarian sphere.
7. Lack of extension of state guarantees to the bank.
8. Impossibility to harvest due to mining of territories or burned equipment.
9. Expropriation of business by the “new government”.
10. Partial or complete destruction of crops and storage facilities, etc.

**Figure 9.** Risks and crises arising from the beginning of the aggressor’s full-scale invasion of Ukraines

**Source:** compiled by the authors based on data from A. Dykun (2022)

The above-mentioned risks and crises, which have become relevant for agricultural producers since the beginning of the full-scale Russian invasion of Ukraine, require the immediate formation of an anticipatory management mechanism. Therefore, it was offered the following suggestions for solving these problems:

1. It is worth introducing electronic queues at the border and in logistic hubs in order to stabilize the logistics corridor.

2. Energy prices are an acute problem for every farmer. The use of flexi tanks, which can be filled with diesel and installed in grain trucks when the latter return from Europe to Ukraine after shipping grain, will partially help to relieve the energy tension in the country.

3. To solve the problem of paying taxes in the occupied territories, it is necessary to provide a clear definition of the term "occupied territories" at the legislative level as its absence forces agricultural producers who have left cultivated lands to pay land tax for them.

4. Regarding the unjustified mobilization of equipment, there is a need to establish standards at the legislative level.

5. The problem of agrarians, namely the lack of state guarantees to the bank can be solved only by extending the state guarantee system until the moment when producers sell products and receive payments under the terms of the contracts.

Solving these problems requires the involvement of specialists at the state level as well as consultants from international organizations. Therefore, offer the creation of an anticipatory team of donors for Ukraine, which would be appropriate to include: investors, international creditors, representatives of the Ministry of Agrarian Policy and Food of Ukraine, companies producing related products for the agricultural industry and scientists. It is this combination of specialists that will allow the development of effective measures to restore the volume of domestic agricultural production and eliminate the food insecurity that exists in the world today.

The formation of anticipatory teams at the level of agricultural enterprises will provide an opportunity

for producers to quickly respond to crisis situations, while it will be appropriate to apply the recommendations developed by the Anticipatory Team of donors. Of course, the creation of anticipatory teams is an important step to securing enterprises from the onset of new crises. However, in times of war, businesses must also change their approach to business as a whole.

Therefore, agricultural entrepreneurs, first of all, should reformat their view on the business processes development, taking into account the new conditions. It is also worth considering that if large enterprises and holdings have the financial opportunity to create an anticipatory department or team, small and medium-sized enterprises do not have such an opportunity and need support. In this situation, the recommendations developed by the Anticipatory Donor Team will be appropriate.

## CONCLUSIONS

In the conditions of a high level of dynamism and uncertainty of the agrarian enterprises functioning, anticipatory management is a relevant type of management activity that improves resource, information and time provision of the process of making various anticipatory management decisions regarding the use of opportunities or elimination of threats to activity. Therefore, the formation of anticipatory teams is an urgent need of every enterprise, which will protect it from possible crises.

An approximate structure of the advanced headquarters is proposed, and its main functions are defined. The agricultural enterprises can use this structure as a model for the further formation of AT. At the same time, the recommendations developed by the Donor Anticipatory Team will also be relevant. Prospects for further research of anticipatory management after the beginning of the full-scale invasion of the aggressor country into Ukraine is becoming increasingly important, as its skilful application will allow agricultural enterprises maintaining production volumes, thus avoiding the preconditions for the onset of the global food crisis.

## REFERENCES

- [1] Bakertilly. (2022). Retrieved from <https://bakertilly.ua/>.
- [2] Binh, T.T. (2022). *A conversation analytic approach to doctoral supervision: Feedback, advice and guidance*. Abingdon: Routledge. doi: 10.4324/9781003265863.
- [3] Burrus, D. (2018). *Anticipation and risk management*. Retrieved from <https://www.burrus.com/2018/01/anticipation-risk-management/>.
- [4] Butkova, O., & Kravchenko, V. (2021). Modern methodology and methods of capital structure analysis of agricultural enterprises. *IOP Conference Series: Earth and Environmental Science*, 937, article number 032066. doi: 10.1088/1755-1315/937/3/032066.
- [5] Butkova, O.V. (2020). *The main directions of ensuring economic security in the conditions of anti-crisis management of agricultural formations*. *Economy, Work, Management in Agriculture*, 1, 10-16.
- [6] Derbyshire, J. (2017). Potential surprise theory as a theoretical foundation for scenario planning. *Technological Forecasting and Social Change*, 124, 77-87. doi: 10.1016/j.techfore.2016.05.008.
- [7] Dovhan, D.A. (2013). *Anti-crisis management as a way to prevent and prevent insolvency of the corporation*. *Bulletin of the Chernivtsi Trade and Economic Institute. Economic sciences*, 3, 152-156.

- [8] Dudareva, A.B. (2019). Improvement of the existing system of anti-crisis management of agriculture. In *Real economy sector: Problems and prospects of development* (pp. 183-190). Kyiv: National Institute for Strategic Studies.
- [9] Dykun, A. (2022). *Ukrainian farmers faced new problems during the war*. Retrieved from <https://agroelita.info/ukrainski-ahrarii-pid-chas-viyny-styknulyisia-z-novymy-problemamy/>.
- [10] Elexa, L., Hvolkova, L., & Knapkova, M. (2019). Anticrisis management: Warning signals before failure. *Marketing and Management of Innovations*, 3, 98-111. doi: 10.21272/mmi.2019.3-08.
- [11] Furlanetto, A., & Poli, R. (2018). Anticipatory risk management. In *Handbook of anticipation* (pp. 1-12). Cham: Springer. doi: 10.1007/978-3-319-31737-3\_57-1.
- [12] Gasca, S., & Schindel, R. (2022). Anticipatory guidance. In *The oxford textbook of palliative social work* (2<sup>nd</sup> ed.) (pp. 653-658). Oxford: Oxford University Press. doi: 10.1093/med/9780197537855.003.0068.
- [13] Glaister, C., & Gold, J. (2022). Bridging the gap between reflective learning and reflective practice through anticipatory reflection. *Education + Training*, 64(8/9), 1060-1073. doi: 10.1108/ET-09-2021-0345.
- [14] Graffin, S. (2011). What's all that (strategic) noise? Anticipatory impression management in ceo succession. *Strategic Management Journal*, 32, 748-770. doi: 10.1002/smj.906.
- [15] Harbar, Z., & Gorinska, V. (2021). *Formation of the mechanism of anti-crisis management in agricultural enterprises*. *Colloquium-Journal*, 4(91), 26-32.
- [16] Hliebova, A.O. (2015). Formation of the anti-crisis management system at the enterprise. *Young Scientist*, 11(2), 35-40.
- [17] Kaminska, B. (2018). Iterative signal processing in anticipatory management of industrial enterprise development. *Virtual Economics*, 1(1), 53-65. doi: 10.34021/ve.2018.01.01(4).
- [18] Kerem, S. (2017). *Integrated approach to surveillance and monitoring for optimizing preventative and anticipatory risk management in investment banking*. Retrieved from [https://www.academia.edu/48848188/Integrated\\_Approach\\_to\\_Surveillance\\_and\\_Monitoring\\_for\\_Optimising\\_Preventative\\_and\\_Anticipatory\\_Risk\\_Management\\_in\\_Investment\\_Banking](https://www.academia.edu/48848188/Integrated_Approach_to_Surveillance_and_Monitoring_for_Optimising_Preventative_and_Anticipatory_Risk_Management_in_Investment_Banking).
- [19] Kistion, D.V. (2019). Organizational and economic measures of anticipatory management of the enterprise in conditions of economic instability. *Construction Law: Problems of Theory and Practice*, 2019, 109-112.
- [20] Komunyar, V.I. (2022). *Simulation of the agricultural enterprise's anticipative trade policy*. (Diploma Paper, Zaporizhzhia Institute of Economics and Information Technologies, Zaporizhzhia, Ukraine).
- [21] Kovalenko, O.V. (2014). Methods of anti-crisis management of the enterprise. *Economic Bulletin of the Zaporizhzhya State Engineering Academy*, 5(1), 60-64.
- [22] LIGA360 team solutions as an aid to anti-crisis teams in solving wartime issues. (2022). Retrieved from [https://biz.ligazakon.net/news/211996\\_komandn-rshennya-liga360-yak-dopomzhniy-zasb-dlya-antikrizovikh-komand-u-rozvyazann-pitan-vonnogo-chasu](https://biz.ligazakon.net/news/211996_komandn-rshennya-liga360-yak-dopomzhniy-zasb-dlya-antikrizovikh-komand-u-rozvyazann-pitan-vonnogo-chasu).
- [23] Matskulyak, I.D., Matskulyak, D.I., & Nagdaliev, N.Z. (2020). Safe anti-crisis business management in an age of changes. *Complex Systems: Innovation and Sustainability in the Digital Age*, 282, 25-32. doi: 10.1007/978-3-030-44703-8\_4.
- [24] Melnyk, S.I. (2020). Theoretical aspects of the application of anticipatory management of the financial security of the enterprise. *Agricultural World*, 5, 31-35. doi: 10.32702/2306!6792.2020.5.31.
- [25] Merritt, T. (2002). *Roadmap for anticipatory management*. Retrieved from [https://www.academia.edu/53262831/Roadmap\\_for\\_Anticipatory\\_Management?email\\_work\\_card=interaction-paper](https://www.academia.edu/53262831/Roadmap_for_Anticipatory_Management?email_work_card=interaction-paper).
- [26] Miller, R. (2018). *Transforming the future: Anticipation in the 21<sup>st</sup> century*. London: Taylor & Francis.
- [27] Morozov, V.I., & Sova, O. (2020). Modern paradigm of anti-crisis management of the enterprise. *Economics and Management*, 31(70), 43-47. doi: 10.32838/2523-4803/70-2-45.
- [28] Olaniran, B., Scholl, J., O'Hair, H., O'Hair, M., Hester, E., & Geegan, S. (2020). Anticipatory model of crisis management and crisis communication center (CCC). In *The need to transfer new knowledge to resources* (pp. 297-311). USA: John Wiley & Sons. doi: 10.1002/9781119399926.ch18.
- [29] Ovcharuk, O. (2022). Organizational and staffing support of anti-crisis management of an agricultural enterprise. *Management of the 21<sup>st</sup> Century: Globalization Challenges*, 3, article number 174.
- [30] Pavlovski, G. (2017). Development of the enterprise management system: Diagnostic and anticipatory approaches. *Business Inform*, 3, 380-384.
- [31] Poberezhets, N., & Klymenko, L. (2019). Anti-crisis management measures to minimize the destabilizing import effect on the economic activity of Ukrainian agrarian units. *Economic Horizons*, 4-15. doi: 10.31499/2616-5236.2(9).2019.195653.
- [32] Podluzhna, N.O., Petchenko, M.V., & Yakushev, O.V. (2020). Challenges of transformation of anti-crisis management of enterprises in modern conditions. *Collection of scientific papers of the Cherkasy State University of Technology. Series: Economic sciences*, 57, 104-109. doi: 10.24025/2306-4420.0.57.2020.206457.
- [33] Poli, R. (2017). *Introducing anticipation studies*. Cham: Springer. doi: 10.1007/978-3-319-63023-6.

- [34] Rogov, V.G. (2018). Anticipatory management of shipbuilding enterprises based on weak signals. In *Problems of regional development: Industrial and economic aspects: Materials of the All-Ukrainian scientific-practical conference* (pp. 104-106). Pervomaisk: Pervomayskiy Polytechnic Institute of Admiral Makarov National University of Shipbuilding.
- [35] State Statistics Service of Ukraine. (2022). Retrieved from <https://ukrstat.gov.ua/>.
- [36] Tanklevska, N., & Miroshnichenko, V. (2019). Theoretical basis of managing of enterprises' financial potential on the basis of anti-crisis management. *Agricultural and Resource Economics: International Scientific E-Journal*, 5(2), 51-61. doi: 10.51599/are.2019.05.02.04.
- [37] Thakral, N., & Tô, L. (2021). *Anticipation and consumption*. Retrieved from <https://equitablegrowth.org/working-papers/anticipation-and-consumption/>.
- [38] Yanchuk, V.I. (2018). *Anti-Crisis management by agricultural enterprises*. *Economy. Finances. Management: Current Issues of Science and Practice*, 12, 38-48.

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**Напрями та рекомендації підприємствам  
щодо подолання кризових ситуацій з використанням антисипативних команд**

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**Анотація.** Антисипативне управління відіграє важливу роль у якісному функціонуванні та розвитку підприємства, що зумовлює актуальність дослідження обраної проблеми. Метою статті є обґрунтування важливості випереджувального менеджменту в управлінні сільськогосподарськими підприємствами через впровадження в організаційну структуру випереджувальних команд, що було викликано дестабілізацією зовнішнього та внутрішнього середовища в умовах російсько-української війни. У процесі дослідження використано загальнонаукові та спеціальні методи: аналізу та синтезу, абстрактно-логічний. Досліджено види кризових ситуацій, які ймовірно можуть трапитися з підприємством. Визначено основні чинники настання кризових явищ у сільськогосподарських підприємствах України. Особливу увагу приділено наслідкам російської військової агресії. Проведено аналіз основних показників діяльності сільськогосподарських підприємств. Визначено частку українських компаній, які мають антикризові команди. Вказано на актуальність формування антисипативних команд в сільськогосподарських підприємствах, що є необхідним засобом прогнозування та подолання всіх можливих кризових явищ. Сформовано базову структуру антикризової команди підприємства. Визначено, що вирішення сучасних кризових проблем потребує залучення фахівців як на державному рівні, так і консультантів міжнародних організацій. Рекомендовано створювати антисипативні команди на рівні сільськогосподарських підприємств, що надасть можливість виробникам оперативно реагувати на кризові ситуації, доречним буде впровадження рекомендацій, розроблених антисипативною командою донорів. Таким чином, дане дослідження привносить нові знання щодо специфіки функціонування випереджувальних команд та має практичну цінність для українських сільськогосподарських підприємств у подоланні наслідків кризових ситуацій, у тому числі російсько-української війни

**Ключові слова:** антисипативне управління, кризові ситуації, війна, кризові команди, аграрні підприємства

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